MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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VOLUME XXXVII.

THE MANGANESE-ORE DEPOSITS OF INDIA, *by* L. LEIGH FERMOR, A.R.S.M., B.Sc. (London), F.G.S., *Assistant Superintendent, Geological Survey of India.*

PART IV: DESCRIPTION OF DEPOSITS.

(With Plates 17 to 57.)

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THE

MANGANESE-ORE DEPOSITS OF INDIA.

PART IV.

DESCRIPTION OF DEPOSITS.

ABRIDGED CONTENTS OF PART IV.

ERRATA AND CORRIGENDA TO PART I.

Page lxv, line 16, *for* into *read* in.

,, lxviii, line 3, *for* fsomorphous *read* isomorphous.

,, lxxx, line 4 from bottom, *for* pyroxenes *read* pyroxene.
line 16, *for* rocs *read* rocks.

,, 16, line 9, *after* pp. *read* 240.

,, 26, line 1 of table, *for* (Ca,Mg,Mn)SO *read* $(Ca,Mg,Mn)SiO_3$.

,, 28, last column of table, 7th figure, *for* 6· *read* 6·5.

,, 32, first column, *for* Dicknsonite *read* Dickensonite.

,, 33, first column, *for* $4H_2.O$ *read* $4H_2O$.

,, 55, last line but one, *for* 79 *read* 70.

,, 70, second column of table, *for* 63·59 *read* 63·22.

,, 91, line 12, *for* thousand *read* thousands.

,, 93, last line, *for* thsee *read* these.

,, 96, line 9 from bottom, *for* Lorsa *read* Lorca.

,, 100, table, column 2, *for* 0·1 *read* 0·10.

,, 101, line 5, *for the second* is *read* in.

,, 106, line 9, *for* 98 *read* 100.

,, 122, line 12, *for* 1^1 *read* 1′.

,, 126, line 4, *for* biseerix *read* bisectrix.
line 10, *for* intertitial *read* interstitial.

,, 127, line 13, *for* $NaMn(SiO)_2$ *read* $NaMn(SiO_3)_2$.

,, 129, line 2 from bottom, *for* $\mathfrak{c}$ *read* a.

,, 133, line 12 from bottom, *for* $2NaFe'(SiO_3)_2$ *read* $2NaFe'''(SiO_3)_2$
last line, *for* Mauselieus *read* Mauzelius.

,, 134, line 17, *for* $\mathfrak{c} \vee \acute{c}$ *read* $\mathfrak{c} \wedge \acute{c}$.
for $25\frac{1}{2}^1$ *read* $25\frac{1}{2}'^1$.
line 22, *for* $\mathfrak{c}\,\acute{c}$ *read* $\mathfrak{c} \wedge \acute{c}$.

,, 159, line 24, *for* finding not succeed in *read* not succeed in finding.

,, 183, line 12, *for* ^{3} *read* ^{1}.

,, 195, line 28, *for* figures *read* figure.

,, 198, line 17, *between* means *and* an *insert* of.

,, 199, line 2 from bottom, *for* Dhárwár *read* Dhárwárs.

,, 211, line 8 from bottom, *for* CP *read* or.

,, 229, line 9, *for* R *read* R″.

ERRATA AND CORRIGENDA TO PART II.

Page 241, line 5, *for* Siliwára *read* Silewáda.
line 23, *for* Sabáthu *read* Subáthu.
,, 242, line 9, *for* Khigerimudia *read* Khijerimudia.
,, 253, line 10 from bottom, *for* Kotākarra *read* Kotakarra.
,, 267, line 5 from bottom, *for* O_2 *read* O.
,, 280, line 20, *between* have *and* the *insert* been.
,, 340, line 14, *for* presence *read* present.
,, 365, line 23, *for* are *read* is.
,, 367, line 11, *for* Konugáon *read* Kanugáon.
,, 372, line 16, *for* uch *read* Such.
,, 376, last line, *for* ftriking *read* striking.
,, 381, line 29, *for* distrit *read* district.

ERRATA AND CORRIGENDA TO PART III.

Page 425, line 10, *for* Bhoj *read* Bhoja.
,, 435, line 23, *for* Vijiarámpuram *read* Viziarámpuram.
,, 436, line 14, *for* Garragliát *read* Gáraghát.
,, 442, line 17, *for* Kannivihalli *read* Kannevihalli.
,, 443, bottom of table, *for* 1902 *read* 1892.
,, 459, last column, *for* 2,617 *read* 22,617.
,, 463, tenth name, *for* Donnavapeta *read* Dannanapeta.
,, 470, 3rd column, *for* 9,23 *read* 9,233.
,, 476, line 15, *for* Bengall *read* Bengal.
,, 477, line 22, *for* Tumsár *read* Tumsar.
,, 494, line 2, from bottom, *for* per ton paid or *read* paid per ton for.
,, 495, line 18, *for* silics *read* silica.
,, 501, table 56, column 4, *for* A.4 *read* A.46.
,, 503, table 59, column 11, *for* 0·112 *read* 0·113.
13, *for* Gu-ma *read* Gud-ma.
table 60, column 2, *first quality is* 40·90.
,, 509, last line, *for* non *read* iron.
,, 512, table 70, column 3, *for* Manganife-us *read* Manganiferous.
column 4 & 5, *for* Belgum *read* Belgaum.
column 12, *second figure is* 7·08.
column 13, *put brackets round* $\frac{29}{29}$ *and* $\frac{26}{26}$.
,, 513, table 70, column 6, ,, ,, ,, $\frac{6}{6}$.
,, 514, table 71, column 6, *last quantity is* 0·13—0·17.
,, 517, table 72, column 8, *for* Carthage *read* Carthagena.
,, 519, table 74, column 1, *for* Mositure *read* Moisture.
,, 520, table 76, column 3, under Panama, *for* 0·2 *read* 0·28.
,, 522, last line, *for* Bislampur *read* Bistampur.
,, 533, line 5 from bottom, *for* to a *read* ton.
,, 567, line 16, *for* method *read* methods.
,, 576, line 9, *for* travelling *read* traveling.
line 22, *for* fioor *read* floor.
,, 589, inset, *for* Phosphorous *read* Phosphorus.
,, 604, line 19 *for* rhodonity *read* rhodonite.
,, 605, line 3, *for* calculation *read* calculations.

ERRATA AND CORRIGENDA TO PART IV.

(This part has been checked for numerical errors only.)

Page 624, line 16, *for* H O *read* H_2 O.
,, 635, line 1, *for* Talevédi *read* Talevádi.
,, 638, line 4, *for* 3·28 *read* 8·23.
,, 657, line 6, *for* $Al_4(MnO)$ *read* $Al_4(MnO_5)_3$.
line 15, *for* Mn_2MnO *read* Mn_2 MnO_5.
,, 763, heading *for* BALAGHAT: JAMRAPANI *read* BHANDARA: ASALPANI I.
,, 823, line 11, *for* SiO *read* SiO_2.
,, 830, line 16, *for* MnO_2 *read* MnO (4·86).
,, 869, line 4, *figure is* 0·35.
,, 894, line 1, table at bottom, *for* 21°F. *read* 212°F.
,, 959, line 20, *for* O_2 *read* O.
,, 979, As early as 1869 *at bottom of page 978 belongs to the top of page 979.*
,, 989, line 2, *the figure is* 2.
,, 1019, table, column 6, *for* 10. *read* 10·00; *for* 0·3 *read* 0·43; *for* 0·5 *read* 0·05.
column 5, *for* 1· *read* 1·00.
,, 1031, line 18, *for* $\frac{1}{5}$ *read* $\frac{1}{8}$.
,, 1050, table, column 2, *for* 1·290 *read* 12·90.
,, 1056, line 5 from bottom, *for* ·25 *read* 0·25.
,, 1057, line 4, *for* Fe_2O_2 *read* Fe^2O_3.
,, 1091, line 12, *for* $NaMnO_5$ *read* Na_4MnO_5.
line 20, *for* P O^5 *read* P^2O^5.
,, 1101, table, column 4, *for* 1,956 *read* 1,965.
,, 1111, line 27, *between* to *and* inch *insert* $\frac{1}{4}$.
,, 1141, line 4, *for* Fe_2O *read* Fe_2O_3.

THE

MANGANESE-ORE DEPOSITS OF INDIA.

PART IV.

DESCRIPTION OF DEPOSITS.

CHAPTER XXIX.

Andaman Islands, Baluchistán and Bengal.

Andaman Islands—Baluchistán.

Bengal—Burdwan—Gangpur—Házáribágh—Kálahandi—Mánbhum—Monghyr—Morbhanj—Puri—Singhbhum—Twenty-four Parganas.

Andaman Islands.

Mr. G. H. Tipper of the Geological Survey of India has found oxide of manganese—probably pyrolusite—in nests in a brownish quartzite of pre-Tertiary age. The locality is west of the Balmi creek, Stewart Sound, North Andaman Island. The occurrence is of no possible economic value.

Baluchistán.

A piece of manganese-ore was found by Mr. G. H. Tipper near the old lead workings of Shekhran, 27°53′—66°28′, 14 miles north-west of Khozdar in Jhálawán. The specimen is mammillated concretionary psilomelane, with calcite deposited in the cavities and to a certain extent incrusting the psilomelane. It seems probable that this ore formed part of the gangue of the lead-ores, which occur in veins traversing hard blue Upper Liassic limestones.

During 1907 work was started at a locality situated at the foot of the Pab Hills in Las Bela State, Kelat Agency, some 70 miles from Karáchi, by the Pabb Syndicate, Karáchi, of which Messrs. Beaumont & Co. are agents. Fifteen tons of ore is the output for that year.

Bengal.

Burdwan District.

No manganese-ores have been found in this district, but many of the iron-ores are manganiferous.

Some analyses of manganiferous limonities and hematites by H. Piddington, published in 1833,[1] shew percentages of manganese oxide varying from 1·50 to 16·00. In one case the oxide is stated to be the red oxide (Mn_3O_4), and probably it is this form of the oxide that is given in all the analyses.

	No. 1, Between Jamde and Sukraj.	No. 4, Mal Chaiti.	No. 5, Paolta Kanowa.	No. 7, Deser Gerh.
Water and carbonic acid	8·50	..	..	..
Water	..	6·0	7·0	6·0
Silex (SiO_2)	4·00	4·50	7·90	3·75
Alumina (Al_2O_3)	4·75	1·75	0·60	0·50
Carbonate of lime	5·15	3·35	..	..
Lime	..	..	0·00	0·50
Phosphate of iron	..	..	Trace	0·90
Oxide of manganese (? Mn_3O_4)	1·55	16·00	10·25[2]	1·50
Peroxide of iron (Fe_2O_3)	..	68·00	74·00	86·00
Deutoxide of iron (? Fe_3O_4)	76·00	..	..	..
Total	99·95	99·60	99·75	99·15
Metallic iron	55·0	47·6	51·8	60·2

It is evident from the figures that the above analyses are only approximations as regards the numerals after the decimal point.

I have been unable to find the position in the map of the above villages, except that Jamde may be the same as Jamdah, and Deser Gerh the same as Dishargarh.

Analyses of iron-ores from Barákar given by P. C. Gilchrist and E. Riley[3] shew from a trace up to 2·78 per cent. manganese protoxide, whilst two analyses of the pig made therefrom by the Bengal Iron and Steel Company show 0·69 and 0·97 per cent. respectively of manganese.

1 *Asiatic Researches*, XVIII, pt. 1, pp. 171-177, (1833); *Glean. Sci.*, I, pp. 295-298, (1829).

2 Stated in the original paper—probably by a slip—to be manganese.

3 *Iron*, XXVIII, pp. 476 8, (1886); *Jour. Iron Steel Inst.*, 1886, No. II, pp. 622-624.

One analysis of Barákar iron-ore by C. R. von Schwarz [1] shews 2·6 per cent. MnO. Mr. F. L. Schwenk of the Bengal Iron and Steel Company, Limited, has kindly furnished the following figures as representative of the iron-ores obtained round Barákar :—

	Average.	Limits.
Manganese	1¾	1·4 to 2·5
Iron	45	41 to 48
Silica	14	8 to 20
Phosphorus	1	½ to 1¾

The Barákar ores are obtained, of course, from the division of the Damudas known as the Ironstone Shales.

Of the other ores used by this company, those from the Adjai valley, Santál Parganas, contain up to 3 per cent. Mn ; those railed from Kustaur, Bengal-Nágpur Railway, in the Mánbhum district, under 0·1 per cent. Mn ; and those from Barabhum, Bengal-Nágpur Railway, in the same district, 0·3 to 1·3 per cent. Mn.

Gangpur State.

Manganese-ore has been reported as occurring 10 miles westwards from Bámra station, Bengal-Nágpur Railway, in Gangpur State ; but I have no details of the occurrence.

The deposit is held by Madhu Lall Doogar of Calcutta and is said to be of considerable size. An analysis of a large specimen from here by Mr. V. G. Spiera of Kámthi showed :—

Dried at 100° C.

Manganese	54·37
Silica	1·50
Phosphorus	0·072

Some specimens collected from this deposit have been sent to the Geological Survey. They show good trapezohedral spessartite garnet and also braunite crystals, and seem to point to the extension of the gondite series as far as Bengal

Házáribágh District.

In the metamorphic rocks of this district occur irregular beds of dark yellowish-brown massive garnet, sometimes of considerable thickness.

[1] *Journ. Iron Steel Inst.*, 1886, No. I, p. 225 ; abstracted from *Oesterr. Zeits. Berg Hüttenw.*, XXXIII, (1886).

This rock, which was named 'calderite' by H. Piddington, was analysed by Mr. Tween and found to be a lime-iron garnet containing traces of manganese.[1] One specimen, however, from Katkamsandi, 12 miles north-west of Házáribágh, of dark brown or black colour and resinous lustre, with a specific gravity of 3·65, was analysed by Piddington[2] and found to be a manganese-iron garnet containing 21 per cent. of MnO. On account of the ratio of protoxide to peroxide being quite wrong for a garnet, Mr. F. R. Mallet[3] throws doubt on the accuracy of this analysis, not thinking it probable that 'calderite' varies to such an extent as the analyses of Tween and Piddington indicate. In support of the fact indicated by Piddington's analysis that some varieties of calderite are very manganiferous, may be mentioned a specimen recently received at the Geological Survey Office from Mr. J. W. Boilard of Kharagdiha. It was collected by him at Sirsia, 5½ miles S. E. of this place and is a massive rock composed of a mixture of a resin-brown garnet (presumably calderite) and a bright green pyroxene (coccolite of Mallet) with specks and veinlets of galena probably introduced by metasomatic replacement. The garnet reacts strongly for manganese and the pyroxene feebly so, and under the microscope the pyroxene is seen to be of a pale bluish colour, probably due to its manganiferous character. For further remarks on calderite see pages 182 to 185.

Kálahandi State.

Along with iron-ore on a hill near Olatura, Dr. T. L. Walker[4] found some very manganiferous varieties containing up to 41·03 per cent. manganese. Mammillary concretions containing cobalt were found. An analysis of one specimen gave the following result:—

Insoluble in HCl.	29·41
Mn calculated as MnO	43·30
BaO	4·51
Fe_2O_3	7·84
CoO	0·82
Loss on ignition	10·46
Constituents of the soluble portion not determined	3·66
	100·00
Metallic manganese	27·37

1 F. R. Mallet, Mineralogy, p. 89, (1887).
2 *Jour. As. Soc. Beng.*, XIX, p. 147, (1850).
3 Mineralogy, p. 90.
4 *Mem. Geol. Surv. Ind.*, XXXIII, pt. 3, p. 20, (1902).

The value of this ore would not, however, lie in its manganese, but in the cobalt contents; and although this constituent is not high enough in the specimen analysed to be worth treating for its extraction, yet ores containing higher percentages of cobalt may exist in the neighbourhood. The rocks of this hill are said by Walker[1] to resemble in many respects those classified as Dhárwárs.

Mánbhum District.

V. Ball in his account of the minerals of Manbhum[2] gives some analyses of rocks and minerals by Ormsby. One of these, a porphyritic gneiss, shows 0·84 per cent. Mn_3O_4; and another, of potstone, 0·64 per cent. Mn_3O_4. The localities for the specimens analysed are not given. See also p. 615.

Monghyr District.

A few years ago Babu Baidyanath Saha[3] found large loose blocks of manganese-ore at the foot of the Katnowa or Kutowa Hills and also in the hill itself. These hills are situated north-west of the block hut between Gidhaur and Jamui Stations, East Indian Railway. He reports that the quantity available is quite small and that a sample assayed by Babu Hem Chandra Dutt of the Albert College, Calcutta, yielded 28·26 per cent. of manganese with a little baryta. Three specimens collected by Baidyanath Saha are in the collection of the Geological Survey.

One of these (19·201), from the Kutowa Hills, 4 miles S. S. E. of Jamui, is dull blue-black manganese-ore with an exterior weathering in a pisolitic manner. The streak is dark brown, so that the ore is probably very high in iron. A second specimen (19·202) from the same locality is similar to the above, but is reniform in shape, showing that the ore is probably of concretionary origin.

A third specimen (19·194) from Pandipahári Hills, 4 miles S. W. of Jhajha Station, E. I. R., consists of detrital laterite composed of angular fragments of quartz cemented by somewhat manganiferous iron oxide. The rock looks blackish because a thin coating of this cement covers nearly all the quartz grains.

Morbhanj State.

Traces of manganese-ore were found by Mr. P. N. Bose in laterite close to banded blackish quartzites near Kuliana.[4]

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1 *Mem. Geol. Surv. Ind.*, XXXIII, pt. 3 p. 19, (1902).

2 *Mem. G. S. I.*, XVIII, pp. 103, 105, (1881).

3 MS. of an unpublished thesis, for M. A. degree of Calcutta University, entitled 'On a peculiar type of breccia of the Monghyr district.'

4 *Rec. G. S. I.*, XXXI, p. 170, (1904).

Puri District.

Amongst some specimens of building stones received from the District Engineer, Khurda, two blocks of somewhat decomposed khondalite from Khijerimudia, 3 miles south of Jatni, shew spots and streaks of soft brownish black manganese oxide; whilst a specimen of ferruginous laterite from Bhomitika, 2 miles east of Jatni, shows dark brownish black manganiferous spots.

Singhbhum District.

History.

In January 1905 I spent a few days in this district examining some deposits of manganese-ore that had been recently prospected near Cháibásá by Messrs. Hoare, Miller & Co., and Messieurs Jambon and Cie., both of Calcutta. Since then these firms have relinquished practically all their interests and the Madhu Lall Doogar Mining Syndicate of Kámthi has obtained the concessions. Prospecting in other parts of the district has resulted in the discovery of other occurrences of manganese-ore, amongst them that on Leda Hill found by Mr. R. Saubolle working on behalf of Messrs. Martin & Co., Calcutta. In January 1908 I was able to visit Leda Hill, and Tutugutu, near Cháibásá, not previously examined. The remarks in the following paragraphs refer to the deposits of the Cháibásá area, unless otherwise stated.

Most of the localities for manganese investigated by the prospectors of the above firms were originally discovered by V. Ball,[1] who mentions the occurrence of iron-ores ' in a number of lodes and veins which occur in the sub-metamorphic rocks in the neighbourhood of, and to the west of, the town of Cháibásá.......Many of them, however, give great promise of being rich in manganese.' He notices a ' well-marked ridge of this manganiferous ore mixed with vein quartz south of Cháibásá and east-north-east of Puráná Cháibásá,' and a somewhat similar outcrop of brown hematite near Lagiá, some of this ore being rich in manganese. The two firms first mentioned took out prospecting licenses in August and September, 1904, respectively, and carried out a considerable amount of surface excavation in the form of pits up to 10 feet deep, and shallow trenches. This enabled me to form a very good idea as to the mode of occurrence and origin of these ores.

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1 *Mem. G. S. I.*, XVIII, pp. 146, 147, (1881); also ' Manual of Geology of India,' Part III, p. 328.

Geology.

The rocks with which these deposits are associated are what Ball calls sub-metamorphics, and are shown on the map accompanying Mr. Maclaren's paper on 'The Auriferous Occurrences of Chota Nagpur, Bengal,' as Dhárwárs.[1] As seen just to the south of Cháibásá, where the majority of the deposits are situated, these rocks consist of unctuous clay-slates and sericite-phyllites; purplish sandstones, quartzites, and grits, which are often of the nature of greywackes; together with red and pink jaspers and jaspery quartzites. These rocks are traversed by abundant veins of white quartz, which often appear to form irregular masses, and frequently show druses lined with quartz crystals. These rocks have a strike averaging north-east, with a gentle to steep dip to the north-west side; but in many places where the greywacke sandstones and grits—which seem to be here the bottom beds of the group—rest on the underlying granite, they are either gently rolling or quite horizontal. Consequently the bottom beds of the Dhárwárs often occur as outlying patches on the underlying granite.[2]

The granite is a whitish rather fine-grained rock containing a bronze-brown mica. It is in places of much coarser grain and occasionally traversed by pegmatite veins, and seems itself to be a true igneous granite. A series of well marked epidiorite dykes traverses the granite in various directions, but usually in a N. 30° E. direction in this neighbourhood.

Mode of occurrence of the ores.

The manganese- and iron-ores are found in a number of irregular ridgy hillocks composed of limonite and psilomelane, with sometimes pyrolusite and red ochre. The limonite is the commonest of these minerals and is usually ochreous and soft, with abundant scattered remains of jasper, quartz, or sericite; but it is sometimes hard and compact; whilst it often occurs as layers of radiate structure coating cavities, and having an outer shining, black, pimply, or botryoidal, surface. Some of these limonitic outcrops seem to be practically free from visible manganese oxides, but others show scattered patches and veins of psilomelane, which in some places predominates over the iron-ore; in one outcrop near Matkamhatu, to be noticed below, the rock is practically all psilomelane, with some pyrolusite, and with limonite in places. The psilomelane that occurs thus

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1 *Rec. G. S. I.*, XXXI, Pl. 5, (1904).

2 The but slightly metamorphosed character of these sandstones and grits and their gently rolling disposition would be more consistent with a Kadapáh than a Dhárwár age for them; but I think that in this case we have to deal with some Dhárwár sediments that have escaped being much folded and have therefore been but slightly metamorphosed.

is cavernous, of irregular shape, and often botryoidal and concretionary: in many places it contains rounded patches of pale pink jaspery quartzite simulating pebbles, but really the remains of an original band of jasper, the larger portion of which has been replaced by oxide of manganese. Much of the ore on being broken shows tiny specks of white quartz, while other pieces show remains of white silky-looking sericite—looking like talc at first sight—and at times fragments of sericitic slate and phyllite.

Besides the above-mentioned irregular deposits of lateritic aspect, the manganese-ore occurs in some places, as at Tekrasai, Tutugutu, and Bistampur, in bed-like layers from one to six inches thick, the ore then being sometimes very fine-looking compact psilomelane. With these layers are also associated the cavernous, botryoidal, or concretionary ores, the whole making up a manganiferous layer, which is in places as much as two or three feet thick. The ores in this bed often show remains of quartz and sericite and invariably rest on horizontal or nearly horizontal purplish sandstones and grits.

Origin of the ores.

Judging from the evidence obtained, both in the field and from the microscopic examination of the specimens collected, there can be little doubt that these manganese- and iron-ores have been formed by the percolation of solutions containing manganese and iron, which have replaced indiscriminately whatever rock was at the surface; the rocks seen to have been thus replaced are slates, sericite-phyllites, jasper, vein-quartz, and purplish felspathic sandstones and quartzites, the two latter to a much less extent than the former. Where the rocks lie at a moderate or high angle the result of this alteration seems to have been a cavernous cindery-looking lateritic rock (*lateritoid*—see page 381): where the dip is horizontal or very small, the manganese has often formed a well-marked bed-like layer, usually where a thin layer of slates or phyllites rested on the purplish felspathic grits and sandstones; the latter rocks not being as a rule much affected, although they are sometimes limonitized at their outcrops.

Source of the manganese.

The iron is doubtless in part a concentration product resulting from the weathering and denudation of the rocks under consideration, but the source of the manganese is not so apparent. As none of these rocks when unaltered seem to be notably manganiferous, it is probable that the manganese has been brought in solution to its present position. Considering the complete parallelism between the mode of origin of the Cháibásá ores and those of the Jabalpur district, and the fact that the associated rocks are in both cases Dhárwárs, one would expect the

Cháibásá manganese to have been derived from micaceous hematites containing manganese, as in the case of the Jabalpur ores. And although I noticed no iron-ore, other than lateritic, near Cháibásá, yet such micaceous-hematite schists may exist in the neighbourhood—if not exposed, then concealed by alluvium or lateritic outcrops. It is interesting to note that such rock, identical in every lithological character with that of Jabalpur, has been found by Mr. C. Aubert in the Dhárwár area of Singhbhum at Hakigora Hill near Kálimáti, about 30 miles east-north-east of Cháibásá.[1]

Time of formation of the ores.

As these ores often occur on the tops of hillocks, it seems probable that they were formed before the present contours of the country were carved out, or perhaps during the process of weathering and denudation of the rocks to their present shape.

Commercial value of the deposits, and analyses of the ores.

Considering the above facts, it is not surprising that these ores are very patchy and irregular in their mode of distribution, and it is not to be expected that more than a few thousand tons of manganese-ore will ever be collected from all the localities combined.

The samples taken by me—which were analysed by Messrs. J. & H. S. Pattinson, and are inserted in the following pages in the accounts of the respective deposits—show the following range and average values for the various constituents :—

Analyses of manganese-ores and manganiferous iron-ores from Singhbhum.

	Samples.				Hand-specimens.	
Nature of ores.	Manganese-ores.		Manganiferous iron-ores.		Manganese-ores.	
Number of analyses.	3		3		3	
	Limits.	Mean.	Limits.	Mean.	Limits.	Mean.
Manganese . . .	46·89—48·08	47·66	4·23—20·66	11·84	50·66—57·14	54·47
Iron	1·22— 6·10	2·90	25·60—41·30	34·97	0·05— 0·35	0·18
Silica . . .	2·45— 8·30	4·63	14·70—18·10	16·46	0·05— 0·10	0·07
Phosphorus . .	0·27— 0·42	0·34	0·35— 1·18	0·74	0·29— 0·32	0·31
Moisture . . .	0·55— 0·80	0·63	1·00— 1·40	1·17	0·35— 0·45	0·42

1 Since I wrote this I have seen the deposits of Sandur and Mysore and I now think that, although the manganese may have been derived from micaceous hematite, yet the small amount of manganese probably present in the other Dhárwár rocks, such as the phyllites, may have been sufficient for the purpose, after concentration by circulating waters.

From the above it will be seen that the ores can be classified into manganese-ores of fairly good quality, except for phosphorus; and very siliceous manganiferous iron-ores. The quantity of either obtainable is, however, small; and considering all the features of the case, it seems improbable that these occurrences can be turned to profitable account for export purposes, except possibly at times of very high prices, such as obtained in 1907. Should it be found possible, however, to use the ores locally under circumstances in which phosphoric ores are not objectionable—such as in the manufacture of basic steel—in which the manganiferous iron-ores could also be turned to account, then these occurrences might be profitably worked.

Output. The output figures given for this district for 1907 are as follows:—

	Long tons.	
Gitilpi	1,304	Madhu Lall Doogar Mining Syndicate.
Tutugutu	2,229	
Kalenda	400	Jambon & Cie.
	3,933	

But this includes 1,000 tons estimated as the output for years previous to 1907, mainly 1906.

During 1907 the Madhu Lall Doogar Mining Syndicate is said to have railed some 1,600 tons of manganese-ore from Chakardharpur Railway Station, Bengal-Nágpur Railway; of this 300 to 400 tons were obtained from Gitilpi and the remainder from Tutugutu. The average manganese contents was not, however, greater than 40 per cent., and it is doubtful if the sum realized for this ore can have paid expenses. The ores that I saw lying at the railway station and Tutugutu, were not selected and dressed to the quality of the stocks I sampled in 1905; had they been, the quantity of ore won would have been very much less.

In addition to the analyses given above I have 13 analyses of hand-specimens of ores from this area, kindly supplied by Mr. C. Aubert. The limits and average value of each of the four principal constituents are shown in the following table:—

Analyses of manganese-ores from the Cháibásá area, Singhbhum.

	Limits.	Mean.
Manganese	39·91 to 61·24	52·16
Iron	0·64 to 11·89	4·11
Silica	0·70 to 17·56	6·62
Phosphorus	0·06 to 0·55	0·25

The following is a list of most of the localities for manganese-ore known in this district:—

List of localities.

1. Purána Cháibásá.
2. Kamarhatu.
3. Matkamhatu.
4. Tekrasai (Tekrahatu).
5. Gitilpi.
6. Kalenda.
7. Tutugutu.
8. Bistampur.
9. Lagia.
10. Leda Hill.

Besides the deposits given in the foregoing list, several other occurrences of manganese-ore have been reported from different parts of the district; but the information received has not been sufficiently exact to warrant their mention here. The first six of these deposits were, in 1905, included in the concession held by Messrs. Hoare, Miller & Co., and No. 8 in that of Messieurs Jambon & Cie. At present (February, 1908) most of the concessions have, I believe, been relinquished, the Madhu Lall Doogar Mining Syndicate still holding Tutugutu, and Messrs. Martin & Co., Leda Hill: concessions are also held, I believe, by various people for the country immediately around Leda Hill. All the above deposits are within an eight miles' radius to the south and west of Cháibásá, except Leda Hill, which is near Goilkora Railway Station, Bengal-Nágpur Railway. Cháibásá is 16 miles from Chakardharpur, Bengal-Nágpur Railway, and the Cháibásá deposits are at distances of 1 to 8 miles from Cháibásá. The deposits will now be dealt with in order.

1. Purána Chaibásá.

The ores of this locality are mentioned by Ball (*supra*, p. 618); they are limonites in which manganese-ore is very scarce, and the ridge in which they occur is partly in—

2. Kamarhatu.

3. Matkamhatu.

Half a mile east-south-east of the village on the east side of the main road to Cháibásá, there is, on the top of hillocky ground, the best outcrop of manganiferous limonite seen by me in this district. In one place there is a well-marked outcrop in which limonite is scarce, the rock being chiefly psilomelane, with some pyrolusite. It is of the usual cavernous lateritic type and shows in places remains of sericite. This very manganiferous portion of the outcrop has a length of 70 paces, is 50 feet wide and rises to perhaps 15 feet above the remainder of the undulating hillocky ground on which it occurs. A sample of ore from here gave the following partial analysis (by Messrs. J. & H. S. Pattinson) :—

Sample No. A. 36.

Manganese peroxide (MnO_2)	29·60
Manganese protoxide (MnO)	2·53
Ferric oxide (Fe_2O_3)	36·57
Baryta (BaO)	0·79
Silica (combined)	5·08
Silica (free)	11·50
Phosphoric oxide (P_2O_5)	1·61
Combined water (H O)	5·70
Moisture at 100°C.	1·00

This is equivalent to :—

Manganese (Mn).	20·66
Iron (Fe)	25·60
Silica (total)	16·58
Phosphorus	0·70

Irregular outcrops of limonite, in places very manganiferous, stretch for 200—300 yards to the south-east, and then continue E. 35° N. along the south-east edge of the north-east one of the four hillocks shown on the 1-inch map of this area. The limonite here is sometimes very good, but also frequently very siliceous. A sample taken all along these outcrops yielded the following results (J. & H. S. Pattinson) :—

Sample No. A. 37.

MnO	5·94
MnO	0·60
Fe_2O_3	59·00
BaO	0·26
SiO_2 (combined)	6·35
SiO_2 (free)	11·75
P_2O_5	2·75
H_2O (combined)	7·90
Moisture at 100°C.	1·40

This is equivalent to :—

Manganese	4·23
Iron	41·30
Silica (total).	18·10
Phosphorus	1·18

From this it will be seen that the ores of this locality are siliceous and highly phosphoric manganiferous iron-ores.

There is still another outcrop of very manganiferous limonite situated ½ mile or so S. 35° E. from Matkamhatu village and striking N. 35° E. It is on the west side of the road.

4. Tekrasai (Tekrahatu).

Half a mile almost due north of the village is the principal excavation made by Messrs. Hoare, Miller & Co. It is on low ground and has revealed a nearly horizontal bed of ore resting on purple quartzites. The section seen in one place was as follows:—

1′8″	ore, including a 1 to 2 inch band of vein quartz.
6″	purplish jaspery quartzite veined with psilomelane.
5″	lavender slate replaced by ore in places.
1′6″+	decomposed purplish sandstone.
4′1″	total.

The ore band varies from 1′3″ to 1′9″ in thickness and is composed of layers of psilomelane ¼ to 1 inch thick, sometimes very good, but usually showing included siliceous remains. Some of the ore is cavernous and botryoidal. This bed of ore could be traced only over a small area and must thin out in all directions. Perhaps 10-15 tons of ore had been collected, and from the heap that contained the best ore—the others required much cleaning—a sample was taken, which gave the following partial analysis (J. & H. S. Pattinson):—

Sample No. A. 33.

MnO_2	69·31
MnO	5·51
Fe_2O_3	1·74
BaO	4·47
SiO_2 (combined)	3·50
SiO_2 (free)	4·80
P_2O_5	0·99
Arsenic oxide (As_2O_5)	0·032
H_2O (combined)	3·50
Moisture at 100°C.	0·55

This is equivalent to :—

Manganese	48·08
Iron	1·22
Silica (total)	8·30
Phosphorus	0·42

Complete analyses, with descriptions of three pieces of psilomelane from this locality are given on pages 100, 107 and 108. I give here the commercially significant part only :—

Number of specimen.	A.380	A.381	J.917
Manganese	50·66	55·61	57·14
Iron	0·15	0·05	0·35
Silica	0·05	0·05	0·10
Phosphorus	0·32	0·29	0·30
Moisture	0·45	0·45	0·35

The comparatively high amounts of oxides of cobalt, nickel, copper, and zinc, in these specimens are, however, worth directing attention to.

5. Gitilpi.

A furlong or more S.E. of the Tekrasai excavations are two more of these limonite hillocks, of which the western is in Tekrasai and the eastern and more important one in Gitilpi village limits. They are separated by some 200 yards of level ground through which runs an epidiorite dyke with a N. 25° E. strike. The western hillock does not contain much good limonite, most of the latter showing the usual siliceous and sericitic remains; it also contains a small amount of psilomelane. The eastern hillock is really a low ridge running E. 40° N. and rising at its east end to about 30 or 40 feet above the surrounding fields. It does not show limonite throughout its length, but in the middle the purplish quartzite (elsewhere presumably underlying) covers the ridge. As before the limonite shows remains of jasper, quartz, and sericite, with the cavities often lined by radiate limonite. A little psilomelane is also present. A sample taken along the outcrop gave the following partial analysis (J. & H. S. Pattinson) :—

Sample No. A. 34.

MnO_2	15·21
MnO	1·30
Fe_2O_3	54·28
BaO	0·85
SiO_2 (combined)	8·50
SiO_2 (free)	6·20
P_2O_5	0·81
H_2O (combined)	8·00
Moisture at 100°C.	1·10

This is equivalent to :—

Manganese	10·62
Iron	38·00
Silica (total)	14·70
Phosphorus	0·35

Round the base and slopes on the N. W. side of the N. E. end of the hillock, psilomelane crops out in force for some 50 yards and predominates over the limonite. A pit dug here almost at the foot of the hillock showed a depth of two to three feet of the lateritic rock resting on a thin stratum of quartzite fragments and this on a much kaolinized granite of medium grain, which in places included patches of hornblendic rock and epidote ? This seems to indicate that this hillock is an outlier of Dhárwár sandstones and quartzites resting on the granite, and that the Dhárwárs have been lateritized at the outcrop.

Some 5 tons of ore had been extracted here ; it was mostly botryoidal, mammillated, or columnar, in structure, and apparently of good quality, at least as regards the manganese content. A sample yielded the following partial analysis (J. & H. S. Pattinson):—

Sample No. A. 35.

MnO_2	70·01
MnO	4·85
Fe_2O	8·71
BaO	3·84
SiO_2 (combined).	1·55
SiO_2 (free)	0·90
P_2O_5	0·79
H_2O (combined).	4·20
Moisture at 100°C.	0·55

This is equivalent to :—

Manganese	48·01
Iron	6·10
Silica	2·45
Phosphorus	0·35

About ½ a mile N.E. of these hillocks I saw, in January 1908, another series of excavations to the west of the road. In one place over an area of several square yards, a single horizontal layer of manganese-ore averaging ¾ inch, and ranging from ½ to 2½ inches in thickness, is said to have been found at 1½ feet below the surface. The material that was pointed out as the underlying rock consisted of pinkish grey jasper and vitreous quartzite, the former being perhaps an altered form of the latter. Further east purplish sandstone-quartzites come to the surface and are being converted into a waddy laterite, films and layers of which extend downwards along the joint planes and also along the bedding planes.

6. Kalenda.

A few pits near the road, where it passes between Kalenda and its *tola* or hamlet, Tunglui, had been filled up; but I was told that they all showed ore resting on the usual purplish felspathic sandstone. Some pieces of somewhat tabular psilomelane that I picked up were said to have come from a bed about a foot thick. Where the ore cropped out it was the usual mixture of limonite and psilomelane.

7. Tutugutu.

This deposit is situated about $1\frac{1}{4}$ miles due south of Tutugutu village on the low ground immediately to the north of a low ridge of the purplish sandstone-grit, with vein quartz, both of them lateritized in places. It has been actively worked by the Madhu Lall Doogar Mining Syndicate during 1907, with the despatch to Chakardharpur, about 22 miles distant, of over a thousand tons of manganese-ore.

The sections visible in the cuttings open in January 1908 showed, in some places, the lateritoid mixtures of manganese- and iron-ores with residual patches of phyllites, jasper, sandstone-grit, and vein-quartz, according to the rock that had been replaced. In one place a network of psilomelane has penetrated vein-quartz in all directions, so as to convert it into a sort of breccia, consisting of angular patches of quartz in a net-work of psilomelane. In other places sections are seen showing up to 5 feet of slates and phyllites, usually gently rolling, with intercalated beds of manganese-ore varying from $\frac{1}{2}$ up to 6 inches thick, 1 to 2 inches being the most usual thickness. These ore-layers are often seen to thin out lenticularly, and also often contain residual remains of the slaty rocks; so that there is little doubt that they are the result of replacement of the slates, and are not original sedimentary ore-beds deposited at the same time as the sediments from which the slates were derived.

The total amount of ore available from both the lateritoid and the interbedded ore-layers cannot be large, whilst its quality must be low. Nevertheless, this seems to be the largest deposit yet found in the Cháibásá area, with the possible exception of Bistampur.

8. Bistampur.

This village is the one marked as Mátágota on the map, the latter village being more to the south. The ore occurs in a group of low hills situated ¼ to ½ mile W. N. W. of the village and known as Tumáng Buru.[1] The hills are composed of an outlier of sandstones and grits resting on a basis of the usual fine-grained granite; in places sericite-phyllite seems to cap the grits. In many places the rocks have been converted into manganese- and iron-ore, especially the former, and as the bedding of the rocks is about horizontal the ore tends to form a bed, which over one small area about 80 yards long and 80 broad often reaches a thickness of two feet. At this particular spot, which is on a plateau-like piece of ground just to the N. W. of the S. E. hillock on the map, perhaps 20 tons of ore had been extracted from a series of shallow pits and trenches. The ore was largely very fine-looking bluish psilomelane with scattered specks of pyrolusite; but some of it showed abundance of residual sericite. A sample of ore taken from these heaps was analysed by Messrs. J. & H. S. Pattinson with the following result:—

Sample No. A. 38.

MnO_2	65·81
MnO	6·84
Fe_2O_3	1·95
BaO	13·76
SiO_2 (combined)	0·10
SiO_2 (free)	3·05
P_2O_5	0·62
H_2O (combined)	4·60
Moisture at 100°C.	0·80

This is equivalent to:—

Manganese	46·89
Iron	1·37
Silica (total)	3·15
Phosphorus	0·27

From the west end of this plateau there rises a hill, somewhat higher than the others, composed of sericite-phyllites with vein-quartz; some pits on its slopes exposed a layer of tabular manganese-ore overlain by débris of white vein-quartz, resting on the phyllites, and obviously derived from them by replacement.

[1] *Buru* is the Kol word for *Hill*.

On a small plateau-area to the north of this phyllite hillock a further quantity of botryoidal and cavernous ore was exposed, resting on practically horizontal quartzites.

As will be judged from the above, this occurrence is probably the best yet found in the district; but probably not more than a few hundred tons of ore of the above quality could be won by working the whole of the manganiferous area here; whilst the railway at Chakardharpur is some 24 miles distant, Bistampur being 8 miles south of Cháibásá.

9. Lagia (Lajia).

According to Ball some of the iron-ore here is rich in manganese. This locality is about 7 miles west by a little south from Cháibásá.

10. Leda Hill.

Leda Hill is situated in Government Reserved Forest about 2½ miles S. by a little W. of Goilkora station, Bengal-Nágpur Railway. It rises to 2,077 feet above sea-level and perhaps 1,000 feet above Goilkora. The top of the hill is nearly half a mile long and has a general N. W.-S. E. strike. Manganese-ores were first discovered here by Mr. R. Saubolle, prospecting on behalf of Messrs. Martin & Co., in 1907. This firm has since obtained the prospecting license for the occurrence, and has opened up a series of 28 pits and trenches, which I was able to examine in my visit to the hill in January 1908. The rocks of the hill as seen in the outcrops and exposed in these trenches consist of alternating quartzites and slates, traversed in places by vein-quartz. Their strike usually varies from N. N. W. to N. N. E. with dips varying from 45° to vertical to the west side; but there are exceptions to the above figures. Almost everywhere these rocks have been partly replaced by oxides of iron and manganese at the surface with the production of the rock I have designated lateritoid. This consists of mixtures of iron-ore (limonite and sometimes hematite) and manganese-ore (chiefly psilomelane) and usually shows residual patches of either quartzite or slate, or of lithomarge formed by the alteration of the slate. The pits and trenches show that manganese-ore that seems to be fairly good at the surface passes down in a few feet into partly replaced rock. Hence the ore is of superficial origin and, as far as can be judged from the pits and trenches, of very limited quantity at any one spot. Such ore as there is, moreover, frequently contains remains of the rocks from which it has been derived by replacement. I have not seen any analyses of the ores from this hill, but I should say they would tend to be very siliceous. As regards quantity, it is possible that a fair amount could be collected over the whole of the hill; but the expense incurred in excavating it would probably render it unprofitable to work the occurrence for export, except perhaps at times of high prices such as prevailed during the earlier parts of 1907.

It must be remembered, however, that in deposits of this type the ore tends to be of the highest grade at the surface; and if the deposit has been subjected to much denudation since its formation, it is probable that the best portions of the ore have been denuded away. In this case they would probably be found on the slopes of the hill in the form of talus. If any attempt be made to work this occurrence attention should be directed to the ore *in situ* on the west side of the hill, where it seems to be of the best quality, whilst the talus accumulations should be examined especially on the western slopes.

In mode of occurrence and origin and its situation on the top of a hill, this deposit bears a great resemblance to many of those in Mysore. It differs from those of the Cháibásá area only in situation and the somewhat different lithological characters of the rocks that have been replaced.

An interesting feature of this occurrence is the cavernous character of the altered rocks revealed in some of the pits. Thus one pit shewed slates irregularly replaced by manganese oxide and themselves softened and lithomargic. In this were some large flat cavities extending irregularly for some feet and even yards along the strike of the rocks, but only a foot or two wide at right angles to the dip planes. These cavities seem to have been formed by the solution or washing away of the decomposed slate, leaving the concretionary manganese-ore projecting into the cavities.

The 24-Parganas.

Mr. T. Munro of the Port Commission has brought to my notice a very interesting occurrence of manganese-ore. I have unfortunately not been able to visit the place myself. This occurrence is all the more surprising because the locality for the ore is in the Gangetic alluvium in the portion of Lower Bengal known as the Sundarbans. The actual locality is the Silver Tree G.T.S. station, which lies on the east shore of the Hughli at a point not quite 3 miles in a straight line N. 17° E. of the telegraph station at Mudpoint. A little below the Silver Cliff obelisk are very numerous small pisolites scattered on the shore just above high-water mark for some hundred yards along the beach. The pisolites have probably been washed up to their present position by the tide, for they also occur *in situ* in the blue clay of which the shore is here composed and can be seen projecting in bunches from the clay all the way between the high-and low-water marks. In this blue clay there are bits of the roots and twigs of plants, as well as small concretionary tubes. The way in which the concretions of manganese-ore have been formed is not known, but is a point of great interest and worth determination. The pisolites from this locality are all very much of one size, namely about 0·2 inch in diameter. Mr. Munro tells me that such small bodies also occur in great numbers scattered on the surface of the ground near the Mudpoint telegraph station. Here, however, they are much smaller than at the Silver Tree G.T.S., averaging about $\frac{1}{12}$ to $\frac{1}{8}$ inch in diameter.

CHAPTER XXX

DESCRIPTION OF DEPOSITS—*continued.*

Bombay Presidency.

Belgaum—Bijapur—Dhárwár—Dhárwár (Sangli)—Nárukot—Pálánpur—Panch Mahála—Rájpipla—Ratnagiri—Sátára.

Belgaum District.

Manganese-ores have been found in this district in rocks of both the Kaládgi and Dhárwár Series. The known occurrences are as follows :—

1. Munnikerri, in Kaládgi rocks,
2. Bhimgad }
3. Talevádi } in Dhárwár rocks,
4. Nersa }

of which Nos. 3 and 4 are of possible economic value.

In the Return of Mineral Production for 1891, page 5, manganese-ore is reported to occur in the trap rock (probably the Deccan Trap) of this district, but no authority for this statement or details of the occurrence are given.

1. Munnikerri.

Lieutenant (afterwards Captain) T. J. Newbold[1] says, in 1840, that he found manganese-ore 'in the sandstone of the Southern Mahratta Country' between Kaládgi and the falls of the Ghatprabha river near Gokák. He later[2] specifies the locality as Munnikerri about 26 miles W. by a little S. of Kaládgi, where 'close to a small pagoda, the sandstone at the S. W. flank of the ridge near the edge of the overlying trap is penetrated with a vein of black manganese, associated with iron, about three inches broad.'[3] The 'sandstones' are quartzites belonging to the Lower Kaládgi Series and the 'trap' is the Deccan Trap.

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[1] *Mad. Journ. Lit. Sci.*, XI, pp. 45, 245, (1840).

[2] *Journn. As. Soc Beng.*, XIV, p. 275, (1845); reprinted in 'Western India,' p. 352, (1857).

[3] *Loc. cit.*, p. 276.

2. Bhimgad.

In 1874, Mr. R. B. Foote,[1] late of the Geological Survey of India, found, near the east gate of the fort, a considerable quantity of a dark blackish-brown powder

'accumulated on the surface of the dolomite from which it had evidently been weathered out. The limestone, the face of which was greatly concealed by vegetation, was here darker in colour than in the main mass of the mountain. The mode in which the black mineral occurred in the original rock was not clear...'

An analysis by Mr. Tween of this ore, which is apparently a very impure wad, showed it to consist of :—

Water and organic matter	14·6
Oxide of iron and a little alumina	22·0
Binoxide of manganese	20·0
Insoluble	44·8
	101·4

while an analysis of the dolomite, also by Mr. Tween, showed :—

Water and organic matter	4·0
Carbonate of lime	56·4
Carbonate of magnesia	34·8
Oxide of iron with a little alumina and manganese	3·6
Insoluble	2·2
	101·0

Judging from the second analysis, it seems as if this wad is a residual crust left on the surface of the dolomite when the carbonates of calcium and magnesium are dissolved away by meteoric waters; it is possible that the manganese was originally contained in the dolomite as the carbonate. The dolomite was included by Foote in his gneissic series. This was, however, previous to the establishment by him in 1888[2] of the Dhárwár Series; and Mr. J. M. Maclaren, late of the Geological Survey, who visited this area in 1904-05, has added, under the name of the Castle Rock Band,[3] a fourth to the three main bands of Dhárwár rocks already distinguished by Foote in this part of India. The dolomites of Bhimgad, and the limestones and schistose rocks of Talevádi and Nersa, are mapped by Maclaren as forming part of this band.

[1] *Mem. Geol. Surv. Ind.*, XII, pp. 56, 259, (1876). *Rec. Geol. Surv. Ind.*, VII, p. 125, (1873).

[2] *Rec. Geol. Surv. Ind.*, XXI, p. 41, (1888).

[3] *Ibid.*, XXXIV, p. 96, (1906).

3. Talevádi.

In 1904, manganese-ores were discovered by Mr. T. B. Kantharia at Talevádi village on the Kelil ghát, some $3\frac{1}{2}$ to 4 miles S. E. of Bhimgad and the same distance from the frontier of the Portuguese territory of Goa. The concession was taken by Mr. Kantharia to Messieurs Jambon and Cie. of Calcutta. A large number of pits were sunk by Mr. D. T. Frizoni, on behalf of this firm, which subsequently (1906) sold the property to Mr. C. P. Boyce of Belgaum.

Mode of occurrence and origin.

According to Mr. Maclaren, who visited this locality early in 1905, when the deposits had been well opened up, the manganese-ores occur in a deposit of laterite 15-20 feet deep. This laterite passes downwards into quartz-schist overlying a slightly manganiferous limestone. Both these latter rocks form part of the Castle Rock Band of Dhárwárs and are nearly horizontally disposed, but have been subjected to a horizontal pressure that has developed in the quartz-schist a foliation having a north-easterly dip. Three specimens of the rocks brought from here by Mr. Maclaren are:—

(1) friable fine-grained sericitic quartz-schist.

(2) fine-grained biotite quartz-schist;

(3) fine-grained grey limestone with bands of darker colour. It is not dolomitic, gives a decided reaction for manganese, and contains abundance of quartz and nests of minute mica scales.

The manganese-ore occurs *only* in the laterite as hard, more or less spherical, concretions, which are sometimes as much as 3 feet in diameter at the surface. They decrease in size and hardness with depth, until, where passing into the decomposed schist, they are very few in number and only 2 to 3 inches long. Fig. 22, on page 384, taken from a paper by Mr. Maclaren in the *Geological Magazine*,[1] illustrates the mode of occurrence of the manganese-ore. The ores are chiefly psilomelane with some pyrolusite and wad, and are associated with limonite and ochres. They are often cavernous and of concretionary shapes.

The two preceding paragraphs were compiled from the notes and specimens of Mr. Maclaren before I had visited the locality myself. This I was able to do in December 1907. The pits had then in most cases become weather-stained and somewhat obscured as compared with their fresh condition at the time of Mr. Maclaren's visit. Work

[1] Vol. III, Dec. V, p. 538, (1906).

was still going on in some, however, and in these the sections were of course fresh. I did not see all that Mr. Maclaren records, but generally speaking, I agree with his description, and with the theory of the origin of the laterite of this locality by the metasomatic replacement of the rocks at the surface, as put forward in his paper in the *Geological Magazine*.[1] The laterite here covers a considerable area, and the manganese-ore is very irregularly distributed throughout it. In some places the laterite is quite free from manganese-ore, whilst in others it consists almost entirely of manganese-ore. In spite of the large area over which the laterite of this locality is spread, so that it seems necessary to designate it 'high-level laterite,' yet I do not think it is necessarily of the same origin as the high-level laterite of the Central Provinces and Sátára, nor that Mr. Maclaren's theory as to its origin is applicable to all high-level laterite. I think rather that the occurrence of manganese-ore at this locality is to be classified with those occurrences in other parts of India, such as Mysore and Jabalpur, that I have found it advisable to distinguish by the term 'lateritoid' to avoid confusion with the true high-level laterites. In fact the Talevádi occurrence may be regarded as a connecting link between the true lateritoid occurrences of Mysore and other parts, and the true high-level laterites. As in Mysore, some of the nodules of lead-like psilomelane have an outer shell of wad, from which, into the psilomelane, there seems to be a gradual passage.

I must notice, however, that the lateritic rock of this locality does not all seem to have been formed at the same time. Thus in one place where work was being carried on at the time of my visit there seemed to be a considerable body of ore. As exposed it was 24 paces long in an N. 30° E. direction, 11 paces broad, and 8 feet deep. This mass seemed to be practically all manganese-ore, except for patches of laterite in it here and there. The ore consists of psilomelane (both lead-like and dull grey) and wad, the former predominating. At the N. E. end of the working this ore-body gives place to laterite containing masses of psilomelane up to 6 and 9 inches in diameter. This ore is mostly hard bright grey psilomelane of considerably better quality than the ore in the ore-body. These included pieces of manganese-ore look in fact as if they are older than the enclosing laterite, and as if they are being corroded by the latter in the same way as I have noticed in the Sandur deposits (see page 1029). Of this I could not be certain, however. But

[1] Vol. III, Dec. V, pp. 536-547.

if it be the case, then the explanation may be that, since lateritic manganese-ores are as a general rule of better quality the nearer the surface they lie, these included pieces may have been derived from the denudation of the upper part of the ore-body noticed above and cemented together by a second generation of laterite formed by percolating waters. This cementing laterite is chiefly ferruginous, but contains a little wad and a few thin veinlets of psilomelane that must be regarded as an integral part of it, formed perhaps from those parts of the included manganese-ores noticed above as having been corroded away.

Mr. C. Aubert has kindly supplied me with the analyses of various hand-specimens from this neighbourhood shown in the following table. They were made by Dr. Pearson of London.

Analyses of manganese-ores and manganiferous iron-ores from Talevádi.

	1	2	3	5	6	8	9	10	11	12	13	14
Manganese .	48·28	35·03	8·23	12·84	40·73	39·91	38·68	31·20	48·16	51·42	53·48	60·85
Iron .	7·58	16·15	51·88	47·22	13·77	14·37	18·38	17·05	8·82	4·96	2·13	0·10
Silica . .	1·80	1·40	2·70	1·85	2·50	1·80	1·40	1·50	0·70	0·70	1·55	0·65
Phosphorus	0·05	0·041	0·025	0·021	0·054	0·029	0·052	0·054	0·017	0·027	0·011	0·119

I was able to examine specimens that were said to be duplicates of those the analyses of which are given above. The mineral composition of these specimens was as follows :—

No. 1.—Manganese-laterite.

No. 2.—Cavernous psilomelane with limonite being replaced by psilomelane.

No. 3.—Limonite and psilomelane mixed.

No. 5.—Sample analysed was made up from two pieces, one of which was very hard limonite, while the other was cavernous manganese-laterite, composed of pyrolusite, psilomelane, and yellow ochre.

No. 9.—Compact dull psilomelane with occasional cavities.

No. 10.—Very cavernous and sooty psilomelane with a little pyrolusite.

No. 11.—Similar to 10, but without pyrolusite.

No. 12.—Dull psilomelane with ferruginous spots.

No. 13.—Massive psilomelane with a thin ferruginous coating.

No. 14.—Dull hard psilomelane with minute crystalline specks.

These 12 analyses give the following range and mean values for the several constituents:—

	Limits.	Mean.	Mean excluding Nos. 3 and 5.
Manganese	3·28 to 60·85	39·07	44·77
Iron	51·88 to 0·10	16·87	10·33
Silica	0·65 to 2·70	1·55	1·40
Phosphorus	0·011 to 0·119	0·042	0·045

It will be seen from these analyses that the manganese and iron contents of the ores are very variable, the percentage of iron increasing as that of manganese decreases, so that the total of the two constituents lies between 48 and 61%, averaging 56. In the fourth column above are given the mean values of the various constituents, excluding the analyses of Nos. 3 and 5, which, being evidently nearer iron-ores than manganese-ores, would not be despatched with the latter. This column may therefore be taken as giving roughly the composition of the ores that would be mined at Talevádi; and considering the unusually small amounts of silica and phosphorus and the proximity of the locality to the port of Mormugáo, it is probable that ore of such quality would find a ready market. It is evident, however, from the descriptions of the specimens given above that the appearance of the ore may be very deceptive and that two equally rich-looking pieces of psilomelane may differ widely in their manganese contents. Thus, Nos. 9 and 12 do not differ much in their physical appearance, both being dull varieties of psilomelane; and yet No. 9 showed on analysis 39 per cent Mn and 18 per cent Fe, while No. 12 showed 51 per cent Mn and 5 per cent Fe. Hence, to ensure the despatch of a fairly uniform product, it is evident that careful analytical work would be necessary.

Although the ore is probably of sufficiently good quality to be marketable and the total quantity available is not inconsiderable, yet the manganiferous nodules are so irregularly distributed in the laterite—as shown by the large number of sections exposed in the various pits—that this occurrence can be only doubtfully regarded as a paying proposition. Probably in times when the price per unit of manganese rules high (one shilling and over) these nodules could be worked at a profit; while with prices as low as ninepence a unit it might be found necessary to close down the workings.

I understand from Mr. Boyce that the following may be regarded as the output figures for the Talevádi deposits :—

Output and labour.

Year.	Output in tons.	Average daily number of people employed.
1904-1905	600	125
1906	234	48
1907	500	..

A road has been constructed by Mr. Boyce from Talevádi to Tinái Ghát Railway Station, Southern Maratha Railway, 12 miles distant, with the gradient mostly in favour of the load, to facilitate the carting of the ore. From this station 144 tons of ore were railed to the port of Mormugáo during 1907, but up till the end of the year no ore was shipped. The figures in the third column above are taken from the Annual Reports of the Chief Inspector of Mines in India. The labour employed is local.

Gibbsite.

An interesting feature of the Talevádi deposits is the occurrence of the hydrated aluminium oxide, gibbsite,[1] in association with manganese-ore. Such an association is, as far as I know, unique in Indian laterites.

4. Nersa.

In 1904-05 Mr. Maclaren also visited Nersa about 5 miles in a straight line S. W. of Khánápur Station, Southern Mahratta Railway. A few pits, the deepest of which reached only 15 feet, had been sunk by Mr. C. P. Boyce of Belgaum on a small hill ½ a mile N. of the village. The manganese-ore takes the form of more or less horizontal thin bands in a soft decomposed rock from which it can easily be extracted. The original character of this rock cannot be stated with certainty, but it was probably a purplish micaceous clay-schist of the Dhárwár Series. Owing to the small amount of work done, Mr. Maclaren was unable to form any opinion as to the value of the property or the origin of the ore. 40 tons of ore were extracted in 1905.

[1] L. L. Fermor. *Rec. G. S. I.*, XXXIV. p. 167, (1906).

Bijapur District.

Although no deposits of manganese-ore of economic value have up to the present been found in this district, yet, if one can judge from the writings of the various authors quoted below, manganese-ores must be somewhat widely distributed throughout the district, both in laterite and in the quartzites and limestones of the Kaládgi series. In all cases the manganese-ore is probably of superficial origin.

'Ingleswára.

Newbold [1] says that manganese veins 'were seen subsequently in the laterite of Ingleswara,' and later[2] that 'among the lateritic debris' 'at the base of the laterite cliffs S. W. of Ingleswara,' intermingled with blocks of limestone passing into chert, 'are interspersed numerous nodules of a black cineritious looking mineral, containing cavities filled with an impure, earthy, brown manganese.' [3] Ingleswára is between Hippargi and Bagewadi and S. E. of Bijapur.

Bágalkot and Kaládgi.

A few years later Lieutenant A. Aytoun, in a paper on the geology of this area,[4] says that iron-ores are abundant in most parts of the district and that ores of manganese occur associated with the iron-ore. 'The limestone at Bagulkot has veins of manganese, but this metal is more frequently met with amongst the sandstone in veins of quartz.' On another page[5] he gives a section showing the undulations passed over in crossing from Bágalkot to Kaládgi and says that 'nearly the whole of this tract abounds in iron and manganese-ores, never seen in veins *in situ*, but covering large spaces from broken up veins.' Regarding a valley on the further side of a low range of hills to the south of Bágalkot, Aytoun[6] says that it is 'covered with soil through which débris of iron-schists, iron- and manganese-ores, and quartz are profusely scattered,' while near the Kaládgi bázár he found a 'great deal of red ferruginous gravel, with occasionally a consolidated block of laterite coated with manganese, which appears as a bluish-black efflorescence on the surface of the block.'[7] He

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1 *Mad. Jour. Lit. Sci.*, XI. p. 245, (1840).
2 *Jour. As. Soc. Beng.*, XIII, p. 1002, (1844), and 'Western India,' p. 82, (1857).
3 Also mentioned in *Jour. Roy. As. Soc.*, VIII, p. 234, (1846).
4 *Trans. Bomb. Geog. Soc.*, XI, p. 33, (1854); 'Western India.' p. 380, (1857).
5 *Ibid.*, p. 46 and p. 390, respectively.
6 *Ibid.*, p. 49 and p. 392, ,,
7 *Ibid.*, p. 54 and p. 395, ,,

further writes that ' vast quantities of iron-ore and manganese' are here and there scattered over the undulations in the east portion of the Kaládgi valley [1] and finally amongst his list of minerals mentions 'perlomelane' (psilomelane) and pyrolusite as being found in great abundance in the elevated tract between Bágalkot and Kaládgi. [2]

The foregoing quotations indicate the occurrence of manganese-ores in great abundance in this district; but Mr. R. B. Foote who mapped this region some years later, refers to Aytoun's paper and observes that the pyrolusite and psilomelane said to be so common ' were only observed by me in very small quantities as films or thin coatings or minute veins in laterite and hematite fragments.'[3] Mr. C. Aubert informs me that he has recently (1905) found a few scattered nodules of manganese-ore about 3 miles east of Bágalkot.

Dhárwár District.

It is only quite recently that ores of manganese have been definitely asertained to occur in this district outside the boundaries of the Sangli State. According to the ' Return of Mineral Production in India for 1891,' page 5, such ores occur in the trap-rock (presumably Deccan Trap), but no information with respect to this supposed occurrence is available. In 1904, however, the late Mr. A. M. Gow Smith found manganese-ores at Tawargatti, Nagargali, and Kumbharde.

Although the Sangli State is included in the Dhárwár Agency, yet for convenience of reference its manganese-ore deposits will be treated in a separate section (page 642).

The manganese-ores, as at present known, of both the Dhárwár district and the Sangli State, are of little or no economic value. They occur either directly on the outcrops of limonite-banded jaspery quartzites of Dhárwár age, as nests, strings and incrustations, or as nodules in laterite overlying Dhárwár rocks. The occurrences of the Dhárwár district lie on the Dhárwár-Shimoga Band of Dhárwárs, while those of the Sangli State lie on the Dambal-Chiknáyakanhalli Band of Foote, re-named the Gadag Band by Mr. Maclaren.[4]

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1 *Trans. Bomb. Geog. Soc.*, XI, p. 54 and p. 395, respectively.
2 *Ibid.*, p. 57 and p. 397, respectively.
3 'The Geological Features of the South Mahratta Country, etc.' *Mem. G.S.I.*, XII, p. 31. (1876).
4 *Rec. Geol. Surv. Ind.*, XXXIV, p. 97. (1906).

1. Tawargatti.

This locality was visited by Mr. J. M. Maclaren in 1904-1905. According to him the deposits are situated about 1 mile east of Tawargatti Station, Southern Mahratta Railway, along a N. N. E.—S. S. W. ridge lying immediately south of the railway line. The railway cutting exposes a good section of the rocks, showing the banded hematitic quartzites of the Dhárwár series resting directly on the foliated granite, the dip of the rocks being easterly. As the granite approaches the junction it apparently becomes a regularly bedded rock, the explanation probably being that the bedded portion represents an original arkose. In the cutting the banded limonitic quartzite shows no manganese-ore, but merely a manganese staining. From the railway cutting to the S. S. E. are a number of old workings probably for road metal. Four or five holes had been sunk (probably by Mr. Gow Smith) to a depth of 10 to 11 feet, but none of them disclosed good ore.

The specimens brought from this locality by Mr. Maclaren show that the manganese-ore, in the form of pyrolusite and psilomelane, occurs only as nests and linings to cracks in the quartzite and as partial replacements of this rock. The quartzite is a very fine-grained jaspery variety interbanded with massive compact limonite, indistinguishable from some of the banded limonite-jaspers of the Jabalpur district.

The occurrence has no economic value.

2. Nagargali.

This locality also was visited by Mr. Maclaren, who says that the manganese occurs in nodules of lateritic character; these have, together with their matrix (probably ordinary ferruginous laterite), been used for road making. As no development work had been undertaken, the value of the deposit could not be ascertained. I do not know the exact position of the manganese-ores.

Dhárwár District (Sangli State).

(*See Plate 13.*)

Amongst the earliest records of the occurrence of manganese-ore in India, are those relating to the range of hills, known as the Kappat Gudda, in Sangli State.

Historical.

A Brahman youth, by name Trimulrow, a pupil of the Rev. Dr. Wilson of Bombay, visited these hills in March, 1839, and gave an account of his trip in the *Oriental Christian Spectator* for July, 1839. Trimulrow did not succeed in visiting the locality of the 'coal', which was amongst other minerals reported to occur in these hills, but a specimen procured for him was pronounced by the editor of the above Journal to be an 'iron ore, probably containing some plumbago.'[1] This mineral, which the natives had designated *iddali kallu*, or *charcoal-stone*, was no doubt the same manganese-ore that, being called *kolsá ka patthar* by the natives, led Newbold [2] to visit the locality, which is in the hills about 2 miles east of Chik-Vadvati village (Chick Wodoorti of Newbold).

'At the base of some of the blackest masses, the guides pointed out partially obliterated excavations which the old inhabitants of the village stated to me had been made by the agents of Hyder and Tippoo[3].'

no doubt under the same mistake as to the nature of this 'charcoal-stone'. So that the first manganese mining in India of which we have any record was probably unwittingly carried out at this locality towards the end of the eighteenth century for the Mysorean princes Haidar Ali and Tipú Sultán. That the black mineral found was really manganese-ore was shewn by Lieutenant J. Braddock [4] who tested Newbold's specimens. Newbold says that 'the formation of the adjacent hills is mica, hornblende, and a chloritic schist, passing in their upper portions, into siliceous ferruginous schists and a lateritic rock' [5]. On page 213 he says that the black mineral is 'more or less blended with siliceous and argillaceous matter' [6], while elsewhere[7] he mentions the occurrence of manganese-ore 'in the laterite area capping the granitic and hypogene rocks of the Kupputgode range'. The occurrence of manganese-ores in these hills is also mentioned in the Bombay Gazetteer.[8]

Early in 1903 Mr. T. B. Kantharia, attracted by Newbold's report, went to Chik-Vadvati and on behalf of the Bombay Company, Limited, obtained a prospecting license for manganese. In 1905, Mr. J. M. Maclaren visited the area, and supplied me with notes and specimens, on which, together with the short account given in Mr. Maclaren's paper 'Notes on some Auriferous Tracts in Southern India'[9], the following

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1 Newbold, *Jour. Roy. As. Soc.*, VII, p. 204, (1843).
2 *Mad. Jour. Lit. Sci.*, XI, pp. 44-46, (1840); *Jour. Roy. As. Soc.*, VII, pp. 212-214, (1843).
3 *Jour. Roy. As. Soc.*, VII, p. 212, (1843).
4 *Mad. Jour. Lit. Sci.*, XI, p. 51, (1840).
5 Same as 2, p. 214.
6 *Ibid.*, p. 213.
7 *Jour. As. Soc. Beng.*, XIII, p. 995, (1844).
8 Vol. XXII, Dhárwár District, p. 25, (1884).
9 *Rec. Geol. Surv. Ind.*, XXXIV, p. 128, (1906).

descriptions are based. As the result of their prospecting operations the Bombay Company, Limited, came to the conclusion that manganese-ore does not exist at Chik-Vadvati in paying quantities.

Situation of the deposits.

The manganese-ores of the Sangli State are found at many points on the outcrops of the banded hematitic or limonitic quartzites that form one of the members of the band of Dhárwár rocks running N.N.W.—S.S.E. through Sangli, Bellary, and Mysore. This band was originally designated the Dambal-Chiknáyankanhalli Band by Foote, but has been re-named the Gadag Band for reasons given in the above-mentioned paper, page 97. Accompanying this paper is a beautiful map, on the scale of 1 inch = 1 mile, of the portion of this band lying in Sangli State. On this map will be found the various localities for manganese mentioned below. The nearest railway station to this area is Gadag on the Southern Mahratta Railway. The village of Chik-Vadvati is 9 miles in a straight line S.S.E. of Gadag.

Chik-Vadvati and Kelur.

The manganese-ores appear 'to be best developed along the ridge lying immediately east of the Chik-Vadvati valley. The rocky outcrops of the ridge as far north as the fault line shewn on the map are stained black with manganese oxides............The chief locality lies in a small gorge in the hills two miles east of Chik-Vadvati'. The containing rock is a banded limonitic jaspery quartzite, striking N.N.W.—S.S.E. and identical in every way with some of the rocks of the manganese area of the Jabalpur district. The dip of this quartzite band is not evident. But the country on either side of the ferruginous band, which is a soft fissile chloritic schist, is seen to dip at about 40° to the E.N.E.

The Bombay Company, Limited, prospected this locality for a period of 2 years (1903 to 1905) and sank over 30 pits along the outcrop within a distance of ¼ mile. The deepest, of 50 feet, was sunk in a old working of 10 feet in depth, in cleaning out which some pieces of broken pottery were discovered. The other main work was the driving of two levels —70 to 80 feet long—through soft decomposed schist until the ferruginous quartzite was reached, at a depth of 15 to 20 feet below the surface. The Bombay Company, Limited, has kindly supplied assays, carried out by Major T. W. Collis Barry, I.M.S., of 10 of the best samples taken from 10 different pits. The assays show the following limits and mean :—

	Limits.	Mean.
Manganese peroxide (MnO_2)[1]	30·77—60·86	..
Manganese	19·45—38·48	31·6
Ferric oxide	19·0 —36·2	..
Iron	13·3 —25·3	16·8
Siliceous residue	7 —31	19·2

It is seen from this that even the best ores are much too siliceous and low in manganese to be of any value, except possibly where a very siliceous ferruginous manganese-ore might be desired. The quantity of ore available was also found to be very small, so that, as already mentioned, the Bombay Company, Limited, finally decided that the ore does not exist in paying quantities.

Mr. Maclaren's specimens show that the ores both at Chik-Vadvati, and at Kelur immediately to the S.E., consist of pyrolusite and psilomelane, intimately associated with banded limonitic jaspery quartzites, from which they have been formed by gradual replacement. Under the microscope this replacement is seen to take place by the gradual extension of a network of veins of manganese-oxide through the very fine-grained quartz mosaic. These veins gradually increase in thickness, reducing the enclosed areas of quartz to smaller and smaller dimensions, until the replacement may become complete. This stage is, however, not usually reached and it is the residual quartz patches that account for the large siliceous residue returned in the assays given above. Vein-quartz is replaced in the same way (see Plate 13, fig. 3).

The occurrence and mode of origin of these ores is in fact practically identical with that of the manganese-ores of the Jabalpur district, and consequently, as in the latter area, the ores—

(1) are very irregular and patchy in their distribution,
(2) occur only at or close to the surface,
(3) are of very variable quality,
(4) are usually of too low grade to be used for export purposes.

[1] It is probable that the manganese was determined as peroxide. It does not necessarily follow that it was all present in this form in the ore.

Hamigi.

Similar manganese-ores occur on the same ridge farther south towards the Tungabhadra river. From the hill above the temples on the river east of Hamigi, pieces of psilomelane of fairly high manganese contents may be broken off, but the deposits appear to be of no importance.

Specimens brought by Mr. Maclaren from Hamigi consist of concretionary psilomelane of concentric structure, evidently formed by the replacement of the jaspery quartzite; while specimens collected by Mr. Kantharia between Chik-Vadvati and the Tungabhadra river consist of pyrolusite, psilomelane, and wad.

Shirhatti.

The late Mr. A. M. Gow Smith told me that some pieces of manganese-ore were found on the surface of fields to the S.W. of Shirhatti.

Nárukot State, Rewa Kántha Agency.

(*See Plate 17.*)

Situation.

A specimen of manganese-ore from near Jámbughoda, collected by the late Dr. W. T. Blanford, caused me to visit this locality. On arriving I found that manganese-ore had recently been discovered by a native prospector in a small hill that rises to some 150 feet above the surrounding plains and is locally known as Ghod-dungri. It is about 2 miles north by west from Jámbughoda and is situated within the boundaries of the village of Jothvád, being about half a mile north of this village just to the east of the road leading from Jámbughoda to Dádiapura. The hill is shown on the 1-inch map of this area as running due north and south; but the south end really runs up as a low spur from the S.W. to join the central mass, and the north end runs away due north as another low ridge. This hill is composed of an intensely folded series of banded gneissic rocks, the strike of which conforms more or less with that of the hill; the dips are usually to the west side of this strike, but sometimes point to the east side. Although there is no manganese-ore of economic value at this locality, yet this hill is of extraordinary interest on account of the variety and beauty of the minerals and rocks composing it and of the relations of these rocks to the surrounding granite. This mass of banded rocks rests on a basis of porphyritic biotite-granite, which occupies all the low-lying ground surrounding the hill and sends out apophyses that traverse the gneisses of the hill. Around

Mode of occurrence.

Fig. 1.—INCLUSIONS OF MANGANESE-ORE AND MANGANESE-SILICATE ROCKS IN PORPHYRITIC BIOTITE-GRANITE.—JOTHVÁD, NEAR JÁMBUGHODA, NÁRUKOT STATE, BOMBAY.

Photographed by L. L. Fermor. *Bemrose, Collo., Derby*

Fig. 2.—OUTCROP OF MANGANESE-ORE ON A QUARTZITE RIDGE.—NEAR SIVARÁJPUR, PANCH MAHÁLS, BOMBAY.

the edge of the hill fragments of the gneisses are seen as isolated inclusions or xenoliths in the granite. The photograph, reproduced in Plate 17, fig. 1, shows a very fine example in which all the fragments included in the granite consist of manganiferous rocks and manganese-ore.

The field evidence thus shows that these gneisses are older than the granite, and that the latter probably passes right under the gneisses of the hill.

Time of alteration of manganese-silicates to ores.

It seems probable that the alteration of manganese silicates to manganese-ores took place before the intrusion of this granite, which has picked up and 'fossilized', as it were, both the unaltered and partially-altered manganese-silicate-rocks, and the completely formed manganese-ore. There can be little doubt about the Archæan age of this granite; it is probably contemporaneous with the Bundelkhand granite. Hence in this one particular locality we can, with a fair amount of certainty, fix the period during which the manganese silicates suffered chemical alteration with production of manganese-ores as Archæan.

Minerals found.

These gneisses consist of bands of a large variety of rocks composed of various combinations of the following minerals :—

Chalcopyrite	(in one rock only).
Quartz.	
Braunite.	
Calcite.	
Felspars	Orthoclase. Microcline. Plagioclase.
Pyroxenes	Several species, including diopside, wollastonite, rhodonite and other manganese-pyroxenes.
Hornblende.	
Garnets	Spessartite. A red garnet. A pale-brown garnet.
Scapolite.	
Zircon.	
Epidotes	Epidote. Piedmontite.
Tourmaline.	
Micas	Manganese-micas. Biotite.
Sphene.	
Apatite.	

Rocks found.

There is a great variety of manganiferous rocks amongst these gneisses, but the following are the chief types :—

1. *Pyroxene-spessartite-quartz-rock* (pyroxene-gondite), often with calcite. The pyroxene may be rhodonite, a yellow or a colourless pyroxene.
2. *Spessartite-quartz-rock* (gondite), with apatite.
3. *Apatite-pyroxene-spessartite-quartz-rock.*
4. *Apatite-spessartite-piedmontite-rock* with some felspar.
5. *Calcite-spessartite-quartz-rock.*
6. *Mica-pyroxene-microcline-quartz-manganese-ore-rock.* The mica is a manganiferous one with the following pleochroism :—

   𝔞 = pink ;
   𝔟 = pale green ;
   𝔠 = orange.

   The pyroxene has the following pleochroism :—

   𝔞 = pink ;
   𝔟 = lilac ;
   𝔠 = blue ;

   this is the blanfordite type.
7. *Crystalline limestone* with *spessartite,* quartz, microcline, and apatite.
8. *Crystalline limestone* with spessartite, piedmontite, and rhodonite (?).
9. *Wollastonite-apatite-calcite-quartz-spessartite-rock.*

At one spot a vein-like cavity was found traversing one of the piedmontite-bearing rocks. In this were found some small but well-formed crystals of piedmontite with measurable faces (see page 190).

Several of the above rocks are of great interest. This remark applies especially to No. 4, on account both of the large amount of apatite it contains and because of its beauty when viewed in thin slices under the microscope. In several of these manganiferous rocks apatite is so plentiful as to constitute almost $\frac{1}{4}$ or $\frac{1}{3}$ of the rock.

These manganiferous rocks are, of course, often blackened, owing to the partial conversion to manganese-ore, usually braunite.

The principal non-manganiferous rocks are the following :—

1. *Epidote-hornblende-quartz-rock,* with sphene, apatite, tourmaline, wollastonite, and chalcopyrite.
2. *Scapolite-garnet-pyroxene-quartz-rock,* with calcite and apatite.
3. *Quartz-felspar-wollastonite-pyroxene-rock.*
4. *Quartz-garnet-pyroxene-rock.*
5. *Microcline-biotite-quartz-rock.*

All the above rocks, both manganiferous and non-manganiferous, are banded and usually fine-grained with granulitic structures.

Granite veins.

The *granite-veins* or apophyses that pierce the gneissic rocks are very interesting; for they often contain various manganiferous minerals, which were no doubt formed by the absorption of materials from the gneisses when the granite was intruded. One vein, consisting of felspar (intergrowths of microcline and oligoclase) with a little interstitial quartz, contains an abundance of accessory minerals. One of these is a pyroxene showing the blanfordite type of pleochroism, and a second is a prismatic hair-brown mineral that microscopically shows all the characters of sphene, but has the rather unusual type of pleochroism peculiar to the manganiferous variety of sphene —*greenovite*. As it reacts for titanium and very slightly for manganese it probably is greenovite.

North Kanara District.

In 1904 the late Mr. A. M. Gow Smith reported the find of several deposits of manganese-ore in the area just north of Supa. They may be divided into 4 blocks :—

1.—In Virkhol, Konáda (15° 16′—74° 34′) and Kálávahal.

2.—In Aveda, Bádgund, and Konáda (15° 18′—74° 37′).

3.—In Puseli.

4.—In Shingargáon.

According to Mr. P. N. Bose, who prospected this area in March and April 1906 on behalf of Mr. P. Gow, administrator of the late Mr. Gow Smith's estate, there is in this area to the north and north-east of Supa a large expanse of the Dhárwár Series. Banded hematitic quartzites form well-defined ridges running in a N.—S. direction, roughly parallel to the strike of the rocks, whilst in the low ground between the ridges phyllites and other softer rocks are met with. These rocks are probably a continuation of the Castle Rock Band of Dhárwárs seen at Talevádi and Bhimgad. Highly granitoid gneisses are found to the north of the Dhárwárs in the neighbourhood of Shingargáon and Kodalgáon.

The manganese-ores consist of pyrolusite and psilomelane and are of lateritic (lateritoid) origin, resting on the outcrops of the Dhárwár rocks;

the occurrence and mode of origin of the ores is similar to that of the ores of the Jabalpur district, Central Provinces, as described by Mr. Bose in *Rec. G. S. I.*, XXI, pp. 71-89 and XXII, pp. 216-226.

Specimens of these ores were brought to the Geological Survey Office by Mr. Gow. They were from Puseli, Shingargáon, and Virkhol, and consisted of psilomelane, often concretionary in shape, and usually mixed with a certain amount of pyrolusite. One piece (from Puseli) contained little patches of what may be manganite. In several of the specimens limonite was associated with the psilomelane. Two pieces, from Virkhol, showed respectively :—(1) a quartz-schist (or else a quartzite), now very friable, and largely replaced by psilomelane so as to form a sort of breccia; and (2) a piece of quartzite banded with limonite, with both of these now largely replaced by psilomelane so as to produce the usual brecciate or network appearance. Another specimen was a beautiful piece of stalactitic limonite. Analysis shows that these ores, like those of Talevádi, are very variable as regards their manganese and iron contents, while the silica and phosphorus are uniformly low, ranging 0·25 to 2·63% and 0·03 to 0·08%, respectively.

The result of the prospecting work was to show that although manganese-ores are fairly widely distributed in this area, yet they are not to be found in any quantity at any one spot. Where a good surface indication was found, the ores were found, when the outcrop was dug into, to pass into unaltered rock below.

During 1907 very active prospecting has taken place in this district, and I believe a large number of claims have been taken up. But I have no information as to the quality and quantity of the ores found.

Pálánpur State.

Some specimens collected in this State by Babu Baidyanath Saha, include :—

(1) Some brownish jaspery quartzite with secondary psilomelane, from 2 miles north of Rohu station, Bombay, Baroda and Central India Railway, and

(2) A rock composed of manganese-garnet (in trapezohedral crystals), tourmaline, orthoclase, and quartz, from Hoshanpur near Chitrasáni station.

Panch Mahāls District.

(*See Plate 17.*)

The only mention I have found of manganese-ore in this district is one by the late Dr. W. T. Blanford, who says 'near Soorajpoor quartzite-sandstone is met with associated with bands of impure magnetic iron, for the most part earthy, and containing much manganese'.[1] Consequently I visited this locality in February 1905 on my way to Jámbughoda, in the Nárukot State, and the following account is based on observations then made.

History.

I found, however, that I had been forestalled by Mr. T. B. Kantharia, who had had his attention drawn to Blanford's account by a reference in the *Records*, *G. S. I.*, and who had some 2 weeks previously explored the ground to the south of the road. The occurrences I visited are the ones he discovered. Mr. Kantharia took his find to Mr. F. A. H. East of Cory Bros. & Co., Bombay. In spite of the rather unfavourable account I was able to give Mr. East about the occurrences, judging from the outcrops, he formed a small syndicate, which spent some money on opening up the most promising occurrence (I believed this is the one I have called A); this was afterwards formed into a limited company entitled 'The Shivrajpur Syndicate, Limited,' in 1905, for an account of which see page 427. The operations of this company have revealed the presence of a body of ore of large size, so I am told. Moreover several others of the outcrops seen by me are said to have been found to correspond to much better ores below.

To facilitate the transport of the ore a mono-rail has been constructed to connect the deposit with Champaner Road station, Bombay, Baroda and Central India Railway, some 17 miles distant.

The output of this company up to date has been as follows :—

Year.	Long tons.
1906	7,286
1907	19,689

In June 1907 another company entitled 'The Bamankua Manganese Company, Limited' with Messrs. Shaw, Wallace & Co., of Bombay, as agents, was floated to work a deposit situated on Bámankua Hill some 3 miles north of the deposit being worked by the Shivrajpur Syndicate, Ld.

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1 *Mem. G. S. I.*, VI, p. 341, (1869).

This company began to export during 1907, and up to the end of the year extracted 2,428 tons of ore.

Geology.

The rocks near Sivarájpur ('Soorájpoor' of Blanford and 'Siorájpur' of map) consist of siliceous slates, often sericitic and calcareous, and of very fine-grained, often jaspery, quartzites. The slates are usually some shade of grey in colour, while the quartzites are, as a rule, either white, purplish, or reddish, and are often banded with limonite, probably of secondary origin.

The strike is somewhat variable, but usually varies from E.S.E. to S. E.; but as the direction of cleavage of the slates is also E. S. E., it tends to obscure their true dip and strike. These rocks belong to the Chámpáner group of Blanford; and on looking over his collection of Chámpáner rocks, I find, included amongst them, in addition to those mentioned above, a specimen of schistose micaceous hematite with little pimples on the schistosity planes due to scattered octahedra of magnetite. This rock is indistinguishable from one variety of the schistose micaceous hematites of the Jabalpur district; taking into consideration both this and the fact that the slates and quartzites (often jaspery and limonite-banded) of this area are likewise very similar to those of the Jabalpur district, there can be but little doubt that the Chámpáner rocks must belong, like those of Jabalpur, to the Dhárwár system. Blanford himself says that he only bestowed the name 'Champaneer', or more correctly 'Chámpáner', on this group of rocks as 'a temporary and local name'; and now that it is possible in the light of more recent investigations to correlate the Chámpáners with their equivalents in other parts of India, the Dhárwárs, it will be convenient to dispense with the term 'Chámpáner' in favour of the more generally used 'Dhárwár'.[1]

In a somewhat hasty examination of the hills immediately to the east of Sivarájpur, and stretching thence about 2 miles south, I found that manganese-ores are of frequent occurrence in this neighbourhood, usually occurring on the tops of the hill-ridges, which rise to 200 to 300 feet above the plains.

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[1] By the rules of priority the word 'Dhárwár' should be discarded and 'Chámpáner' used instead: for Blanford introduced the term 'Chámpáner' in 1869, (*Mem. G. S. I.*, VI, p. 203); while Foote did not establish his *Dhárwár* system till 1886 (*Rec. G. S. I.*, XIX, p. 98). Owing, however, to the frequent use of the term 'Dhárwár' in Indian geological literature and the rare use of the term 'Chámpáner', it would be in the highest degree inconvenient to make this change (see page 283).

The accompanying sketch-map shows the spots at which I found these ores; a careful examination of the hills to the east and north would doubtless reveal many more such occurrences, such as that now being worked by the Bamankua Manganese Co.

Fig. 38.—Map of the Sivarájpur manganese area.

Origin of the ores.

The manganese-ores are, as far as I could tell from the field evidence and the study of microscope sections, of superficial origin resulting from the replacement—more or less complete—of the Dhárwár quartzites (and sometimes of the slates) by oxides of manganese. These ores, like those of the Jabalpur and Singhbhum districts, are, in consequence, very irregularly distributed; and at none of the outcrops examined by me did there seem to be any evidence of the existence of ore in quantity sufficient to be of much economic importance, with the possible exception of the occurrence (A) to be noticed below. Since the opening up of some of the occurrences—I believe of A and others on the same ridge—is said to have shown the presence of large quantities of ore to a depth of 40 feet, with no signs of its lessening in quantity at that depth, and since the ores often contain a certain quantity of braunite (see page 657), it is possible that in addition to the ore formed by superficial replacement there is some representing original manganiferous sediments since compacted; but of this I have seen no evidence myself. And considering the large bodies of manganese-ore in the Sandur Hills that have been in all probability formed by superficial replacement, it does not seem improbable that all the ore of Sivarájpur has been formed in the same way. If so, then it must not be expected to continue of good quality below a depth of, say, 100 feet, if so far. Moreover, the ores are as a rule very impure owing to the presence of small residual patches of the original quartzite or slate that have escaped replacement.

Source of the manganese.

With regard to the source of the manganese that gave rise to the manganese-bearing solutions by the percolation of which the replacement of the quartzites and slates must have been brought about, it is probable that it lies in the Dhárwár rocks themselves, as, for example, in the form of an undiscovered bed of slightly manganiferous hematite, or even in the slates, which no doubt contain traces of this element.

Nature and quality of the ores.

The ores consist of pyrolusite, and what looks like psilomelane at first sight, the latter ore being by far the commoner. On close examination this latter ore is seen, however, to contain minute shining specks suggesting the presence of braunite. That braunite is present is shown by the complete analysis of a hand-specimen given on page 656, and also by the partial analyses of samples on pages 657 to 660, for in these also the silica has been separated into fre and combined. In the bulk samples the braunite ranges from 8 to 24 per cent. and in the complete analysis of a hand-specimen it is 42 per cent.

The ores are often very impure owing to the presence of small residual patches of the original quartzite or slate that have escaped replacement; but such ores would of course be rejected in working the deposits.

The limits and average values of the constituents of commercial value in the samples taken by me are as follows:—

	Limits.	Mean.
Manganese	30·20 to 49·35	41·68
Iron	3·05 to 6·25	4·07
Silica (total)	2·80 to 40·65	19·11
Phosphorus	0·16 to 0·25	0·20
Moisture at 100°C.	0·30 to 0·40	0·35

The figures given in the last column cannot, however, be taken as representing the average of the ore worked, because they include figures for deposits giving high amounts of silica that have naturally been left alone by the miners. The two analyses A. 45 and A. 46, pages 657 to 659, more nearly represent the quality of the ore exported. Mr. East informs me (December 1906), that the average ore despatched runs about :—

Manganese	52
Silica	4 to 6
Phosphorus	0·17

Messrs. Shaw, Wallace & Co. of Bombay have furnished me with the following analyses of Bámankua ores, by Messrs. J. & H. S. Pattinson of Newcastle, representing :—

1. 'The main reef hard Ore.'
2. 'The float Ore at the foot of the hill.'
3. 'Soft Ore from a part of the hill.'

	1.	2.	3.
Manganese	56·65	55·59	50·06
Silica	5·30	2·85	3·30
Phosphorus	0·189	0·170	0·258

Messrs. Shaw, Wallace & Co. remark that it is hardly likely that ore of so high a manganese percentage will be mined throughout, and that an average of 48 to 50 per cent. is likely to be obtained by ordinary fair selection.

Economic value of the deposits.

As already mentioned, my examination of the Sivarájpur outcrops in their virgin condition did not lead me to form a very favourable opinion as to their economic value, especially for working at times of low prices. All that I could say was that it would be necessary to open up the deposits a little, before it could be definitely stated that any of them had much economic value. I am told by Mr. East that, as the result of such development work, the existence of very large quantities of ore has been proved, and that many of the outcrops of manganese-ore—apparently of little value as judged from their outcrops, on account of the presence of abundance of quartz or other impurity—have been found to contain much less foreign matter below the surface, and to consist to a considerable extent of merchantable ore.

Description of deposits.

Brief notices will now be given of the more interesting occurrences of manganese-ores as seen before they were opened up.

Sivarájpur.

At the point marked A on the sketch-map, there was, on the north side of the top of the ridge, quite a large mass of psilomelane forming a cliff 17 feet high and 36 feet measured in a downward-sloping direction along the strike, which is W. by N. This mass of ore seemed to be at least a yard thick, and possibly much more; wherever chipped it was found to consist of a beautiful compact metallic grey psilomelane, containing minute braunite specks. This was the finest mass of ore of presumed superficial origin that I had then seen anywhere; and the only deposits of this origin I have since seen that surpass it in size are Kumsi and those of the Sandur Hills.

A picked specimen of ore from here of specific gravity 4·25 was analysed by Messrs. J. & H. S. Pattinson with the following result:—

Specimen No. A. 607.

Manganese peroxide	60·30
Manganese protoxide	17·13
Ferric oxide	6·00
Alumina	1·19
Baryta	0·79
Lime	1·32
Magnesia	0·94
Potash	2·27
Soda	0·23
Combined silica	4·20
Free silica	2·70
Sulphur	0·021
Phosphoric oxide	0·366
Arsenic oxide	*Nil.*
Cobaltous oxide	*Nil.*
Nickelous oxide	*Nil.*
Cupric oxide	0·02
Lead oxide	*Nil.*
Zinc oxide	0·05
Titanic oxide	0·04
Chlorine	*Nil.*
Fluorine	*Nil.*
Combined water	2·00
Moisture at 100°C.	0·60
Carbonic oxide	*Nil.*
	100·167
Manganese	51·40
Iron	4·20
Silica (total)	6·90
Phosphorus	0·160
Specific gravity	4·25

The analysis can be recalculated into terms of its mineralogical composition as follows :—

Apatite		0·846
Braunite (containing 6·00 Fe_2O_3)		42·17
Psilomelane, composed of :—		
$Al_4(MnO\ )$	2·99	
Ba_2MnO_5	1·06	
Ca_2MnO_5	1·61	
Mg_2MnO_5	2·14	
K_4MnO_5	3·51	
Na_4MnO_5	0·42	
Cu_2MnO_5	0·03	
Zn_2MnO_5	0·08	
H_4MnO_5	7·71	
Mn_2MnO_5	33·81	
	53·36	53·36
Quartz		2·70
Sulphur		0·021
TiO_2		0·04
Moisture		0·60
		99·737
Oxygen unused		0·43
		100·167

From this it will be seen that the specimen consisted of about 42 per cent. of braunite and 53 per cent. of psilomelane, with small amounts of other constituents.

A little further to the east along this ridge there was, at the point B, another outcrop, this time consisting of psilomelane and pyrolusite with much residual quartzite, sericitoid slate, and vein quartz. The photograph (Plate 17) shows this outcrop. A sample taken all along the top of the ridge, starting from A and going east as far as the bend to the north, consisted mainly of psilomelane with some pyrolusite. A partial analysis by Messrs. J. & H. S. Pattinson gave the following result :—

Sample No. A. 46.

Manganese peroxide	71·87
Manganese protoxide	5·06
Ferric oxide	8·92
Baryta	1·22
Silica (combined)	0·80
Silica (free)	2·00
Phosphoric oxide	0·58
Arsenic oxide	0·055
Water (combined)	3·00
Moisture at 100° C.	0·35

This is equivalent to :—

Manganese	49·35
Iron	6·25
Silica (total)	2·80
Phosphorus	0·253

On the south and east edges of the top of the hill C, some very fine-grained, often jaspery, quartzites of red, pink, grey, white, and dark brown tints, crop out. Apparently interbedded with them are bands of psilomelane, which, though evidently only replacement products, often attain a state of great apparent homogeneity and purity. They vary from 1 to 6 inches in thickness, averaging 2 to 4 inches, and often sweep round and join so as to enclose lenticular patches of quartzite, as is shown by the accompanying sketch copied from the cross-fracture of a block of this rock.

Fig. 39.—Quartzite partly replaced by manganese-ore.

A sample taken both from the loose fragments occurring on the N. W. slopes of the hill and from the outcrop was partially analysed by Messrs. J. and H. S. Pattinson with the following result :—

Sample No. A.45.

Manganese peroxide	64·10
Manganese protoxide	10·18
Ferric oxide	10·26
Baryta	3·84
Silica (combined)	2·45
Silica (free)	4·75
Phosphoric oxide	0·362
Water (combined)	2·00
Moisture at 100° C.	0·35

This is equivalent to :—

Manganese	48·41
Iron	3·60
Silica (total)	7·20
Phosphorus	0·158

On following the strike of the rocks of the hill C in an E. S. E. direction, manganese-ore fragments are seen right down the slope; and then, on rising again up the small valley occupying the angle where the main range bends from S. S. W. to west, several large outcrops of impure manganese-ores are to be found.

Pyrolusite is not as a rule as plentiful in these hills as psilomelane; but at the point D there is an outcrop of pyrolusite about 7 paces wide and 10 paces long on the strike (E. 35° S.). An outcrop sample taken here, and containing a little psilomelane in addition to the pyrolusite, yielded on analysis :—

Sample No. A.44.

Manganese peroxide	56·80
Manganese protoxide	3·61
Ferric oxide	4·85
Baryta	1·25
Silica (combined)	1·10
Silica (free)	24·70
Phosphoric oxide	0·512
Water (combined)	1·90
Moisture at 100° C.	0·30

This indicates the presence of nearly 25 per cent. of residual quartz and is equivalent to :—

Manganese	38·77
Iron	3·40
Silica (total)	25·80
Phosphorus	0·223

Road section.

Where the road from Chámpáner to Jámbughoda cuts through these hills, there is (at point E on map) a very instructive section—doubtless the one seen by Blanford. It consists of alternating quartzites and sandy slates very much folded, so that in the course of some 250 yards several anticlinal and synclinal folds are to be seen. The quartzites are fine-grained, compact, pinkish, yellowish, and white, break with a conchoidal fracture, and have mostly been more or less replaced by manganese oxide deposited from solution percolating along the bedding and joint planes; consequently the exteriors of the various blocks are blackened to a depth of from ½ to 3 inches, whilst the quartzite inside is sometimes decomposed and friable, and sometimes almost quite fresh. The blackened rock may be either soft or hard; in the latter case it has a dark grey fine-grained appearance. A microscope section of the latter shows that it really consists of a net-work of oxide of manganese sweeping round and enclosing remains of the separate tiny quartz grains composing the quartzite. Fig. 1 of Plate 10 shows a photo-micrograph of the junction between a part of the rock that has not been darkened by the manganese oxide, and a part that has been completely blackened.

On the rising ground just to the south of this road section a series of specimens could easily be collected showing a gradation from a quartzite with a few black manganiferous spots, through black manganiferous quartzites with residual patches of unblackened quartzite, to the wholly black rock. As might be expected, this impregnation and replacement by manganese oxide has proceeded to different depths in different places.

On the north side of the road on the top of the hill F is another outcrop of quartzite and manganese-ore. A sample was taken of the latter, partly from the outcrop and partly from the débris scattered on the S. E. slopes of the hill. The majority of pieces of ore were pyrolusitic in nature and some of them contained a little residual quartzite. The sample yielded on analysis (J. & H. S. Pattinson):—

Sample No. A.47.

Manganese peroxide	43·98
Manganese protoxide	3·09
Ferric oxide	4·35
Baryta	0·33
Silica (combined)	1·95
Silica (free)	38·70
Phosphoric oxide	0·40
Water (combined)	1·95
Moisture at 100° C.	0·40

This indicates the presence in the sample of nearly 39% quartz : it is equivalent to :—

Manganese	30·20
Iron	3·05
Silica	40·65
Phosphorus	0·174

In addition to the manganese-ores, there are to the found in several places blackened or manganized slates. Of such places the following may be particularized :—(1) the stream bed immediately west of hill 690 ft. and (2) the points where the road crosses two water-courses just to the west of Jabán.[1] Thin slices of these manganized slates examined under the microscope show that the blackening is due to their impregnation by manganese oxide in the form of thickly scattered minute granules or dust.

Manganized slates.

Rájpipla State.

The Gazetteer[2] records a trace of manganese in an analysis of some iron slag found as large mounds to the W. of Limodra about 25 miles W. of Nándod in Rájpipla.

Ratnagiri District.

Manganese-ores are said to occur in the trap rock—the Deccan Trap—of this district,[3] but no authority for this statement is given. Mr. B. G. Shastree[4] gives a description of an iron-ore from near Malván containing a trace of manganese. Malván is on the metamorphic and crystalline rocks.

Sátára District.

The occurrence of manganese-ores in this district was first brought to the notice of the Geological Survey of India by Mr. C. M. P. Wright, who reported on the manganese-ores of the Mahábaleshwar plateau on behalf of Messrs. McLeod and Co. of Calcutta. This firm kindly allowed me to peruse and make use of Mr. Wright's report. I must here record my indebtedness to Mr. K. C. Cowasji of Mahábaleshwar, who kindly showed me the more important of the localities where manganese-ores had been found

History.

[1] In Nárukot State immediately over the boundary.
[2] Bombay Gazetteer, Vol. VI, p. 11, (1880).
[3] Return of Mineral Production in India for 1901, p. 48.
[4] *Jour. Bomb. As. Soc.*, I, p. 435, (1844).

Geology.

The rocks of this district consist of horizontally-bedded flows of basaltic and amygdaloidal lavas belonging to the main body of the Deccan Trap formation. This covers a vast expanse of the surface of Western India, and, except for some points W. of Nasik, reaches its highest elevation above sea-level on the Mahábaleshwar plateau, the culminating point of which is Sindola (4,713 feet). This, with the exception of the point near Akola already mentioned, is also the highest point on the Deccan Trap portion of the Western Gháts, *i.e.*, north of the South Kanara district. Owing no doubt to the excessive rainfall during the south-west monsoon, Nature's denuding agents acting on the traps have excavated in them deep valleys. Those radiating from the Mahábaleshwar plateau are like deep notches in its edge and are often 2,000 feet and more below the general level of the plateau, which is often bounded by stupendous cliffs descending very steeply in a series of stepped vertical scarps. The highest points of the Mahábaleshwar and Yeruli plateaus, and of other elevated tracts in the district, are capped by patches of laterite, of no great thickness, which possibly once formed a more or less continuous sheet.

Localities.

The manganese-ore occurrences of the following localities were examined by me:—

1. Lingmála,
2. Bhekauli,
3. Chikhli,
4. Yeruli;

but in addition to these Mr. Wright reports manganese-ore from the following localities:—

5. Metgotar,
6. Awkali,
7. Malusar,
8. Sindola,
9. Tekowli,
10. Kas and neighbourhood.

Manganese-ore has also been found by Mr. H. Wallinger of Sátára near:—

11. Khánápur.

All the localities named are on the Mahábaleshwar plateau, with the exception of No. 4, which is on the Yeruli plateau near Wái; No. 10, which is about 16 miles S. S. E. of Mahábaleshwar and 12 miles west of Sátára; and No. 11, which is in the south-eastern corner of the district.

Mode of occurrence and origin.

In every case the manganese-ore seen was concretionary psilomelane of botryoidal and other shapes. These concretions were either lying loose on the surface, or were contained in 1 to 3 feet of reddish or brownish clayey soil, resting immediately on crumbly beds of soft greyish or reddish trap containing decomposed felspar phenocrysts and a copper-coloured micaceous mineral. It is a curious fact that, with one doubtful exception,[1] nowhere was any trace of manganese-ore seen associated with the laterite so abundant at both Mahábaleshwar and Yeruli. The soil containing the manganese concretions was in every case situated at a slightly lower level than, and not far from the edge of, the base of the laterite cap.[2]

There can be no doubt that the laterite, often very aluminous, of this district, has been derived in past times, at least in part, by the chemical alteration of beds of lava similar to those now immediately underlying the laterite. This process has consisted in the main of a concentration of oxides of iron, aluminium, and titanium, and of a removal of silica. Judging from the evidence of the manganese-ores occurring in the laterite of Belgaum, Bidar, and Jabalpur, the tendency, when a rock becomes lateritized, is for any manganese it contains to segregate into veins, patches, and nodules, in the laterite. In this case the manganese, which the traps no doubt contain in small quantities,[3] has, instead of being concentrated in the laterite, apparently been removed, and the question arises as to whether the psilomelane concretions occurring in the above-mentioned manner may not indicate the destination of this manganese. The psilomelane nodules of Chikhli contain little specks of a soft greenish material similar to that occurring in the underlying decomposed crumbly red trap; this indicates that the soil arises from the direct decomposition of the traps and that when the other constituents are removed by meteoric agencies the manganese segregates in the residual ferruginous soil, no doubt using portions of the trap as nuclei. With the access of more and more manganese, such portions of the traps as become enclosed in the manganese-

1 In a little ravine near the Yenna Falls I found a pebble of possible lateritic origin composed of pisolites of wad—averaging $\frac{1}{8}$ to $\frac{1}{4}$ inch, but ranging up to nearly 1 inch, in diameter—set in a red ferruginous clay.

2 The heights above sea-level of the various occurrences of manganese-ore, as taken with an aneroid, varied between 4,050 and 4,350 feet.

3 As an exceptional example of manganese occurring in the traps, I may mention a lavender-coloured earthy lava from the Mahábleshwar-Pratápgad road, mile-stone 84, containing abundance of heulandite and of included fragments of scoriaceous lava. Some small dark blackish fragments included in this lava give a decided reaction for manganese-ore, on fusion with nitre and fusion mixture (28·53 in Rock Register).

ores must suffer gradual replacement, which in all but the case of Chikhli has become complete. The manganese forming these nodules has therefore perhaps been derived :—

1. Partly by concentration during decomposition and removal of the basaltic lavas.

2. Partly from solutions bringing it from the laterite masses.

The laterite cap must once have covered the ground where the manganese now occurs; and it becomes a question as to whether these so-called 'soils' are really such, formed by decomposition of the traps at the surface posterior to the removal of the laterite cap; or whether they existed beneath the laterite as a stratum intervening in places between the laterite and the traps, and serving a locus for the deposition of the manganese removed during the formation of the laterite.

Nature and quality of the ores.

As already mentioned all the ores found were psilomelane of concretionary origin. I took samples of the ores from the four localities visited. These were analysed by Messrs. J. and H. S. Pattinson of Newcastle, and the results are inserted under the respective localities. The limits and mean of these analyses are as follows :—

	Limits.	Mean.
Manganese	37·58 to 45·62	40·79
Iron	4·40 to 9·25	6·94
Silica	2·90 to 4·75	3·75
Phosphorus	0·036 to 0·098	0·067
Moisture	1·70 to 2·50	1·99

From this it will be seen that the ores are low grade manganese-ores; but they are, except for their low manganese, of good quality, being low in both silica and phosphorus.

The combined silica shown in the analyses does not indicate the presence of braunite; it is probably due to the presence of residual portions of siliceous material from the traps, such as was noticed in the ore of Chikhli. The large amounts of combined water are also noticeable.

Economic value.

Judging from the foregoing figures, there is no doubt that manganese-ores of fair quality are to be found at several points on the Mahábaleshwar plateau, and doubtless also in many other parts of the Western Gháts where similar conditions prevail. Their mode of origin, however, holds out no hope of manganese-ores ever being found in sufficient quantity at any one locality to pay for extraction; and certainly no such spot has yet been found.

Waral or múlwi.

It is interesting to note that the Dhávads of Mahábaleshwar, who by caste are iron-smelters, although they no longer ply their profession, recognize the difference between manganese- and iron-ore, and have two separate words to describe the former—namely *waral* and *múlwi*. According to the two Dhávads who accompanied me, they used to smelt a certain proportion of manganese-ore with the iron-ore. If this be the case the resulting iron must have been similar to that of Ghogra in the Jabalpur district and of quite a different character to the ordinary native soft iron. I would suggest this as an interesting point, worth investigation by a future visitor to Mahábaleshwar with more time at his disposal than I had.

A few notes on the localities visited will now be given.

1. Lingmála.

After leaving the Pánchgani-Mahábaleshwar road at mile-stone 72 and going about ¾ mile south along the road to the Lingmála forest bungalow, a small stream-bed is found crossing the road. A few yards upstream a pit had been dug; this showed a section 13 feet deep of red clay containing fragments of laterite and very decomposed earthy lavas and also a few small botryoidal nodules of psilomelane, which were found to within 4 feet of the base of the section. In a little ravine in the trap near the Yenna Falls were seen several loose pieces of shiny botryoidal psilomelane; a sample collected partly from these and partly from the concretions in the pit gave the following partial analysis :—

Sample No. A.48.

Manganese peroxide	56·57
Manganese protoxide	2·36
Ferric oxide	13·21
Baryta	4·86
Silica (combined)	3·30
Silica (free)	0·15
Phosphoric oxide	0·082
Water (combined)	7·25
Moisture at 100° C.	2·50

This is equivalent to :—

Manganese	37·58
Iron	9·25
Silica (total)	3·45
Phosphorus	0·036

2. Bhekauli.

Two pits were seen just west of the Sátára-Mahábaleshwar road at about 29½ miles from Sátára. As usual the manganese-ore nodules occurred in laterite soil resting on a crumbly decomposing trap. A fairly large number of psilomelane concretions of curious botryoidal shapes had been collected into small heaps; a sample taken from these showed :—

Sample No. A.50.

Manganese peroxide	62·78
Manganese protoxide	2·85
Ferric oxide	6·28
Baryta	2·66
Silica (combined)	2·75
Silica (free)	0·15
Phosphoric oxide	0·168
Water (combined)	7·40
Moisture at 100°C	2·00

This is equivalent to :—

Manganese	41·89
Iron	4·40
Silica	2·90
Phosphorus	0·073

3. Chikhli.

About 4 miles S. by E. from Mahábaleshwar, and a little west of Chikhli village, is a flat piece of ground at a level of about 4,100 feet, with small elevations or hills of laterite rising from it. A large number of small psilomelane concretions were found scattered on the surface, and a pit put down in one place showed 1 to 2 feet of brown clayey soil containing nodules of manganese-ore together with some laterite fragments. This rested on crumbly altered red trap containing (1) spots of a soft greenish-white stuff, corresponding, no doubt, to original amygdular infillings; and (2) soft white phenocrysts that were probably once felspar. The manganese-ore when fractured shows, as already noticed on page 663, tiny specks of a substance very similar to the greenish-white amygdular material. This is the locality at which I saw the most ore; and, as the following analysis of a sample taken here shows also that which yields the highest grade ore :—

Sample No. A. 51.

Manganese peroxide	68·76
Manganese protoxide	2·79
Ferric oxide	7·14
Baryta	2·99
Silica (combined)	3·90
Silica (free)	*nil.*
Phosphoric oxide	0·14
Arsenic oxide	0·023
Water (combined)	3·70
Moisture at 100° C.	1·70

This is equivalent to :—

Manganese	45·62
Iron	5·00
Silica	3·90
Phosphorus	0·060

4. Yeruli.

The Yeruli plateau consists of Deccan Trap lavas, but has standing up from it three elevations, which are flat-topped and capped with laterite. On the plateau to the S. E. of the most easterly of these laterite caps, and about ½ mile east of the village of Yeruli, is another occurrence of manganese-ore. As usual the ore is found in 1½ to 2 feet of red clay resting on crumbly grey trap. The manganese-ore seems to have formed as pisolitic concretions in the clay. These are sometimes isolated, but, by the union of several of them, botryoidal aggregations are formed. Flat concretions also occur at times.

A sample taken here was analysed by Messrs. J. and H. S. Pattinson with the following result :—

Sample No. A.52.

Manganese peroxide	58·04
Manganese protoxide	1·80
Ferric oxide	13·00
Baryta	2·63
Silica (combined)	4·70
Silica (free)	0·05
Phosphoric oxide	0·225
Water (combined)	6·50
Moisture at 100°C	1·75

This is equivalent to :—

Manganese	38·08
Iron	9·10
Silica (total)	4·75
Phosphorus	0·098

A piece of black magnetic slag sent by Mr. K. C. Cowasji to the Geological Survey was found to be manganiferous. It was picked up in a field at Yeruli, and is probably another indication of the fact that manganese-ores were formerly made use of in this district in iron-smelting (see page 665).

11. Khánápur.

Three small concretions of psilomelane, found on the surface of a low hill 4 miles east of Khánápur, were forwarded to the Geological Survey Office in 1905 by Mr. H. Wallinger, Assistant Superintendent of Police, Sátára. From specimens obtained from a pit dug there, it seems that these concretions were lying on the surface of lateritic rock free from manganese-ore.

CHAPTER XXXI.

DESCRIPTION OF DEPOSITS—*continued.*

Burma and Central India.

Burma—Amherst—Hantha-wadi—Magwe—Mergui—Myingyan—Ruby Mines—Sagaing—Salwin Hill Tracts—Taung-ngu—Tavoy.

Central India—Bhopál—Dhár—Gwalior—Indore—Jhábua—Rewah.

Burma.

Amherst District.

O'Riley [1] says that manganese-ore occurs as 'grey oxide' in the 'secondary formations' pierced by the Thaungyín and Gyaing (Gyne) rivers. Mr. H. Thompson also records the occurrence of manganese-ores in this district.[2]

Hantha-wadi District.

Whilst exploring the post-tertiary strata for coal at Insein (Engsein) 6 miles from Rangoon, 'nodules and bands of a hydrated peroxide of iron containing manganese' were found throughout the surface bed of sand.[3]

Magwe District.

Concretions consisting principally of oxide of manganese were found either at Yenangyaung or further up the Irrawadi river,[4] the report quoted not being clear on this point. This occurrence is possibly in the Fossil Wood Group.

Mergui District.

Manganese-ores have been recorded from several localities; but none of these occurrences has yet been shown to be of economic value. The large deposit of wad that Captain Tremenheere reported finding in

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1 *Journ. Ind. Archip.*, III, p. 733, (1849).

2 Letter No. 440-4S-11, dated 15th March 1895, to the Revenue Secretary to the Chief Commissioner, Burma, p. 3.

3 Romanis, *Rec. Geol. Surv. Ind.*, XV, p. 138, (1882).

4 Romanis, Report on the Yenanchaung Oil-wells. Rangoon. p. 2. (1884).

1841 [1] in the basin of the Great Tenasserim River was shown by Mr. Piddington [2] to contain no manganese, and to be almost wholly carbonaceous.[3] In the Museum there is a specimen from Mergui, of psilomelane with limonite. Dr. Mason [4] says that manganese-ore occurs on some of the islands of the Mergui Archipelago, while Dr. J. Anderson collected specimens of impure manganese oxide, chiefly psilomelane, from Gua Islet, Padau Bay, King Island, in this archipelago.[5]

Some specimens of tin-store from Kumong, Maliwún, sent to the Geological Survey office for assay by Mr. T. W. H. Hughes, were found to contain large quantities of iron, manganese, and tungsten, derived from the wolfram mixed with the cassiterite.[6]

Myingyan District.

Mr. E. H. Pascoe, of the Geological Survey of India, in a paper about the Kabat Anticline, near Seiktein, in this district, writes : [7]—

'In the extreme north of this fold, water-worn blocks and pebbles of a hard, impure, detrital limestone occur in the stream-beds and on the summits and slopes of the hills. This interesting rock consists largely of bryozoan and foraminiferal tests, the material of which has been replaced by brown oxide of manganese, while their interstices and the space immediately surrounding them are commonly occupied by ferric oxide. Fragments of brachiopods, pelecypods and gastropods are frequent. Another prominent feature, is the occurrence of fragments—possibly pebbles—of a felspathic sandstone, consisting of clear angular grains of felspar, often of large size and frequently showing twin-lamellation, with more or less accessory quartz, cemented together by oxide of manganese, which has in all probability replaced calcite, since this mineral formed the cementing material in a few cases. One pebble of a fine sandy clay was observed. The general cementing material of the rock as a whole is calcite, but there is so much manganese that the rock is quite dark in colour.'

The age of these rocks is presumably Miocene, but possibly Pliocene.

Ruby Mines District.

Professor J. W. Judd,[8] in describing the pegmatites of this area, says 'Epidote is often found developed along the cracks of these ortho-

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1 *Jour. As. Soc. Beng.*, X, pp. 852-3;
Cal. Jour. Nat. Hist., III, pp. 55-56, (1843);
Sel. Rec. Beng. Govt., VI, pp. 12-13, (1852).
2 *Jour. As. Soc. Beng.*, XVI, pp. 369-371, (1847).
3 See also Mallet's Mineralogy, pp. 10 and 11, (1887).
4 The Natural Productions of Burmah, p. 48, (1850).
5 Mallet's Mineralogy, p. 61, (1887).
6 *Rec. Geo. Surv. Ind.*, XXIV, p. 135, (1891).
7 *Rec. G. S. I.*, XXXIV, pp. 248, 249, (1906).
8 *Phi. Trans. Roy. Soc. London*, Vol. 187 A, p. 197, (1896).

clases, and in one instance (*viz.*, in a specimen collected on the road between Mogok and Momeit), the epidote has the peculiar colour and pleochroism of withamite, due, no doubt, to the fact that it contains some manganese.'

Sagaing District.

Among some minerals received from Ava and forwarded by Major Burney, Mr. J. Prinsep[1] found a sample of black oxide of manganese with an earthy fracture and shining black mammillated surface. Nothing is known as to the mode of occurrence of this ore.

Salwin Hill Tracts.

Wad has been noticed in thin films coating the rocks in the neighbourhood of Yetagon, a few miles above Yimbaing, a large village on the Salwin, about 70 or 80 miles from Maulmain.[2]

Taung-ngu District.

According to Mr. Theobald[3] irregular tabular masses and botryoidal nodules of manganese-ore occur in some of the beds of sandstone, of the Fossil-wood Group, forming the low range of hills dividing the Yayuay and Saing Chaung from the Sit-taung river. An analysis by Mr. Tween showed 28% of manganese oxide.

Amongst some specimens of laterite forwarded in 1906 to the Geological Survey Office by Mr. F. J. Branthwaite, Officiating Conservator, Tenasserim Circle, Burma, was one collected by Mg. Shein, Deputy Ranger, Gwethe Range, Taung-ngu Division, on low land, the exact locality not being specified. This particular specimen cannot be regarded as a true laterite, but rather as sand or sandstone cemented by oxide of manganese. In places where the sand is not cemented by manganese oxide the grains are held together by interstitial clayey matter.

Tavoy District.

Captain J. Low [4] says that 'manganese exists in considerable quantities' in this area, the exact locality not being clearly stated; but it is

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1 *Jour. As. Soc. Beng.*, I, p. 15, (1832).
2 R. Romanis' Report on Minerals of Tenasserim, 28th July 1885. Quoted in Mallet's Mineralogy, p. 62, (1887).
3 *Mem. Geol. Surv. Ind.*, X, p. 267, (1873).
4 *Jour. Roy. As. Soc.*, III, p. 49, (1836).

possibly a low rocky ridge described as running parallel to the Tavoy river for some miles. There is in the Museum a specimen of ferruginous manganese-ore that is partly psilomelane. Mr. Theobald[1] once obtained near Henzai an impure earthy cobalt containing manganese, but could learn no further particulars beyond the locality.

Central India.

Bhopal.

In 1907, the Private Secretary to Her Highness the Begum of Bhopal forwarded some specimens to the Geological Survey that were found to consist of psilomelane. My colleagues Messrs. A. M. Heron and H. C. Jones subsequently examined the occurrence and the following is taken from their account of it. The ore was found during the excavation of a tank about 500 yards N. E. of Kanugáon, a village 2 miles west of Bhopal town. It occurs in the lower part of the surface soil as irregular nodules up to 6 inches across. These have apparently weathered out of the Lower Bhander Sandstone (a division of the Upper Vindhyans) beneath. This rock here contains several bands of conglomerate, in which, and in the sandstone, the psilomelane forms irregular patches. The psilomelane also occurs as dendroid films in the sandstone, and, to a small extent, as a cementing material in the conglomerate. Patches of limonite are also found, and this mineral is sometimes mixed with the psilomelane. In the immediate vicinity of the excavation the rock, wherever exposed, shows some of these structures, but they were not seen elsewhere in the neighbourhood. No commercial value is attached to this occurrence; for the ore loose in the soil is small in quantity, whilst it is even more scattered in the rock.

The Dhar Forest.

In the outlying portion of the Dhár State known as Nimánpur or the Dhár Forest, as well as in Indore State, Central India, and the Nimár district of the Central Provinces, the sandstones and conglomerates of the Lameta formation rest on a peneplain of Bijáwar and Archæan rocks. In this area the Bijáwars consist principally of limestones, with quartzites, slates, and curious breccias, which are probably fault-breccias and hence, although in the Bijáwar formation, probably of later age, prob-

[1] *Rec. Geol. Surv. Ind.*, VI, p. 95, (1873).

ably post-Vindhyan. They are usually very siliceous and have been referred to by Blanford[1] as 'hornstone-breccias.' The Bijáwar rocks seemed to have been lateritized at the surface in pre-Lameta times by a process analogous to that by which the post-trappean laterites have been formed. This pseudo-laterite has been designated 'porous breccia' by Mr. Vredenburg, and is composed of angular fragments of quartz, hornstone, quartzite, etc., set in a soft porous, loamy, matrix. In many cases this porous breccia has probably been formed directly from the hornstone or chert-breccias ; but it is not certain that this is always the case, and that other rocks, such as siliceous limestones, may not have given rise to some of the porous breccias. The lowest Lameta beds probably consist sometimes of this porous breccia rearranged by water, so that it is often impossible to decide where the latter ends and the Lametas begin. The argillaceous-sandy matrix of this breccia is often found replaced by manganese oxides (pyrolusite, wad, or psilomelane), so as to yield a breccia of angular fragments of white quartz, etc., set in a black matrix of manganese oxide.

The Lameta sandstones and conglomerates, where porous, have also often been impregnated by oxides of manganese, and where the sand grains and pebbles were originally set in an argillaceous matrix, the latter has often been replaced by psilomelane. No cases have yet been found of undoubted original manganese oxide in the Lameta rocks.

The following is a list of the occurrences of manganese in this State :—

1. Hill 925 feet, Kanár.
2. Rátagarh.
3. Hill 888 feet (S.-W. of).
4. Katotia.
5. Pola Khal.
6. Kheria Kund.
7. Pán Kuár.

Of these Nos. 1 and 7 were found by myself, and the remainder by Mr. Vredenburg. None of them are of any economic value.

1. Hill 925 ft., Kanár

In a small stream-bed draining down to the east, from hill Δ 925, which lies about 1 mile east of Kanár on the Kanár River, is a small

[1] *Mem. G. S. I.*, VI, p. 198, (1869).

deposit of manganese-ore. The manganese occurs in the form of patches of pyrolusite in a breccia composed of pieces of white quartzite up to 6 inches in diameter set in an ochreous matrix, which seems to be decomposed limestone. Possibly this is a case of a Bijáwar breccia of limestone and quartzite decomposed at the surface with the introduction of pyrolusite, since the predominant rock round the occurrence is Bijáwar limestone. But as there is Lameta sandstone resting on the Bijáwar limestone close by, it is just possible that this rock is of Lameta age. I had a small trench dug across the nálá; this showed that at a depth of 2 feet the manganese-ore became scarce, the breccia of quartzite in a yellow matrix still persisting (17·338, 17·433, 17·592, and 17·593).

2. Rátagarh.

In a tributary of the Kanár at Rátagarh Mr. Vredenburg found a solitary boulder, which when broken open was found to consist largely of a beautiful dark grey silky mineral occurring in divergent plume-like tufts, and showing the structure known as cone-in-cone. The mineral itself is too hard for pyrolusite, and too soft for psilomelane. Hence it is not improbable that it is a very finely fibrous variety of hollandite; but it would need a complete analysis to decide this.

Rátagarh is not marked on the 1-inch map of this area. It is the name of a camping place on the east bank of the Kanár River, about 7 miles east of Kátkut, and ½ a mile S. E. of the hill marked on the map as △818 (16·462).

3. Hill 888 ft. (S. W. of).

Some manganese-ore was found by Mr. Vredenburg at a point in a nálá 1·6 miles W. S. W. of the point △ 888 on the 1-inch map. The specimen brought is wad, very calcareous in places, and perhaps the result of the surface replacement of Bijáwar limestone (16·458).

4. Katotia.

In a tributary of the Katotia Khál, at a point E. S. E. of Katotia, Mr. Vredenburg found a manganiferous and ferruginous sandstone with a calcitic cement (16·504).

5. Pola Khál.

In the nálá lying to the N. E. of the village of Pola Khál Mr. Vredenburg found a considerable amount of basement conglomerate and conglomeratic grit of the Lameta formation with the matrix of the pebbles and sand grains replaced by manganese-ore, mainly psilomelane. In some places the manganese-ore had assumed curious concretionary forms. A sample of conglomeratic grit and sandstone, with the manganiferous cement, and weighing about 30 lbs., was analysed by me with the following result:[1]—

Sample No. M.1.

MnO_2	28·84
MnO	2·66
Fe_2O_3	5·21
Al_2O_3	2·83
BaO	6·84
Siliceous residue	50·35
P_2O_5	0·04
CoO	0·27
NiO	0·56
H_2O (combined)	2·50
Moisture at 100°C	0·75
	100·85
Manganese	20·29
Iron	3·65
Phosphorus	0·016

The ore is evidently of no value. After eliminating the siliceous residue from the analysis, the remainder corresponds in composition with psilomelane (16·459, 16·460, 16·464, and 16·465).

6. Kheria Kund.

To the north of Kheria Kund in the large tributary joining the right bank of the Ghorapáchar river about 4½ miles north of Katotia Mr. Vredenburg collected some specimens of mixed wad and yellow ochre, sometimes very calcareous. The localities are on the slate division of the Bijáwars (16·438 and 16·461).

7. Pán Kuán.

This is the name of a camping place situated about 6 miles along the road from Kotkhera to Palási along the northern edge of the Dhár Forest. It is marked on the 1-inch map as 'WELL', and is about 6 miles east of Kotkhera. About ¾ mile down the nálá running south from the well a tributary joins the right bank. About 200 yards up this tributary there is an exposure of Bijáwar limestone, the steeply sloping surface of

[1] *Rec. G. S. I.*, XXXI, p. 48, (1904).

which is in one place coated with very good pyrolusite. This pyrolusite is evidently the result of the replacement at the surface of the limestone and has extended to a depth of about 2 to 3 inches only. In one place there is conglomerate of pieces of this pyrolusite cemented together by tufa (see Plate 15) (17·432 and 17·587).

Gwalior State.

Mr. F. R. Mallet[1] records a specimen of manganite received some years ago from the Political Agent at Gwalior and presumably obtained from that neighbourhood. Mr. C. A. Hacket found psilomelane associated with limonite at Gangar north of Nimach[2], while in 1902-1903, Mr. K. D. Kulkarni found some impure psilomelane on a hill ¼ mile south of Behat, 35 miles east of Gwalior. This would be on the Gwalior (Bijáwar) series. Also 'Ritter von Schwartz found red iron ore from this district to contain 66 per cent. metallic iron; the ore also contained manganese.'[3]

Indore State.

The only parts of this State in which manganese-ores are known to occur are the country round Kátkut, lying to the west of the Dhár Forest, and near Bhámar in the Nimáwar pargana of Indore, they were found by me in the field season of 1902-1903. The occurrences are either in the Lametas or the porous breccias associated with the Bijáwar rocks, for which see the account of the Dhár occurrences. None of these occurrences are of any possible economic value; and in fact they can hardly be dignified with the name of ore.

The following is a list of the occurrences :—

1. Near Kátkut.
2. The Kánar River.
3. Barel.
4. Bhámar.

1. Near Kátkut.

At a point about 3 miles N.E. of Kátkut, a small tributary flows east to join the Kanár River, which marks the boundary between Indore territory and the Dhár Forest. The rocks exposed in this nálá for about

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[1] Geology of India, Pt. IV, Mineralogy, p. 59, (1887).
[2] *Ibid.*, p. 61.
[3] *Iron*, XXVIII, p. 477, (1886); and *J. I. S. I.*, No. II of 1886, p. 621.

¾ mile up from the junction with the Kanár are Bijáwar limestones with associated breccias. These breccias are often decomposed, so that instead of being chert- or hornstone-breccias, as they are when fresh, they are better described 'as sandstone-breccias'. Further west these Bijáwar rocks are overlain by Lametas, and as a part of the breccias may have been rearranged at the time of deposition of the Lametas, it is difficult to determine the precise age of these breccias. In one place the breccia contains a considerable quantity of scattered wad with a little psilomelane in places.

Near the edge of the Lametas, fragments of manganiferous varieties of Lameta rocks are rather common in the nálá. Amongst those found were Lameta grits, partly cemented by red oxide of iron, and partly by psilomelane; and clay largely converted into a mixture of wad and limonite, probably by replacement. The manganiferous grit was also found *in situ* in the Lametas, when this formation was reached (17·408, 17·434, 17·435, 17·590 and 17·591).

2. The Kanár River.

In the Kanár River at a point about 3½ miles E.N.E. of Kátkut, and opposite the 'stone quarries' and Δ 831 shown on the 1-inch map, there is a good exposure of the porous siliceous breccias, associated with Bijawár limestone. In places the sandy matrix is replaced by black oxide of manganese, usually taking the form of wad, with the production of a breccia composed of angular fragments of white quartz-rock set in a matrix of wad (17·410, 17·594 and 17·595).

3. Barel.

In a tributary of the Kundi nálá about 3¾ miles south-east of Kátkut there is an exposure of Bijáwar rocks, one band of which is a yellow and white siliceous breccia, which is more sandy in one place, then containing manganese oxide (17·598).

4. Bhámar.

The three foregoing occurrences are in the portion of Indore lying to the west of the Dhár Forest. Bhámar, on the other hand, lies in the Nimáwar pargana of Indore on the eastern side of the Dhár Forest and Chándgarh. Bhámar is about 7 miles N.N.E of Chándgarh village. The manganese occurs as black impregnations in breccia of dark reddish colour, with whitish quartzite, and associated with Bijáwar rocks (17·400).

Jhábua State.

History.

The first mention of the occurrence of manganese-ore deposits in this State is contained in the 'Review of Mineral Production in India for 1896', page 48; it seems that the occurrence had been known for some time, the mineral being supposed to be black oxide of copper; to confirm this a specimen was sent by the Political Agent of the Bhopáwar Agency to the Reporter on Economic Products, when the true nature of the mineral was discovered. A prospecting license for this State was obtained by Messrs. Kiddle, Reeve & Co. of Bombay in May 1902; a mining lease for the Kájlidongri deposit, the only one on which any serious work has yet been done, was taken out in June 1904. The first recorded output of ore was 6,800 tons in 1903; the following table shows the figures to date:—

Year.	Long tons.
1903	6,800
1904	11,564
1905	30,251
1906	50,073
1907	35,743

Geology.

The manganese-ore deposits at present known lie to the W.N.W. and N.W. of Meghnagar station, Godhra-Ratlám Railway. This area has never been geologically mapped, but a brief visit has shown me that the rocks probably belong to the Arávalli System, being doubtless a southward extension of the main outcrop of these rocks in Rájputána. They consist of chloritic, talcose, and sericitic, slates, phyllites, and schists, of quartzites of various colours, schistose grits and conglomerates, crystalline limestones often dolomitic, and of augen-gneisses, granites and pegmatites, the two last-named being of younger age than the preceding and probably intruded into them after the folding of the Arávallis. The general strike of these rocks near Rambhápur and Kájlidongri is N.N.W., and, owing to the sharp folding of these rocks about axes parallel to the strike, the dips may be towards either the east or the west side of the line of strike. One would think from the 1-inch map of this area that the country is extremely rugged. This is not the case; but it is cut up by numberless small ravines into a large number of small hillocks and mounds partly put under cultivation by the Bhils, and partly covered by a thin jungle of small trees and bushes.

The following deposits have been located in this area :—

1 Kájlidongri
2. Rambhápur
3. Amlámál
4. Talái
5. Tumdia
6 Pitol
7. Nagankheri-Mandli

and will be dealt with *seriatim.* Of these deposits, Nos. 1 and 2 were examined by me in 1905, and Nos. 3 to 7 by Messrs. H. Walker and A. M. Heron in 1907. Of these only Kájlidongri, and possibly Rambhápur, have any considerable economic value, as far as I am aware.

1. Kájlidongri.[1]

(*See Plates 18 and 19.*)

Mode of occurrence of the ore.

This deposit is situated 5 miles to the W.N.W. of Meghnagar station, Godhra-Ratlám Railway, to which it has been connected by a 2-foot gauge tramway (converted later for steam traction), which also passes across the Rambhápur deposit. The ore-deposit is about 1,000 yards long and forms a long, low, rounded ridge or mound, which has a general strike of N. 30° W., and rises to about 60 or 70 feet above the water-courses on either side of it. As is shown in the sketch-plan (Plate 19), this deposit has been exploited[2] by a series of surface cross-cuts and open quarries, the latter, which are mostly not indicated on the plan, lying on either side of the central ridge of the ore-mound. In addition to facilitating the comprehension of the structure of the ore-deposits, these cross-cuts afford convenient passages for tram-lines. The sections seen in these cross-cuts are shown in Plate 19. The manganese-ore occurs intercalated with black and red vitreous quartzites as a 'bed' about 20 feet thick; but instead of dipping straight to the deep, as seems usually to happen in the deposits of the Nágpur-Bálághát area, this 'bed' is kept at the surface by a series of folds, so that a larger proportion of the ore than usual is available for quarrying. The diagrams on Plate 19 show to a large extent what is actually visible in the cross-cuts, but there are many parts in which the structure of the ore-body is not clear; this has

[1] The name means 'sooty hill'.

[2] This description, and the sections and plan given in Plate 19, refer to the deposit as it was at the time of my visit in January 1905.

been interpreted as well as possible and as a result it will be seen that while cross-cuts Nos. 3, 3A, and 7, indicate that the western edge of the ore 'bed' is turned up, 4 and 6 indicate that it is turned down and presumably goes below the surface to some depth. Both 3 and 4, however, the only two cross-cuts illustrated that show the eastern side of the deposit, agree in showing that this edge is turned up and consequently does not go to the deep. If only half a dozen cross-cuts had been made at regular intervals right across the deposit it would have been possible to estimate the quantity of ore in it with fair accuracy. Even now a rough estimate can be made. From cross-cuts 3 and 4 it is seen that a width of some 250 feet of the deposit measured along the folds of the ore-band lies within 50 feet of the surface. Taking the average thickness of the ore-band as 20 feet, of which 10 feet can be reckoned as merchantable manganese-ore, the remainder being quartzite and poor ore, the length of the deposit as 1,000 yards, the average specific gravity of the ore as 4, and assuming that cross-cuts 3 and 4 fairly represent the whole deposit, the total quantity of merchantable ore lying within 50 feet of the surface can be estimated as :—

$$\frac{1{,}000 \times 3 \times 250 \times 10 \times 62{\cdot}5 \times 4}{2240} = 837{,}000 \text{ tons.}$$

This is probably considerably above the mark; for it is not likely that cross-cuts 3 and 4 do fairly represent the whole deposit.

'Country'.

The 'country' consists of silky, silvery, and often crinkled, phyllites (sometimes slates or schists), with usually a thickness of sandy rocks between them and the ore-band. These phyllites usually owe their characters to layers of sericitic mica; but as they sometimes contain talc instead of sericite and at other times contain both minerals, and it is not possible to tell the character of any piece of the rock from merely looking at it, they have all been grouped together as *sericitoid*[1] *phyllites*. The sandy rocks between these and the ore-body are usually of some shade of lavender or lilac, and very friable. They have sometimes, where more argillaceous, assumed a slaty character, and in one place in cross-cut 3, where they have been subjected to intense pressure in some very sharp folds, have been converted into sericitoid phyllites, on the cleavage planes of which little prisms of piedmontite have developed where the pressure has been the most severe (see Plates 18 and 19).

[1] Meaning that the glistening mineral is *like sericite*, though not always actually sericite.

FIG. 1.—INTENSE FOLDING IN MANGANESE-ORE AND SANDY SLATES KÁJLIDONGRI, JHÁBUA STATE, CENTRAL INDIA.

Photographed by L. L. Fermor. *Bemrose, Collo., Derby.*

FIG. 2.—QUARRYING MANGANESE-ORE AT KÁJLIDONGRI.

Origin.

Judging from the examples of spessartite-bearing rock partly altered to manganese-ore, and of manganese-ore containing residual spessartite, so often seen in the parts of the deposit north of the waist, it seems probable that the portion of the ore-body north of the waist has been formed, at least in part, by the chemical alteration and replacement of the manganese-silicate-rocks of the gondite series.

In view of the apparent absence of spessartite and rhodonite in the part of the deposit south of the waist, we must conclude either (A) that the alteration and replacement processes were more complete here, so that no trace of these silicates is now left; or, (B) and perhaps more probably, that this part of the deposit was not sufficiently metamorphosed for the development of manganese silicates to take place. In the latter case the part of the deposit south of the waist probably consists partly of original fairly pure manganese-oxide sediments since compressed, and is partly a replacement deposit formed at the expense of the quartzites from materials brought either from the part of the deposit north of the waist or from buried portions of the deposit.

As evidence for B it may be mentioned—see also the sections, Plate 19—that in many parts of the deposit, especially south of the waist, the manganese-ores and quartzites are interbedded, suggesting that they were deposited as alternating layers of sand and manganese oxide. Only a portion of these manganese-oxide layers can be original, however; for

1. The bands of ore and quartzite are not usually continuous for any distance, a band of ore giving place to quartzite and *vice versâ*.
2. Many examples can be found of the gradual replacement of the quartzites by manganese-ore, the change being first noticed in the appearance of spots of manganese-ore in the quartzite.
3. Residual nodules of quartzite, like those seen at Bálághát, can be found in places in the manganese-ore bands—*e.g.*, in cross-cut 4—, indicating that these bands have arisen by the replacement of an original quartzite band.

Numerous fissures—probably formed during the folding of these rocks—have been filled with vein deposits, which contain such minerals as hollandite, barytes, and arsenates.

The winchite-bearing rocks were no doubt formed during the folding by the metamorphism of impure calcareous sediments containing a certain proportion of manganese.

Interesting points to notice are the abundance of apatite and the presence—though usually in small quantities—of felspar, in the spessartite- and rhodonite-bearing rocks.

Nature and quality of the ores.

In Plate 19 is shown a rough sketch-plan of the deposit for the purpose of indicating the position of the various cross-cuts. At about A there is a constriction or waist to the ore-mound, and it is a curious fact that the ore is of two different characters north and south of this waist. That south of the waist is mainly a very fine-grained mixture of psilomelane and braunite with no signs of spessartite or rhodonite; according to Mr. H. J. Winch, the manager of the deposit, the ore shipped from this part of the deposit (in 1905) has the following average analysis :—

	Limits.	Mean.
Manganese	46–48	$47\frac{1}{2}$
Iron	8–9	$8\frac{1}{2}$
Silica	6–9	$7\frac{1}{2}$
Phosphorus.	0·08–0·25	0·17
Baryta	3–4	$3\frac{1}{2}$
Moisture under		0·25

A sample taken by me, representing 1,550 tons of manganese-ore from the deposit south of the waist, was subjected to complete analysis by Messrs. J. and H. S. Pattinson, with the following result :—

Sample No. A.39.

Manganese peroxide	50·82
Manganese protoxide	20·19
Ferric oxide	12·29
Alumina	0·85
Baryta	4·14
Lime.	1·40
Magnesia	0·80
Potash	0·74
Soda	0·27
Silica (combined)	5·15
Silica (free)	1·45
Sulphur	0·030
Phosphoric oxide	0·378
Arsenic oxide	0·055

Cobaltous oxide	*Nil.*
Nickelous oxide	*Nil.*
Cupric oxide	0·03
Lead oxide	0·02
Zinc oxide	*Nil.*
Titanic oxide	0·08
Chlorine	trace
Fluorine	*Nil.*
Water (combined)	1·00
Moisture at 100° C.	0·20
Carbon dioxide	*Nil.*
	99·893

This is equivalent to:—

Manganese	47·77
Iron	8·60
Silica (total)	6·60
Phosphorus	0·165

and indicates the presence of about equal proportions of psilomelane and braunite in the ore. The agreement of this analysis with Mr. Winch's figures is noteworthy.

North of the waist of the ore contains a larger portion of braunite and is often more coarsely crystalline, whilst there is abundance of spessartite and some rhodonite. According to Mr. Winch the average analysis of the ore exported from this part of the deposit is as follows:—

	Limits.	Mean.
Manganese	46–52	48½
Iron	8–9	8½
Silica	7–11	9½
Phosphorus	0·15–0·30	0·22
Baryta	1–3½	1½
Moisture under		0·25

I took two samples (A. 40 and A. 41) from the part of the deposit north of the waist. They represent 580 and 1,130 tons of stacked ore, quarried respectively from the southern and northern portions of this part of the deposit, and were subjected to complete analysis by Messrs J. and H. S. Pattinson :—

	Sample No. A. 40.	Sample No. A. 41.
Manganese peroxide	38·15	41·80
Manganese protoxide	31·46	28·17
Ferric oxide	14·86	13·50
Alumina	0·47	1·34
Baryta	1·77	0·79
Lime	1·56	1·89
Magnesia	0·72	0·36
Potash	0·12	0·13
Soda	0·18	0·24
Silica (combined)	7·90	7·50
Silica (free)	0·50	1·10
Sulphur	0·060	0·034
Phosphoric oxide	0·552	0·623
Arsenic oxide	0·214	0·305
Cobaltous oxide	*Nil.*	*Nil.*
Nickelous oxide	*Nil.*	*Nil.*
Cupric oxide	0·15	0·05
Lead oxide	0·01	0·02
Zinc oxide	*Nil.*	*Nil.*
Titanic oxide	0·12	0·14
Chlorine	Trace	Trace
Fluorine	*Nil.*	*Nil.*
Water (combined)	1·10	1·80
Moisture at 100° C.	0·20	0·45
Carbon dioxide	*Nil.*	*Nil.*
	100·096	100·242
These are equivalent to :—		
Manganese	48·49	48·25
Iron	10·40	9·45
Silica (total)	8·40	8·60
Phosphorus	0·241	0·272

These analyses indicate the presence in the samples of 79% and 75%, respectively, of braunite, with most of the balance consisting of psilomelane.

It will be seen from these analyses that the ore is rather high in phosphorus, but it is, I understand, sent to Luxemburg for use in manufacturing pig-iron from sulphurous iron-ores. Another interesting feature of the manganese-ores as revealed by the analyses is the high percentage of baryta (BaO), namely 1 to 4 per cent., averaging about $2\frac{1}{4}$. This is due, as explained below (page 686), to the manganates (and barytes) in the deposit. Owing partly to this baryta the percentage of manganese—only 48 on the average—is lower than in the Central Provinces; but this inferiority in manganese contents is to a certain extent neutralized by the fact that Meghnagar is only 361 miles from Bombay as against the 520 to 701 miles distance of the deposits of the Central Provinces from Bombay and Calcutta respectively. Taking the average advantage in railway lead of Meghnagar over the Central Provinces as 240 miles, which is equivalent to a difference of railway freight of about 4*s*. 6*d*., we see that—taking the price of manganese-ore at 9*d*. per unit—this advantage in lead is roughly equivalent to a 6% increase in the manganese contents of the ore.

The sulphur and arsenic returned in the foregoing analyses are probably due to the presence of barytes and arsenates respectively (see page 687).

Labour.

The local labour available is Bhil, but, as the Bhils are very uncertain in their attendance and of too wild a disposition for continuous hard work, coolies have been imported from Ahmadábád.

Mineralogy of the deposit.

For variety of rare and new minerals this is the most interesting manganese-ore deposit in India; the following is a list of the minerals hitherto found either in the ore-body itself or in the associated rocks :—

Quartz	Rhodonite
Rose-quartz	Asbestos
Hematite	*Winchite*
Pyrophanite (?)	Spessartite
Magnetite	Piedmontite
Braunite	Carpholite (?)
Rutile	Tourmaline
Pyrolusite	Sericite
Hollandite	Crimson mica
Psilomelane	Bronze mica
Calcite	Talc
Orthoclase	Kaolin
Plagioclase	Apatite
Blanfordite	*Two species of arsenates*
Yellow pyroxene	Barytes

Braunite.—Many fine crystals of braunite have been obtained from this deposit. An account of them will be found in Part I, pp. 55—57.

Hollandite.—The most interesting of these is hollandite, for an account of which see Part I, pp. 87—91. It occurs in the quartz veins that traverse the ore-body south of the waist of the hill and is especially abundant in cross-cut 3 and the adjacent quarries. As has been previously indicated, it forms with psilomelane a group of complex manganates in which barium is a prominent constituent, and we see from this the reason why the ore deposit south of the waist is much higher in baryta than that north of the waist, where there is a much larger proportion of braunite to psilomelane and where hollandite is absent.

Winchite and Blanfordite.—The blue amphibole, winchite, which may be regarded as a variety of tremolite containing iron and small quantities of manganese and alkalies and having curious optical properties, occurs at the north end of the deposit in a band about 4 feet wide, conforming to the general strike of the deposit. The typical rock is composed of winchite, braunite, calcite, and quartz, and may be called a winchite-schist. But associated with this are bands of a very fine-grained white or pale grey quartzite containing abundance of lavender-coloured winchite, often in beautiful simple prisms. In this rock are green spots, and sometimes green crystals, which consist of a pyroxene showing what I have designated as the *blanfordite type of pleochroism* (see page 127). In quarry No. 2 a certain amount of winchite occurs in a pinkish clayey rock immediately underlying the ore-body. The winchite is most abundant at the contact with the manganese-ore and rapidly diminishes in quantity, so that at 2 feet from the ore-body the rock becomes a sandy-argillaceous one without any winchite.

Rhodonite.—This mineral occurs at the very north end of the deposit in a ridge just to the S.W. of the quartzite hill shown in the plan. All that I saw was much blackened owing to partial conversion into manganese-ore. In one place in this outcrop is a nodule of red quartzite rounded at one end and drawn out at the other. It is included in a rock composed of rhodonite, apatite, quartz, and yellow pyroxene, with some spessartite. This rock is partly altered to manganese-ore and curls round and envelops the quartzite in such a way as to suggest that the manganese-silicate-rock must have once been molten and have picked up the quartzite when in that condition.[1]

Spessartite.—This occurs as typical spessartite-quartz-rock (gondite), with abundant associated apatite, in the dyke-like outcrop running N. 10° W. towards the river from the west side of the quartzite hill at the north end of the deposit. This outcrop consists of grey, clove, and pink, quartzites, in which occur bands of spessartite-bearing rocks, in places much mixed up with vein-quartz. Some of these manganese-

[1] The occurrence is, however, regarded as a part of the gondite series—of sedimentary origin—see Chapter XV.

silicate-rocks contain various pyroxenes and a yellow amphibole in addition to, or to the exclusion of, spessartite. Yellow spessartite is also frequently found in the manganese-ores north of the waist and also in some red quartzites in the quarry N.W. of cross-cut 6; while brown spessartite and spessartite-quartz-rock occur in cross-cut 7.

Carpholite (?).—A bright yellow mineral in radiate fibrous tufts occurs in little veinlets in the manganese-ore in cross-cut 7. It resembles carpholite and gives chemical reactions which agree on the whole with those of this mineral. But owing to certain discrepancies it will be necessary to make a quantitative analysis of this mineral before it can be identified with certainty; it is possibly only an amphibole

Hematite.—In the part A of cross-cut 7 a fair amount of platy specular hematite, in thin plates up to 2 inches across, occurs in vein-quartz.

Piedmontite.—Besides a little piedmontite associated with the carpholite(?) in cross-cut 7, scattered prisms of this mineral have, as already mentioned on page 680, been found scattered on the cleavage planes of certain sericitoid phyllites in cross-cut 3.

Crimson-mica.—In several parts of the deposit, especially in cross-cut 4, where a golden-bronze mica also occurs associated with psilomelane, and at the north end in the winchite-bearing rocks, there is found a mica occurring in tiny scales, which are crimson as seen in the hand-specimens, but show under the microscope the pleochroism given on page 198.

Barytes.—At a point in cross-cut 6 where the manganese-ore 'beds' are nearly horizontal there is a coarse vein-rock of white barytes and quartz (with some braunite). Several specimens of manganese-ore collected from the ore-stacks north of the waist also contained a little barytes in patches.

Arsenates.—Scattered through the quartz-barytes-rock are a few rounded crystals of a sage-green arsenate of calcium and magnesium; while in a quarry to the north-west of this cross-cut (6), is a rock composed of quartz, spessartite, braunite, and a second species of green arsenate, chiefly of magnesium, that constitutes at least half the rock. This is possibly also a vein-rock.

2. Rambhápur.

This deposit lies immediately to the N.W. of Rambhápur town, is about 250 yards long and forms a very low mound running N. 30°

W. It is on the line of strike of the Kájlidongri deposit, the S.E. end of which is about 1¾ miles to the N.N.W. That these two are probably genetically connected is also indicated by the outcrop at Piploda, about half way between them, of some pyrolusite and psilomelane formed by the replacement of quartzite and also of a little spessartite-quartz-rock.

The few pits that had been made along the strike of the Rambhápur deposit showed that the manganese-ore forms a bed composed of alternating layers of ore and red quartzite. This is folded 2 or 3 times and might be as much as 20 feet, but is probably not more than 10 feet, thick. Owing to the folding the dip is variable, being in some places to the N.E. side of the strike and in others to the S.W. side. The 'country' is a siliceous crystalline limestone with abundant secondary pyrolusite replacing both calcite and quartz.

The tramway connecting Kájlidongri to Meghnagar crosses this deposit so as to divide it into two portions. I took two samples, one (A. 42) from the stacks to the S.W. side of the tram-lines and the other (A. 43) from those to the N.E. side, so as to represent roughly the northern and southern portions of the deposit respectively. A. 42, representing about 120 tons of ore, consisted of dirty ore, usually a mixture of pyrolusite and psilomelane, showing spessartite in places and with small calcite veins in several pieces. A. 43, representing about 35 tons of ore, consisted of much harder ore—psilomelane and braunite with less calcite and more visible quartz. The analyses (by J. and H. S. Pattinson) are as follows:—

	Sample No. A. 42.	Sample No. A. 43.
Manganese peroxide	53·77	47·71
Manganese protoxide	13·29	20·35
Ferric oxide	11·28	8·37
Baryta	1·68	2·20
Silica (combined)	4·25	5·95
Silica (free)	1·60	5·30
Phosphoric oxide	0·42	0·385
Water (combined)	3·40	2·50
Moisture at 100° C.	0·75	0·55
These are equivalent to:—		
Manganese	44·29	45·92
Iron	7·90	5·86
Silica (total)	5·85	11·25
Phosphorus	0·183	0·168

The combined silica in analysis A. 42 cannot be taken as an index of the amount of braunite present, because of the spessartite also present. In A. 43 the presence of 59% braunite is indicated, although this may be too high owing to a certain proportion of spessartite.

On the N.W. side of the tank immediately to the S.S.E. of Rambhápur is an outcrop of red and lavender quartzites and of siliceous crystalline limestone, the latter of which has been in places much replaced by pyrolusite and yellow ochre.

3. Amlámál.

According to my colleague, Mr. H. Walker,[1] who was able in 1907 to visit some manganese occurrences in Jhábua not seen by me :—

'Two occurrences are to be seen here—one. ¼ mile to the N. of the Tarwi's (village headman) house, and the other ¾ mile to the S.W. of the same house.

'In each case the surface indications are confined to quartz blocks containing manganese-ore and are very limited in extent. A few small pits have been opened in these deposits and from these it is seen that the manganese-ore is contained in a steeply dipping fine-grained reddish-quartzite.'

5. Tumdia.

This deposit is close to Mandli. Mr. Walker writes :—

'The occurrence is in a hill which lies ¼ mile to the N.W. of the house of the Tarwi of Mandli. The hill is about 200 yards long, is 20 to 30 feet high, is whale-backed in shape and runs in a general direction to the N.N.W.

'The ore-body outcrops on the top of the ridge and forms a small spine-like prominence which strikes N.N.W.—S.S.E. It consists of a white to pink quartzite which contains veins and lenticles of manganese-ore. From a pit dug in the outcrop of the ridge-top, it is seen that the manganese-ore-bearing band varies from 2-3 feet in thickness and is almost vertical.

'In places the ore is good, but on the whole there is too much quartzite.'

6. Pitol.

Mr. Walker says :—

'This occurrence lies about 1 mile to the south-east of the Thana of Pitol. It forms a low mound—about 140 yards long—on each side of which runs a cart road leading from Pitol to Jhábua.

'The ore—which seems to be very low grade—occurs interlaminated with quartz.................. .'

Some iron-ore containing a little manganese was noticed about 2 miles to the N.E. of the Thana of Pitol.

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[1] MS. report.

7. Nagankheri-Mandli.

Mr. Walker writes :—

'About midway between the villages of Nagankheri and Mandli (B) a tumbled mass of boulders—approximately 20 feet high, 30 feet wide, and 100 feet long—is to be seen. From the deposit Pitol bears N. 20° W. and Mandli (B) E. 15° S.

'The boulders are siliceous with a limited quantity of included manganese mineral.'

Rewah State.

Impure psilomelane was found by T. W. H. Hughes [1] as nodules in red (Jabalpur ?) clay near Básí, west of Tiki in the South Rewah coal-field. It contains a large amount of insoluble matter, some iron, and a trace of cobalt. Manganiferous hematite was found by P. N. Datta [2] in 1895 at the foot of the Kaimur scarp, north-west of Baghwar, near Burgáona.

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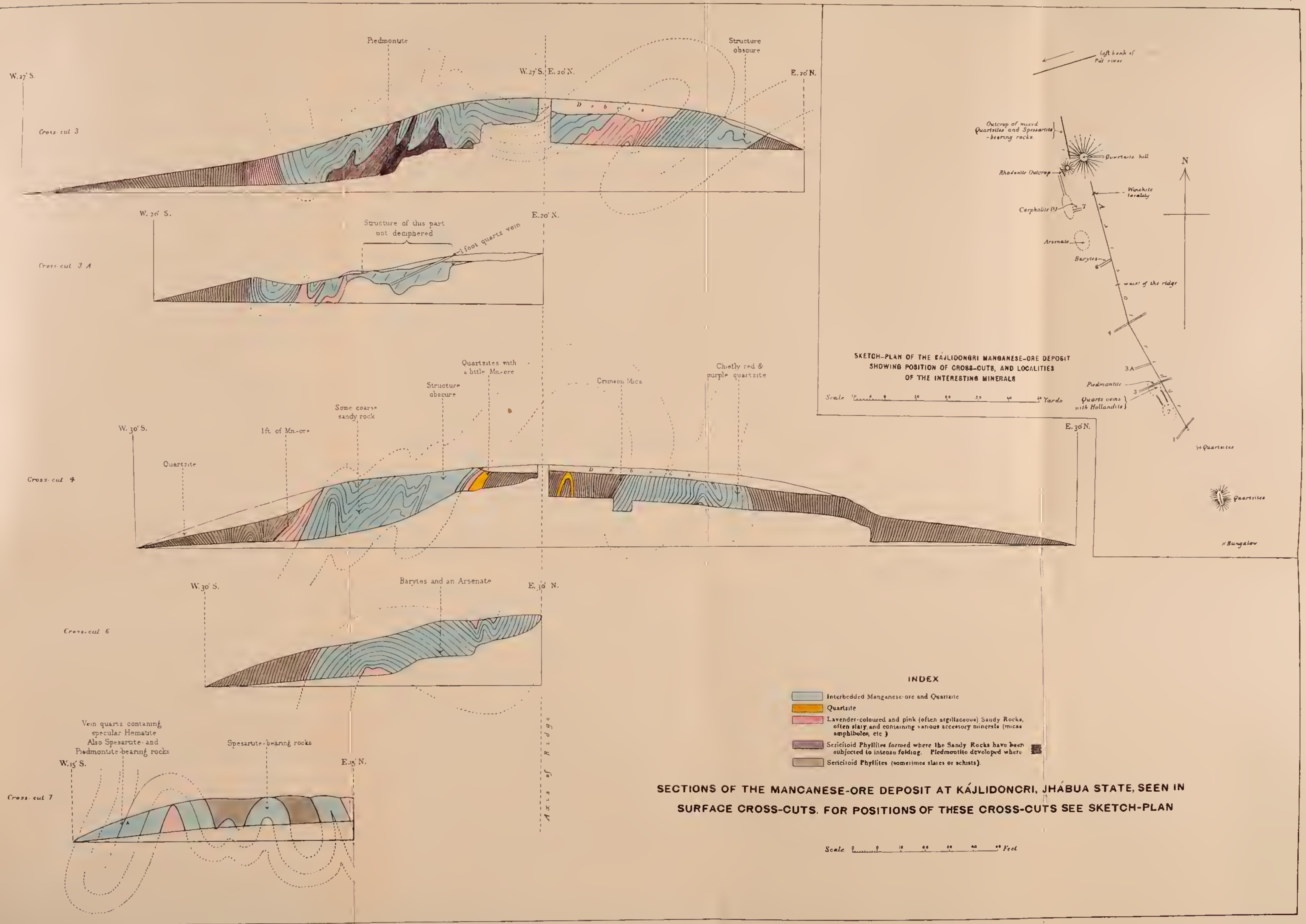
1 Ball, Economic Geology, p. 331. Mallet, Mineralogy, p. 61.
2 *Rec. G. S. I.*, XXX, p. 255.



SECTIONS OF THE MANCANESE-ORE DEPOSIT AT KÁJLIDONCRI, JHÁBUA STATE, SEEN IN SURFACE CROSS-CUTS. FOR POSITIONS OF THESE CROSS-CUTS SEE SKETCH-PLAN

CHAPTER XXXII.

DESCRIPTION OF DEPOSITS—*continued.*

The Central Provinces—Amráoti and Bálághát Districts.

Amráoti District—'Peepul Cottah.'

Bálághát District.—History—Output and labour—Physical characters and geology—List of deposits—Nature and quality of the ores—Communications and transport—Chándadoh—Thirori, Ponía, and Jámrapáni—Gáraghát—Sonegáon—Arjoni and Jám—Nándgáon—Ramrama—Katangjheri I—Katangjheri II (Shodan Hurki)—Other localities—Bálághát—Laugur—Chondi—Ukua, Gudma, and Samnapur—Other localities.

Amráoti District.

The occurrence of manganese-ore in Berar was first mentioned by Newbold,[1] and the reference may have been either to this district or to the Wun, or perhaps to some district in which the existence to this mineral is not at present known.

Some specimens of manganese-ore containing 80 per cent. of manganese oxide were discovered in 1877 at 'Peepul Cottah' or 'Pimpul Koonta' village in the Morsi Taluk ; but local enquiry showed 'that the broken fragments of ore which had been found at a short distance below the surface inside the village had been brought from some unknown locality by the former inhabitants.'[2]

Bálághát District.

(*See Plates 12, 13, 20, 21, and 43.*)

History.

Mr. Grant[3] says that 'a few miles to the east of Búrhá, surmá (sulphide of antimony) occurs in large quantities. The latter is, however, of no value here, and no one takes the trouble to collect it.' *Surmá* is the Hindustani word for collyrium and it is probable that black oxides of manganese are at times substituted by the natives of India for stibnite, the substance customarily

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1 *Jour. Roy. As. Soc.*, VII, p. 214, (1843).
2 Ball, Economic Geology, p. 331, (1881).
3 Central Provinces Gazetteer, p. 18, (1870).

used. As no stibnite has been recorded from this district the *surmá* mentioned by Mr. Grant is doubtless some oxide of manganese, probably obtained from the Bálághát deposit (No. 9, below).

The first explicit reference, however, to manganese-ore in this district, is contained in a letter, dated 3rd September 1883, from Colonel Bloomfield to Mr. F. R. Mallet. He refers to the Bálághát deposit. In 1888-89, Mr. P. N. Bose investigated this occurrence and also discovered the Ukua deposit on the Baihar plateau. In the same season Kishen Singh of the Geological Survey of India discovered manganese-ores at Ghondi, Dharampur, Kanaridha, and Kurthitola. Soon after the manganese industry was started in the Central Provinces in 1899-1900, the Central Provinces Prospecting Syndicate secured the Bálághát deposit; they started working it in September 1901; active prospecting throughout this district has subsequently led to the discovery of many more deposits. Up till 1906, practically the only deposit worked to any extent was that of Bálághát, but during 1906 the high price of manganese led to the opening up of several of the deposits already known—especially Thirori, Jámrapáni, Ramrama, and Ukua—and to the discovery of several ore-bodies not previously known.

The following table shows the yearly output and average daily number of workers employed from 1901 to date :—

Year	Output in long tons.	Average daily number of workers.[1]
1901	3,839	(*a*)
1902	1,975	105
1903	7,898	385
1904	10,323	295
1905	16,246	362
1906	102,260	1,836
1907	210,601	2,663

(*a*) Not returned, although work was progressing.

and illustrates the constant expansion of the industry.

[1] Figures taken from the Annual Reports of the Chief Inspector of Mines in India.

Physical characters and geology of the manganese-ore belt.

The manganese-ore deposits of this district are, as far as is at present known, confined to a belt of country stretching east-north-east from Chándadoh and Thirori near Katangi at the western end, through Bálághát and Ukua, to Jairási at the eastern end, a total distance of about 75 miles. Such a belt bounded by two parallel lines 9 miles apart contains all the known deposits.* The northern line runs close to Ramrama, Bakoda, Kurthitola, and Lilameta, and the southern close to Jámrapáni, Wárásconi, Bálághát and Kanaridha. Produced to the west this belt includes the deposits of Kosumbah, Sitapathúr and Sukli in the Bhandára district, and then runs into the—to a large extent geologically unknown—northern part of the Nágpur district, and southern part of the Seoni district.

A length of about 32 miles of this belt at the western end — practically those portions of the belt west of the Gondia-Jabalpur branch of the Sátpura Railway (Bengal-Nágpur Railway)—consists of plain country at an average elevation of perhaps some 1,000 feet above sea-level, and is in fact a part of the Nágpur-Bálághát 1,000-foot plain. The surface of the plain is composed to a large extent of alluvium and soil with a small quantity of low-level laterite, and the rock exposures occur chiefly in the small hills and mounds that protrude from this alluvium, etc., and also in stream-beds. This part of the belt is largely given up to rice cultivation or else covered with thin tree jungle, but the hills rising from the plains are often densely wooded. To the east of the railway the belt, starting on the spur wherein the Bálághát manganese-ore deposit is situated, soon rises on to the Baihar plateau, which has an average height of about 2,000 feet, with numerous, usually well-wooded, hill ranges rising to as high as 2,761 feet at Tipágarh hill, and 2,793 feet on the Deccan Trap range at the northern border of the district outside the belt. On this plateau rock exposures are very numerous in most parts, although there are patches of alluvium bordering the larger rivers such as the Nahára and Banjar. This belt, to the west of the longitude of Baihar, is drained by the Wainganga and its tributaries the Lusra, Uskál and Nahára. To the east and north-east of Baihar the plateau is drained by the Tonar (Taunaur) and Banjar, which flow north eventually to join the Narbada river.

Except for a small patch of Deccan Trap basalt, capped by laterite on Tipagarh hill, and numerous patches of high-level laterite—often

* Manganese-ore is said to have been recently found near Kinhi some 20 miles south-east of this belt.

extremely aluminous and then designated bauxite—resting partly on the Chilpis and partly on the metamorphic and crystalline series, especially in the neighbourhood of Laugur, Ukua, Samnapur, and Sonpuri, the whole of the belt consists of Archæan rocks. These can be divided into three groups :—

(1) the Chilpi Ghát series ;
(2) the metamorphic and crystalline series (designated Baihar gneiss by Bose);
(3) the intrusive granites (designated Chauria gneiss by Bose and probably equivalent to the Bundelkhand granite).

The granites are of subordinate importance in this belt, but according to Bose, they occupy wide spreads of country to the south-east.

The Chilpi Ghát series* consists, where I have seen it, of slates, phyllites, and mica-schists, with some quartz-schists and schistose grits or arkoses, and is probably to be identified with the Dhárwárs. The areas occupied by it are shown on the map (Plate 43). The band stretching from Wáráseoni through Laugur to Tipágarh hill is apparently a synclinal fold of these slaty and schistose rocks, resting on various schistose gneisses with granite intrusions along the bedding planes of the gneisses. The manganese-ore deposits Nos. 9,10,11, and Kurthi-tola, are situated near or at the base of this series, as are possibly Jairási, Dharampur, and Kanaridha, further to the east. The deposits are overlain by the phyllites and schists and rest on the schistose conglomeratic grits or arkoses. At Bálághát itself these grits are easily distinguished ; but at Ukua, some 16 miles to the north-east, the rocks are much more metamorphosed so that the grits now look like crystalline gneisses ; but their original character is betrayed by the pebbles of gneiss, granite, and quartzite, in the gneiss. Judging from this and other evidence it seems probable that a considerable portion of the rocks mapped as part of the Archæan gneisses and schists (coloured pink on the map) are only more intensely metamorphosed forms of the Chilpis. See pages 311—314.

The metamorphic schists and gneisses consist of muscovite- and biotite-gneisses, mica-schists, quartzites, various more basic pyroxenic and epidotic gneisses, and occasional hornblende-schists. With these are

*Or rather the portion included in this belt ; for it is not certain that two distinct groups of rocks have not been included in this series. See article on geology in the Bálághát Gazetteer, pages 16 and 17, (1907).

intercalated the manganese-ore deposits Nos. 1 to 8, invariably characterised by the presence of various manganese-silicates. And, on the supposition that the Chilpis have, in the western parts of this belt, become converted into gneisses and schists, one may suspect also that these manganese-ore deposits are only the metamorphosed forms of the manganese-ore bed occurring at or near the base of the Chilpis further to the east.

The strike and dip of the deposits (Nos. 9 to 11) at the base of the Chilpis conform to those of the Chilpis, namely a strike of north-north-east to east-north-east, with the dips to the north-west side. The strike and dip of the deposits in the metamorphic and crystalline series are much more variable.

The following is a list of the manganese-ore deposits and occurrences of this district :—

	Deposit.	*Concessionaire.*
Group I.	1. Chándadoh.	
	2. Thirori, Ponía, and Jamrapáni.	*Thirori* :—Central Provinces Prospecting Syndicate (C. P. P. S.) D. Laxminarayan, and M. M. Mullna. *Ponía* :—C. P. P. S., P. C. Dutt, Burn & Co., and B. Parmanand. *Jámrapáni* :—C. P. P. S., and D. Laxminarayan.
	2*a*. Gáraghát	D. Laxminarayan.
	3. Sonegáon.	
	4. Arjoni and Jám	P. C. Dutt, Burn & Co.
	5. Nandgáon	Rai Sahib Mathura Prasad.
	6. Ramrama	C. P. P. S., and Tata, Sons & Co.
	7. Katangjheri I (Govt. Forest)—Shodan Hurki	Tata, Sons & Co.
	8. Katangjheri II (Malguzari)	Do.
	8*a*. Other localities :—	
	Bhui Hurki	Tata, Sons & Co.
	Ballarpur	Diwan Bahadur Kastur Chand Daga.
	Bakoda	Raja Gokuldas.
	Chaukhandi	D. Laxminarayan.
	Chikmára	Do.
	Sherpur (Sirpur)	Carnegie Steel Co.
	Kochawáhi	Dutt, Burn & Co.
	Budbuda	C. Veluaya.
	Botajheri	Dutt, Burn & Co.
	Sáonri	D. Laxminarayan.
	Nándhi	E. G. Beckett.
	Tumsur.	
	Tatekasa.	
	Gajpur.	
	Jarha Mohugáon.	Mathura Prasad.

Group II.	9. Bálághát (Bharweli, Hirapur, and Mánegáon)	C. P. P. S.
	9a. Laugur	Indian Manganese Co.
	10. Ghondi	Dutt, Burn & Co.
	11. Gudma, Ukua, and Samnapur	Carnegie Steel Co.
	12. Dharampur.	
	13. Kanaridha.	
	14. Jairási.	
	15. Kurthi-tola.	
	16. Dharpiwára.	
	17. Other localities:— Parsatola, Bodraghát.	

Group I comprises those deposits situated in the plain country to the west of the Wainganga, including those in the southern fringe of the range of hills north of Katangi. These deposits are mapped as occurring in an area occupied solely by the metamorphic and crystalline series, and are probably only a more metamorphosed facies of the deposits forming Group II. The latter comprises those situated in the hill country to the east of the above-named river; these deposits occur, as far as is known, near the base of the Chilpi Ghát series.

I have visited all the above deposits except those mentioned under 2*a*, 8*a*, 9*a*, 10, and 12-17. The deposits will be described in the sequel in the foregoing order. The numbers correspond with those on the geological map (Plate 43) of the Nágpur-Bálághát area; but 2*a*, 8*a*, 9*a*, and 17, are not shown on this map, because they were not known to me at the time the proofs of the map were passed.

Nature and quality of the ores.

The ores of this district can be divided into two groups, according to whether the deposits in which they occur are included in group I or II. The ores of group I are typically mixtures of braunite and psilomelane, as in other parts of the Central Provinces. The mixtures may be either fine- or coarse-grained. Sometimes the braunite becomes predominant in quantity and coarsely crystalline, as in portions of the Thirori deposit. There is also the ore that I have called *speckled ore*. This consists of a small proportion of braunite granules scattered through a matrix that is in parts dull grey psilomelane, in parts the bright lead-like psilomelane, and in parts soft, black, and soot-like, the latter usually occurring in cavernous spots, giving rise to the speckled appearance of the ore. This variety of ore is particularly common in the Jámrapáni deposit.

The ores of group II means, practically, those of the Bálághát deposit. The chief ore of this deposit is a compact fine-grained psilomelane, often with cavernous black spots. There is also a large quantity of massive very finely crystalline hollandite. The psilomelane found at Bálághát is also commonly found at Ukua. Where the braunite-psilomelane mixtures are also met with.

The thirteen samples taken by me from deposits Nos. 2, 3, 6, 7, 8, 9, and 11, were analysed at the Imperial Institute. The results are inserted later in the descriptions of the respective deposits, but the limits and mean of these thirteen analyses are shown in the following table :—

	Limits.	Mean.
Manganese	49·08 –54·51	51·88
Iron	5·28 – 9·10	7·40
Silica	1·62 – 6·02	3·74
Phosphorus	0·05 – 0·24	0·11
Moisture	0·12 – 0·85	0·37

These figures are remarkably close to the similar figures for the Bhandára district given on page 735. The analyses indicate an average of 32 per cent. of braunite.

Communications and transport.

Most of the deposits in this district are unfavourably situated as regards distance from the railway. The Bálághát deposit is the only exception, and is served by a 2-mile siding joining the Bengal-Nágpur Railway near Bálághát station. Practically no ore had been despatched from the deposits in the western parts of the district (Group I) up till the end of 1906. But considerable quantities had been extracted at Ramrama, Thirori, Jámrapáni, and other places, in anticipation of the extension to Katangi of the 2-foot steam tramway under construction by the Central India Mining Company from Tumsar Road. During 1907 considerable quantities of this ore were despatched to Tumsar Road station, some use being made of this steam tramway, which, however, has not yet been carried into the Bálághát district. Such ore as is being despatched from those deposits above the gháts (Nos . 9*a* to 11) is at present being carted over considerable distances, often as much as 20 miles or more. Carts, however, are very scarce and no considerable quantity of ore can be despatched from these particular deposits until some form of tramway or railway has been built. Two possibilities are mentioned on page 731.

1. Chándadoh.

This village is situated at the extreme western end of the Bálághát district and is separated from the Sitapathúr village area in the Bhandára district by the 'Muggurkutta' N. ('Annapangree Nullah' on the Bhandára Main Circuit map No. 9). About ¾ mile east of the village, after crossing a tributary of the 'Muggurkutta' and entering the Government Forest, an ore-band crosses the road leading to Thirori. This band is just seen on the west side (right bank) of this tributary, but does not reappear at the surface to the west-north-west and so has possibly been cut off by the pegmatite cropping out there. On the east side of the watercourse the band goes for 310 paces in an E. 35° S. direction, and probably continues further in this direction, but I did not follow it up. The ore-band consists of very quartzose spessartite-quartz-rock (gondite) mostly tinted purple, and containing also the brown fibrous-platy mineral (supposed to be an amphibole) found at Nándapuri, Nágpur district. There is also a little soft black manganese-ore containing remains of yellow garnet. The ore is, however, not sufficiently abundant to be worth working.

The nálá shows gneissic mica-schist cropping out about 100 yards further up stream than the ore-band, and above this occurs biotite-gneiss dipping at 30° to S. 35° W., which hence may possibly be the dip of the ore-band.

This ore-band may be a continuation of the subsidiary Sitapathúr band (page 741), but if so there has been a curling round of the strike from north-east to E. 35° S. To the east the band must either be faulted or else curl round still more so as to run parallel to the Thirori bands into which it would otherwise run nearly at right angles.

Mr. C. E. Low, formerly Deputy Commissioner of this district, informs me that he has found loose fragments of manganese-ore at two other places in the Chándadoh forest. One of these is about ½ a mile north-east of the occurrence described above, and the other 2 miles north-north-east of the same spot, close to the northern boundary of the forest.

2. Thirori, Ponía, and Jámrapáni.

[With Gáraghát (2a).]

(CENTRAL PROVINCES PROSPECTING SYNDICATE, DUTT, BURN & Co., D. LAXMINARAYAN AND OTHERS.)

The series of parallel bands of manganese-ore traversing these villages is held on mining lease by the Central Provinces Prospecting Syndicate, except for portions that did not crop out at the surface and have been secured by Mr. D. Laxminarayan, and portions of Ponía held by Messrs. P. C. Dutt, and Burn and Company. The total length of outcrop measured along the curves, is about 6 miles, the longest I have seen anywhere. There seem to be 5 parallel ore-bands[1], but in most places only 1, 2, or 3 of these bands are to be found, probably owing to the remainder being hidden by soil and alluvium. How the bands exposed in the various hills and hillocks join one another I could not usually determine owing to the breaks in continuity of outcrop in passing from one hill to another. The accompanying map shows the various bands seen, but a closer search than I had time for would probably reveal the extension of many of these bands. Thus, hidden in the jungle on the slopes of South Hill, other bands may exist running parallel to that marked along the crest of the ridge.

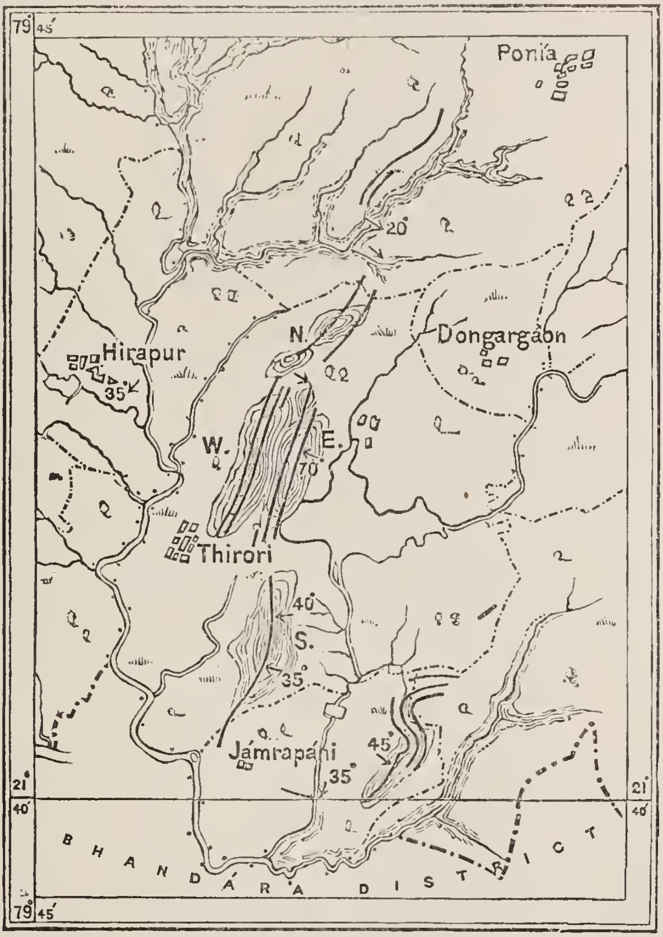


Fig. 40.—Map of the Thirori manganese-ore bands. Scale 1 inch = 1 mile.

[1] Mr. W. H. Clark informs me that the quarrying carried out by his syndicate during 1906 has shewn that these parallel outcrops are due to the folding of a single bed of ore bringing it to the surface several times.

The total breadth of the ore-bearing belt may be as much as 400 to 500 yards.

I obtained very few measurements of the thickness of the ore-bands, as they were usually so hidden in the jungle. The greatest was an outcrop width of 30 yards seen where the track from Karparia to Bawldongri crosses the ore-bands on the low ground immediately south of East Hill, and the next greatest was on the South Hill of Thirori, where one band must be at least 35 feet wide; while on the West Hill I obtained two measurements of 15 and 18 feet respectively and one in the Jámrapáni nálá of 9 feet. Taking 15 feet as the average horizontal width of each ore-band, 75 feet, or $\frac{75}{1500}=\frac{1}{20}$ of the total width of the ore-belt, may consist of manganese-ore, but the fraction might be as high as $\frac{100}{1200}=\frac{1}{12}$. Taking the average angle of dip as 30° to 45°, the actual total thickness of the 5 bands of ore works out as 37 to 53 feet. This may however very easily be an underestimate, for the outcrop widths given above are not necessarily the full widths of the bands. The accompanying rocks are mostly mica-schists traversed (as also is the ore-band in places) by a muscovite-quartz-pegmatite, which often contains an iron-ore (magnetite, martite, or hematite) and is sometimes of not very coarse grain and often apparently interbedded with the mica-schists; hence in many places it seems doubtful whether this supposed pegmatite is a variety of the schists or really intrusive.

On South Hill fragments of granulitic hornblende-gneiss were seen, while at a point near the east base of East Hill granulitic epidote-gneiss was found. As will be seen from the map the main portion of the ore-belt has a roughly north-north-east strike with local flexures. The extreme north end of it lies in Ponía village limits, whilst the remainder of this north-north-east striking portion lies in Thirori, where it gives rise to the three ridges that I have designated the West, East, and South Hills, and to the hillocks designated as the North Hillocks, and indicated as W, E, S, and N, respectively, on the map (figure 40). The belt curls round at its south end where it enters Jámrapáni limits so as to run first east-south-east and then roughly north-north-east, over a range of low hillocks, where it is flexed into a S-shape, the north-east end of the S terminating in the Gáraghát Government forest. Some $\frac{3}{8}$ of a mile north north-east of this point is another isolated ore-hillock within Thirori limits; this may indicate another flexure in the strike. I should note that a careful search may show that the belt extends further to the north in Ponía limits or to the north-east in the Gáraghát forest. The dips in the southern parts of the belt are always directed outwards or away from the rocks occupying the ground between the two arms of the belt, so that Thirori South Hill and the Jámrapáni outcrops form three sides of a quaquaversal. In Ponía and the Thirori North-Hillocks, however, the dip is to the east side, indicating an overturn. There is a very large quantity of merchantable ore in each of the three village areas of Ponía, Thirori, and Jámrapáni. The workable parts of the belt are the two hillocks of Ponía, the north end of Thirori East Hill, the whole length of the West Hill, the South Hill chiefly at its north end, and along the whole Jámrapáni outcrop at intervals.

Ponía.

There are apparently two ore-bands, which consist at the south-west end of spessartite-quartz-rock; but a little to the north-east, where the Government forest clearing crosses the outcrop, these bands give rise to two ore hillocks corresponding, apparently, one to each band. The hillock corresponding to the south-east band is dome-shaped and perhaps 80 feet high, and both it and the second hillock contain a large quantity of good hard grey ore, occasionally coarsely crystalline. The north-west band can be followed as a low ridge for about $\frac{1}{2}$ a mile, good-quality ore being seen at intervals for nearly this whole length. These two bands may continue further to the north-east. A sample (No. 51) was taken along the outcrop of the north-west band and consisted entirely of the fine-grained hard grey braunite-psilomelane mixture. It was analysed at the Imperial Institute with the result shown on page 704. This analysis shows a very high grade ore consisting of about 43 per cent. braunite and 57 per cent. psilomelane.

Thirori North Hillocks.

In the most northern of the Thirori hillocks the ore-band consists of the speckled variety of manganese-ore, in some places of good quality; while in the low hillock due east of Hirapur the ore-band consists of interbanded ore, quartzite, and spessartite-quartz-rock (gondite), with some intrusive quartz-felspar-rock containing a brown mineral (either spessartite or pyroxene) altered in places to manganese-ore. The second band, marked to the south-east of this band, is obscurely exposed.

Thirori West Hill.

Two ore-bands traverse the length of this ridge in a north-north-east direction, the eastern one occupying the crest. This band shows in one place a very steep westerly dip and consists throughout its whole length of merchantable ore, the speckled variety predominating at the southern end and the hard grey variety at the northern. The greatest outcrop width seen was 6 yards. The other band is about 60 to 70 yards to the west of this and at a slightly lower level. I did not follow this second band throughout its length, but it seemed, at the points where I examined it, to be as good as the eastern band. Where, however, the western band gives rise to two hillocks at the southern end there is, in addition to ore, also a fair quantity of spessartite-quartz-rock (gondite) with large garnet crystals. There is also a certain amount of garnet and quartz to be found in the eastern band. This ridge reaches its highest point at the northern end, where it is about 130 feet above the 'Kareekussa N.' to the north. Sample No. 50 was collected all along the outcrop of the eastern band and consisted mostly of the fine-grained braunite-psilomelane mixture with a certain quantity of the speckled ore showing the usual sooty black spots and lead-like patches of psilomelane. The analysis (see page 704) shows that the average ore contains about 20 per cent. braunite and 80 per cent. psilomelane.

Thirori East Hill.

Where the road from Hirapur to Bawldongri crosses the ore-belt between the Northern Hillocks on the north, and West and East Hills on the south, four bands are seen cropping out, as marked on the map. The most easterly of these rises to the south up the hillock shown immediately to the north of East Hill and from there on to East Hill itself, where it forms the western ore-band. On this hillock there is also a hematite-quartzite composed of granules of hematite in a rather glassy quartz-rock containing a little muscovite; there are also some blocks of a coarse muscovite-quartz-rock probably of pegmatitic origin. Where this ore-band reaches the East Hill it consists of good hard grey ore. I did not, however, follow up this band, seeing it again only on the low ground at the south end of East Hill, where it consists of the speckled ore. The east band runs along the top of this ridge, but is not always exposed. It consists of good and poor ores and spessartite-quartzite. At the northern end, where the ore is probably in sufficient quantity to be worked, I took sample No. 48 from the outcrop, a few pieces being also added to the sample at various other parts of the outcrop. The sample consisted of the usual hard grey braunite-psilomelane mixture and the analysis of it (see page 704) indicates the proportions to be 27 per cent. braunite to 73 per cent. psilomelane. On the low ground between East and South Hill, where the Kaiparia-Bawldongri road crosses, three ore-bands crop out. The most easterly of these is 30 yards wide and consists of speckled ore shewing garnet, quartz, and the altered chocolate amphibole; and where this band, a little to the north, forms part of the barrier across the outlet from the Thirori lake, it partly consists of a coarse quartz-spessartite-rhodonite-rock (rhodonite-gondite) like that found in the Kámthi Lady Pit at Chárgáon, Nágpur district (see page 883).

Thirori South Hill.

The outcrop along the ridge of this hill is very pronounced, and dips taken at various points ranged between 25° and 50° in directions between W. 30° N. and W. 5° S. The top of the hill is about 260 feet above the rice fields to the south. The ore in usually the hard grey variety, often interbanded with quartzite. Sample No. 49 was taken from the outcrop along the ridge of the hill and from the north base and consisted largely of the hard grey braunite-psilomelane mixture; but some pieces were entirely of compact psilomelane, and some were composed of the lead-like variety of psilomelane containing black powder in cavities. The analysis (see page 704) indicates a mixture of 38 per cent. braunite, 60 per cent. psilomelane and 2 per cent. quartz.

Jámrapáni.

The small hillocks forming the southern arm of the ore-belt consist largely of the speckled variety of manganese-ore, and to the east of Jámrapáni nálá the single ore-band runs north-east along what is marked on the map as a single ridge, but is really a series of hillocks and small hills. Further north there are probably 3 bands as shown. The ore-bands along this mass of hillocks and low hills consist partly of hard grey and speckled ore and partly of spessartite-quartzite. But as everything here is much obscured by jungle, it is not possible to give any details as to width, etc. Sample No. 53 was taken all along the Jámrapáni hillocks and hills, wherever the outcrop consisted of apparently merchantable ore. It consisted partly of the speckled ore, partly of psilomelane, and partly of the fine-grained braunite-psilomelane mixture. A few pieces contained a little of the bronze-coloured mica (?) The analysis (see page 704) indicates a proportion of 31 per cent. of braunite to 69 per cent. psilomelane.

Martite and fuchsite.

At one point on the ridge due east of the village the ore-band is partly cut off by quartz-muscovite-pegmatite injected on to the line of strike. This pegmatite contains a large quantity of octahedral crystals up to an inch across of what must be regarded as *martite*, since the powder of the mineral is usually reddish brown and only slightly magnetic. Some pieces, however, give a black streak and are strongly magnetic and these must be regarded as the original magnetite that by alteration has given rise to martite. A little further along the outcrop this pegmatite becomes more quartzose, and finer-grained, and contains small crystals of light emerald-green mica, probably fuchsite.

2a.—Gáraghát forest.

Along the Government Forest lane dividing Jámrapáni from the Gáraghát forest there are outcrops of three ore-bands striking east by north. These three bands continue a little way into the Gáraghát forest and if search were made might be found to crop out for some distance to the east. At a point about $1\frac{1}{2}$ miles further east and about the same distance west of Piparia, a deposit of loose fragments of ore has been found and worked by Mr. D. Laxminarayan of Kámthi.

Nature and quality of the ores.

The ores found in Ponía, Thirori, and Jámrapáni, consist partly of the hard grey braunite-psilomelane mixture and partly of what I have designated *speckled ore* (see page 696). There is also a certain amount of the coarsely crystalline braunite with subordinate psilomelane, like that of Lohdongri in the Nágpur district. Six samples were taken from various parts of the ore-belt; the results of the analyses made at the Imperial Institute are shown in the following table:—

Localities.	Ponía.	Thirori West Hill.	Thirori East Hill.	Thirori Stacked ore.	Thirori South Hill.	Jámrapáni.
Page reference	701	702	702	705	703	703
No. of sample.	51	50	48	52	49	53
Manganese peroxide . .	52·88	58·72	52·38	50·01	51·49	55·82
Manganese protoxide . .	27·15	18·05	24·67	27·97	23·02	21·11
Ferric oxide . . .	12·64	9·99	10·76	9·74	10·94	12·57
Silica (combined) . .	4·30	2·06	2·74	4·90	3·77	3·12
Silica (free) . . .	0·00	0·44	0·00	0·18	1·67	0·00
Phosphoric oxide . .	0·18	0·33	0·25	0·28	0·24	0·23
Moisture at 100° C. . .	0·40	0·70	0·30	0·32	0·21	0·38
Manganese	54·51	52·16	52·06	52·92	50·42	51·69
Iron	8·85	6·99	7·53	6·82	7·66	8·80
Silica	4·30	2·50	2·74	5·08	5·44	3·12
Phosphorus	0·08	0·14	0·11	0·12	0·105	0·10

It will be seen from the above analyses that the characteristic features of these ores are the low per cent. of combined silica and consequently of braunite, and the somewhat high per cent. of phosphorus.

The above analyses give the following average :—

Manganese	52·29
Iron	7·77
Silica	3·86
Phosphorus	0·11
Moisture	0·38

and a mean braunite per cent. of 34·8.

Mr. W. H. Clark, Manager of the Central Provinces Prospecting Syndicate has kindly supplied the following analyses by Mr. R. D. Connell, of the ores actually quarried during 1906 :—

Locality.	Ponía.	Ponía.	Ponía.	Thirori.	Thirori.	Jámra-páni.
Description of ore.	'Boulder-ore.'	'Boulder ore.'	'Bed ore.'	'Boulder ore.'	'Bed ore.'	'Boulder ore.'
Tonnage represent-ed.	Limit of four analyses on ton-nages of 186 to 1,764 tons.	1,764	253	1,274	102	Mean of 2 ana-lyses' 1,814
Manganese . .	48·63 —53·29	52·34	51·48	50·17	50·11	49·02
Iron . . .	7·32 — 8·70	7·62	7·83	8·16	7·86	10·74
Silica . . .	4·60 — 7·95	7·30	4·30	6·15	1·75	5·82
Phosphorus . .	0·06 — 0·18	0·08	0·18	0·13	0·17	0·13

These analyses agree with those made by the Imperial Institute in pointing to a progressive deterioration in quality on passing from the Ponía to the Jámrapáni end of the band.

The working of the deposit.

A little quarrying had been carried out at the time of my visit (March 1904) on the north ends of West and East Hill, where some 600 tons of ore had been stacked. This ore included both the fine grained braunite-psilomelane mixture and the coarsely crystalline facetted braunite with only subordinate psilomelane. Consequently the sample taken from these stacks (see analysis No. 52, page 704) indicates a higher proportion of braunite 49 per cent.) than usual for this set of ore-bands. By working all the ore-bands a large quantity of merchantable ore could be obtained, and by careful cleaning, and mixing the ores from various parts, this ore would probably approximate to the average composition indicated on page 697. During 1906, a considerable amount of work is said to have been done on this deposit by the Central Provinces Prospecting Syndicate. Mr. D. Laxminarayan has opened up the alluvial ground occupying the breaks in the outcrop of the ore band at different places, especially in Jámrapáni, and has found ore quite close to the surface.

Output. The production of ore from these localities is shown below :—

	1902.	1906.	1907.
Thirori (Central Provinces Prospecting Syndicate) .	361	3,088	654
Thirori (D. Laxminarayan)	*Nil*	*Nil*	3,342
Ponía (Central Provinces Prospecting Syndicate) .	*Nil*	4,742	3,824
Jámrapáni (Central Provinces Prospecting Syndicate) .	*Nil*	4,059	2,064
Jámrapáni (D. Laxminarayan)	*Nil*	27½	17,065
Gáraghát (D. Laxminarayan)	*Nil*	1,753¼	16,344

3. Sonegáon.

About ¼ mile south-west of the village there is an outcrop some 300 yards long that has a strike of about S. 20° W. and rises in one place to form a very low hillock. This outcrop is composed of interbanded grey quartzite and garnet-rhodonite-quartz-rock (rhodonite-gondite) with some spessartite-quartz-rock (gondite), and a little manganese-ore. In one place a dip of 40° to W. 40° N. was seen. The 'country' on the east side of the band is mica-quartz-schist. Nowhere did this outcrop seem to be worth working.

There is another outcrop of manganiferous rocks some 2¾ miles west-south-west of the village, but this (Gáraghát) has been noticed, in describing the Ponía-Thirori-Jámrapáni ore-belt, of which it forms a part (see page 704).

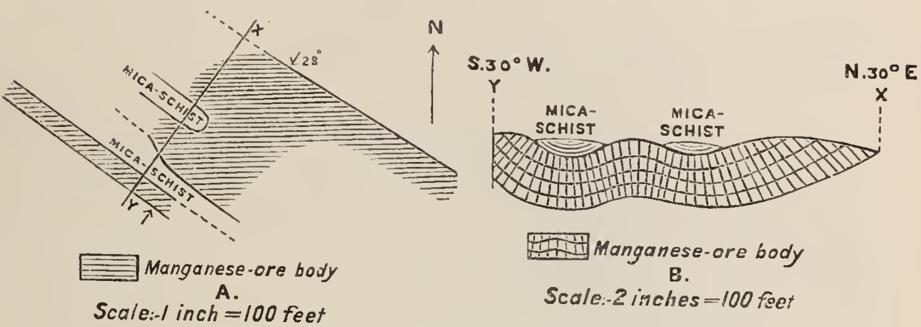
4. Arjoni and Jám.

(P. C. DUTT, BURN & CO.)

A little to the north of the main village of Arjoni (not shown on the 1-inch map) is the south-east end of an outcrop about ½ mile long, striking W. 30° N., of which the south-east half is in Arjoni and the north-west in Jám limits. This outcrop is composed of 3 or 4 bands of manganese-silicate-rock, as many as 3 being exposed in some places, but more often only one. The rock is extremely quartzose, being composed of inter-banded spessartite-quartz-rock (gondite), grey quartzite, and, except at the north-west end in Jám limits, nowhere shows any appreciable quantity of manganese-ore. The outcrop rises in places into low mounds perhaps 15 feet high. The dip is very variable, being directed, at the south-east and north-west ends, towards the north-east side at angles of 40° to 45°, and towards the middle at 50° to the south-west side. At one place near the south-east end, where three bands crop out, the following are the widths of outcrop from N. 30° E. to S. 30° W. :—

8 paces	ore-band.
11 do.	white quartzite (like vein-quartz).
7 do.	ore-band.
19 do.	probably mica-schist.
11 do.	ore-band.

These outcrops give no indication of the dip. Near the north-west



A = Plan of a part of the ore-outcrop in Jám limits.

B = Section along line XY in A.

Fig. 41.

end of the band the outcrop forms a small mound and seems to become 33 yards wide. A careful examination, however, showed the state of affairs to be somewhat as in A., fig. 41, and the apparent great width of the outcrop is probably explained as shown by the section in B, fig. 41, the patches of mica-schist, according to this explanation, resting on the ore-band. If this be the correct interpretation it seems probable that the repetition of the bands at other parts of the outcrop may also be due to the folding up of one or perhaps two bands. The mound referred to above is the only part of the whole outcrop where there seems to be any possibility of a sufficient quantity of ore worth working, but even this is very doubtful. A sample (No. 56) taken from this outcrop consisted partly of the hard fine-grained braunite-psilomelane mixture and partly of ore composed of psilomelane with porous black patches. The analysis made at the Imperial Institute showed :—

Sample No. 56.

Manganese peroxide	60·98
Manganese protoxide	13·62
Ferric oxide	13·00
Silica (combined)	2·14
Silica (free)	0·00
Phosphoric oxide	0·38
Moisture at 100° C	0·34

This is equivalent to :—

Manganese	49·15
Iron	9·10
Silica	2·14
Phosphorus	0·17
Moisture	0·34

and indicates a content of 21 per cent. braunite, the remainder being psilomelane and soft black oxides.

5. Nándgáon.

(RAI SAHIB MATHURA PRASAD.)

On the road from Sherpur to Nándgáon, at a point about 200 yards past Nándgáon-tola and $\frac{1}{2}$ mile W. 15° S. of Nándgáon, there is an obscure outcrop of spessartite-quartz-rock (gondite) and manganese-ore. The strike is N. 20° E., and the length of the outcrop 110 paces, of which 36 are to the north and 74 to the south of the road. A small water-course crosses the road 24 paces east of the ore-band. This occurrence is of no apparent economic value.

6. Ramrama.

(CENTRAL PROVINCES PROSPECTING SYNDICATE, AND TATA, SONS & CO.)

A portion of this deposit is held on mining lease by the Central Provinces Prospecting Syndicate, whilst another portion of it has been secured by Messrs. Burn & Co. and P. C. Dutt, and by them transferred to Messrs. Tata, Sons & Co. It is situated about a mile north-east of the village. The outcrop is about $\frac{3}{8}$ mile long, the western $\frac{2}{3}$ of this lying in *málguzári* land and the eastern $\frac{1}{3}$ in Government Forest; it forms a low ridge rising at its highest point to perhaps 100 feet above the low ground at the base, and shows a change in strike from about east at the western end to E. 35° S. at the eastern. In the western half of the outcrop the dip varies from 25° to 70° to the north side, about the middle the rocks become vertical, and in the eastern half they dip at about 50° to the S. 30° W. The greatest width of outcrop seen was 14 yards, at a point a little to the west of the middle, the dip being 60° to N. 40° E. This corresponds to an actual thickness of 36 feet. The 'country' was not properly exposed, but probably consists of mica-schist and white vitreous quartzites. At the point where the ore-band is vertical there is seen in actual contact with the ore a rock composed of vitreous white quartz and flattened plates, up to ¼ inch across, of slightly magnetic hematite, which gives a decided reaction for manganese and hence is perhaps to be regarded as manganiferous hematite.

Where the forest lane, dividing the *málguzári* land from reserved forest, crosses the ridge, a second ore-band is indicated at a distance of 70 to 80 paces to the south of the main band. It consists here of good-quality ore and is possibly to be traced along the south slopes of the ore-ridge.

Constitution of the ore-band.

The main ore-band consists nearly entirely of good-quality ore in the parts to the west of the forest lane, there being a little spessartite and quartzite in places. Where the lane crosses, these latter become much more abundant, and to the east of the lane there is not a large quantity of good-quality ore exposed, spessartite and quartzite being much more abundant.

Nature and quality of the ores.

The ores consist mostly of the hard grey fine-grained braunite-psilomelane mixture, often containing a little of the bronze manganese-mica (?) This ore tends in places to pass into coarsely crystalline braunite, and one piece was found of the friable type, consisting very largely of small grains of braunite with but a small proportion of the psilomelane cement. Another specimen contains a band of the very magnetic manganese-ore (vredenburgite) found at Beldongri (see page 609). A sample was taken from the outcrop in *málguzári* land and consisted of all the varieties of ore, but chiefly of the first-named. It was analysed at the Imperial Institute with the following result :—

Sample No. 57.

Manganese peroxide	48·78
Manganese protoxide	28·28
Ferric oxide	11·19
Silica (combined)	5·35
Silica (free)	0·00
Phosphoric oxide	0·21
Moisture at 100°C.	0·22

This is equivalent to :—

Manganese	52·78
Iron	7·83
Silica	5·35
Phosphorus	0·09
Moisture	0·22

and indicates that the average ore contains more than 50 per cent. of braunite.

Mr. W. H. Clark has kindly supplied the following analysis by Mr. R. D. Connell representing over 3,000 tons of ore stacked at the deposit in September 1906 :—

Manganese	50·64
Iron	7·32
Silica	7·05
Phosphorus	0·09

At the time of my visit (March 1904) this deposit had not been worked, but there is no doubt that the parts of it in *málguzári* land would yield a large quantity of high-grade ore. It is at present simply a question of communications, the nearest railway station being Bálághát, Bengal-Nágpur Railway, situated some 17 miles to the east. During 1906 the Central Provinces Prospecting Syndicate quarried some 6,000 tons of ore at the place, but have not yet despatched any of it. Messrs. Burn & Co. and P. C. Dutt (their concession has since been transferred to Messrs. Tata, Sons & Co.) are said, however, to have carted a certain quantity of Ramrama ore as far as the Wainganga near Bálághát.

The working of the deposit.

Output.

The output for this deposit for 1906 and 1907 is as follows :—

Year.	Long tons.
1906	6,091 (C. P. P. S.)
1907	2,114 (C. P. P. S.).

7. Katangjheri I (Government Forest).

(P. C. DUTT AND BURN & CO.)

This deposit is situated in Government reserved forest about $2\frac{1}{4}$ miles north-north-west of the village of the same name. The outcrop is some 550 to 600 paces long and rises near the middle to form a low hill. It is crossed at each end by a small nálá. The strike at the west end is about east, soon curling round to E.30°S. The only dip seen was one of 20° to the N.27°W. at the west end of the outcrop. The outcrop was too obscure for any measurements of width to be made. The immediate wall-rocks of the deposit were not exposed, but to the south of the deposit, in the nálá at the west end, muscovite-quartz-pegmatite and magnetite-quartz-rock were exposed.

The ore-outcrop consists mainly of hard grey ore, often interbanded with grey quartzites, or spoilt by included feslpar or mica ; but towards the east end the ore becomes soft and poor in quality. A sample broken from the outcrop over a length of some 80 to 90 yards on either side of the top of the small hill, where the band consists almost entirely of ore, was composed of the fine-grained braunite-psilomelane mixture. The analysis made at the Imperial Institute showed :—

Sample No. 58.

Manganese peroxide	47·39
Manganese protoxide	30·93
Ferric oxide	8·53
Silica (combined)	5·06
Silica (free)	0·96
Phosphoric oxide	0·09
Moisture at 100° C.	0·23

This is equivalent to :—

Manganese	53·96
Iron	5·97
Silica	6·02
Phosphorus	0·04
Moisture	0·23

and indicates a mixture of about equal parts of braunite and psilomelane.

This ore is evidently of very high grade, but it will require some development of the deposit before it can be stated that such good ore exists in considerable or large quantities. Bálághát, Bengal-Nágpur Railway, is some 17 miles distant as the crow flies.

I was told of another deposit situated further to the north-east of this one and also in reserved forest. The hill visited is probably the one marked on sheet No. 91 $\frac{S.E.}{2}$, Central Provinces Forest Department, scale 4″=1 mile, as Shodan Hurki; but of this I am not certain; for I had not this map with me at the time of my visit and did not enquire the name of the hill. Mr. C. E. Low tells me that several other ore hillocks have been found in this forest.

8. Katangjheri II (Malguzari).

(P. C. DUTT AND BURN & CO.)

This deposit, which is held by Messrs. P. C. Dutt and Burn & Co., is situated so that its north-west end is one mile W. 15° N. from

Katangjheri village.[1] The outcrop is about $\frac{3}{8}$ to $\frac{1}{2}$ a mile long and is not quite continuous. It lies on low ground, but rises here and there into small hillocks. The north-west end of the ore-band lies close to a nálá and here the strike is S.30°E. Further along, the strike changes to about E.35°S. and then returns to S.30°E. in the south-east half of the deposit. The dip is everywhere to the north-east side of the band, the amount varying from 30° to 60°.

The outcrop varies in character. At the south-east end it consists of coarse grey quartzite with thin bands of yellow spessartite, but in many other places the spessartite-bearing rock is partly altered to ore. In one place about the middle of the outcrop red spessartite in quartz is to be found.

At one point only was there exposed any manganese-ore of possible value. This was on a small hillock near the north-west end of the outcrop. A sample broken off the outcrop on this hillock consisted of the dirty speckled ore composed mostly of black oxides and dull grey psilomelane with a little braunite and lead-like psilomelane. The analysis made at the Imperial Institute shows :—

Sample No. 59.

Manganese peroxide	69·13
Manganese protoxide	6·89
Ferric oxide	9·47
Silica (combined)	1·34
Silica (free)	0·28
Phosphoric oxide	0·26
Moisture at 100° C.	0·85

This is equivalent to :—

Manganese	49·08
Iron	6·63
Silica	1·62
Phosphorus	0·11
Moisture	0·85

and indicates a content of only 13 per cent. of braunite.

Considering the very limited quantity of ore indicated in this hillock and its situation, it is doubtful if it will be worth working, except at times of high prices ; unless, of course, opening it up should lead to unexpected developments.

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1 Or about 1 mile north-north-west of the Katangjheri marked on the 1″ map dated 1870. This latter, however, is now only the *tola* or hamlet, the main village being that shown to the north of the pond.

8a. Other Localities.

The active prospecting carried out during 1906 has led to the discovery of many fresh occurrences of manganese-ore, so that almost every village-area in the western part of the manganese-belt has now been taken up on prospecting license. I am indebted chiefly to Mr. C. E. Low, for what information I have about these new discoveries.

The most important of these is said to be Bhui Hurki, a small hill lying in Government forest at a point about 2½ miles due north of Katangjheri village and 3½ miles north-east of Ramrama village.

Half a mile east of Bhui Hurki starts a ridge running interruptedly for about 1½ miles in a north-east by east direction. This ridge is said to be largely composed of spessartite-bearing-rock and a specimen from here given me by Mr. C. E. Low showed garnet crystals, up to ½ inch diameter, in quartz. This deposit is held by Rai Sahib Mathura Prasad of Chhindwára.

The other localities for manganese-ores in this area are :—Ballarpur, Bakoda, and Botajhari, where ore is said to have been found *in situ* ; Chaukhandi, Chikmára, Sirpur (Sherpur), Kochawáhi, Budbuda, Sáonri, and Nándhi, where the ore is said to be only fragmentary ; and Tumsur, Tatekassa, Gajpur and Jarha Mohugáon, concerning which I have not heard whether the ore is *in situ* or detrital.

Bakoda.

A specimen of ore from Bakoda, in the possession of Mr. H. R. Holmes of the Bálághát mine, consisted partly of lead-like psilomelane, and partly of the fine-grained mixture of braunite and psilomelane.

Palæolith of manganese-ore from Budbuda.

A rather fine specimen of a Palæolithic implement, 3·4 inches long, made of manganese-ore (hard fine-grained mixture of braunite and psilomelane) was found by Mr. Low near Budbuda, and is now in the Geological Survey collections. As regards Material, it is probably unique amongst pre-historic implements in the Museum collections of the world.

The following production, in long tons, from deposits of this group has been recorded :—

	1906.	1907.
Chikmára and Chaukhandi	1,297¾	..
Sáonri	339½	812

9. Bálághát.

(Bharweli, Hirapur and Mánegáon.)

(CENTRAL PROVINCES PROSPECTING SYNDICATE.)

(*See Plates 13, 20 and 21.*)

History.

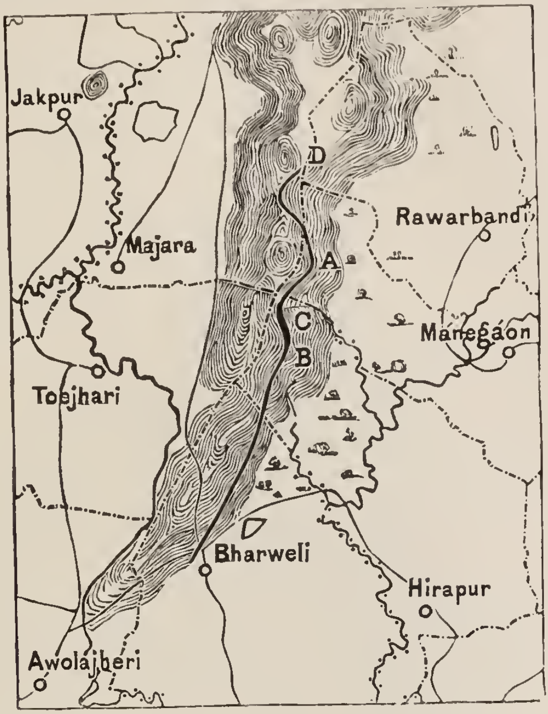
The first reference to this deposit is probably that contained in the 'Gazetteer of the Central Provinces of India' published in 1870, page 18.

The first explicit reference, however, is contained in the letter, dated 3rd September 1883, from Colonel Bloomfield (see page 692), according to whom the ridge on which the manganese-ore occurs is composed of granite, the manganese-ore being 'some hundred feet wide bounded on either side by the red granite'. Mr. P. N. Bose, late of the Geological Survey of India, examined this deposit in the field season of 1888-89, and in his progress report described the ore-body as being composed of sandstone-quartzites and quartzites, usually jaspery, interstratified with thick beds of manganese-ore, the quartzites being often impregnated with manganese. These, he says, are overlain by mica-phyllites and underlain by 'massive gneiss weathering like gritstone'. He places the ore-band at the base of the Chilpi Ghát series of transition rocks and says that there is a denudation-unconformity between the 'quartzite-sandstone' and the gneiss. As will be explained below, the underlying rock is not a gneiss, but a conglomeratic grit that has been rendered more or less schistose and sericitic. There is, moreover, no marked unconformity between the 'quartzite-sandstone' and the conglomeratic grit and they must both be referred to the same series of rocks. (See pages 311—314.)

Finally, in 1901, this deposit was secured by the Central Provinces Prospecting Syndicate and opened up by Mr. A. D. Sanders. After several changes in the manager of the mine it passed into the charge of Mr. H. R. Holmes, and has now become the largest producing deposit in India.

Geology.

The Bálághát manganese-ore deposit occupies a spur jutting out from the 2,000-foot plateau forming the highlands of Bálághát and Bilaspur (conveniently designated the 'Baihar plateau'), into the 1,000-foot plain extending from Nágpur to Bálághát. The trend of this ridge is south-south-west curling round to south-west at the southern extremity (see fig. 42), where it approaches within 2 miles of the town of Bálághát (formerly known as Búrhá). This spur consists mainly of mica-phyllites, in places approaching to mica-schists



Scale 1″ = 1 mile.
Black band = Mn-ore horizon.
Fig. 42.—Map of the Bálághát manganese-ore deposit.

(when they are found under the microscope to contain ottrelite, rutile, and tourmaline). In the latter case they are often extremely contorted. In places they contain quartz lenticles, sometimes of large size (one was 28 paces long, by 19 broad in the middle). These phyllites usually have a steep dip towards the western side of the ridge[1] and rest upon the rocks constituting the ore-body, these in their turn being superposed upon a great thickness (probably at least 400 feet) of schistose sericitic conglomeratic grits, the base of which is hidden by the alluvium of the plain to the east of the ridge. The ore-body consists of beds of manganese-

[1] At the southern end of the ridge the dips vary from vertical to very steep to either side of the strike.

ore interbanded with red, black, and sometimes grey, quartzites, and is usually separated from the underlying schistose grit by a thickness of fine-grained whitish, yellowish, or pinkish, jaspery quartzites. These are sometimes rendered schistose by layers of tiny scales of sericite and at other times have a sugary appearance due to these scales being uniformly disseminated through the quartz-mosaic seen under the microscope. These quartzites are often as soft and friable as sandstones, and are frequently replaced in part by oxides of manganese and iron, the result of a further continuance of this process being black and brown replacement-rocks respectively. In some cases the replacement takes place along veins, which may increase in number and width until the whole rock is replaced; while at other times the oxide of iron or manganese, as the case may be, finds its way along the boundary between each grain and replaces them from the periphery inwards so that the usual result is a network of opaque oxides enclosing residual quartz grains. The replacement by manganese often takes place in patches, the resultant rock being very similar in appearance to that figured on Pl. 10, fig. 1.

The red and black quartzites.

The hard red jaspery quartzite is seen under the microscope to consist of a fine-grained mosaic of quartz, each grain of which contains a cloud of minute particles of red dust, doubtless ferric oxide, the cloud usually occurring towards the centre of the grain so as to leave the periphery clear. This quartzite is thus identical in all respects with the red quartzites found at Kájlidongri, Jhábua State. The bands of it are not usually continuous for any distance, but thin out in lenticular fashion, and evidently have often been effaced by complete replacement with manganese-oxides so as to produce good manganese-ore. The accompanying figure shows an actual case seen in one place. The two nodules, A and B, were doubtless once part of a continuous layer of quartzite that has since been largely replaced by manganese-ore. An interesting feature is that the ends of these nodules are rounded and not drawn out to a point. In many places in the ore-body the red quartzite

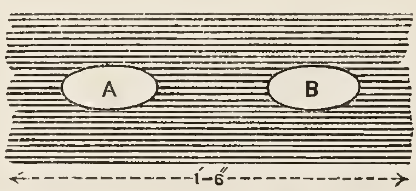


Fig. 43.—Round nodules of red quartzite in manganese-ore.

bands have become so friable that on quarrying they break down into a red powder, like brick dust. The hard black flinty quartzite is also interbanded with the ore; and when these bands are thin, they may, owing to their resemblance, as far as colour goes, to manganese-ore, give considerable trouble to inexperienced coolies, causing them to stack siliceous ore. But when the black quartzite is in thick bands it is easily recognized by the coolies on account of its lighter weight. Like the red quartzite this rock is composed of a fine-grained quartz-mosaic; but instead of containing red-dust, the quartz is full of minute black prisms, presumably of some manganese-mineral, and is in all respects similar to the black quartzite found at Kodegáon and other places in the Nágpur district. (See Plate 13, fig. 1).

Length of the deposit.

The total length of the deposit exposed is $1\frac{3}{4}$ miles. Of this a length of over $\frac{3}{4}$ mile at the south-west end is within the village limits (or *mauza*) of Bharweli; the middle and most valuable portion, over $\frac{1}{2}$ mile long, is within Hirapur limits; while a length of about $\frac{3}{8}$ of a mile at the northern end is in Mánegáon limits. The deposit is usually known as the Bálághát deposit after the town and railway station of that name situated about $2\frac{1}{2}$ miles south-west of south end of the ore-band, the intervening ground being covered by thick alluvium. According to the letter of Colonel Bloomfield above quoted 'in one place in the middle of the town the manganese again appears mixed with quartz of an inferior and sometimes partially decomposed quality'. This ore has been recently re-discovered, so that we may conclude that the Mánegáon-Bharweli band reappears at the surface here. Bloomfield also mentions that in several places between Bálághát and the ore-deposit he sank trial pits about 20 feet deep into the alluvium without finding anything like rock or hard substance on which a bridge foundation could be placed. We can conclude from this that it is hopeless to try and uncover any of the ore-band, should it exist, between Bálághát and Bharweli.

Width of the deposit.

At the time of my first visit (in March 1904), although a considerable amount of quarrying had been done, in no place had a continuous section across of the ore-body been exposed; such a cross-cut had been made by the time of my second visit (in December 1906), but, since advantage had been taken of a sharp local twist in the ore-band, the evidence of this cross-cut was not of much value in gauging the true thickness of the band. Consequently it is not easy to give an accurate value for the true thickness of the ore-bands *plus* interbedded quartzites. But, as far as I could judge from the exposures seen, it is probably about 40 or even 45 feet where thickest, namely in the Hirapur portion of the deposit. Although the strike of the main portion of the ore-band has been given as north by east, it must be noted that all along the outcrop there are many very crumpled portions where ore and quartzite layers are sharply folded. One such case is well shown in the photograph in Plate 20; whilst the plan, Plate 21, of this mine shows some of the kinks in the ore-band.

Description of the ore-band: general.

At Bharweli the ore-band first appears on low ground from beneath the alluvium, the mica-phyllite ridge lying to the west. Going north-north-east along the band it is found to give rise to a low ridge running parallel to the phyllite ridge. This ridge increases in elevation, and consequently in width, on passing northwards, until it coalesces with the phyllite ridge at the manager's bungalow. The two ridges are again separated north of this point, the ore-ridge lying in Hirapur limits, within which it reaches its maximum elevation—about 330 feet above the plains—at about the point B (figure 42). A little further north the strike of the ore-band curls round to north by west, so that the ore-ridge (at C) seems, as seen from the south, to fill the head of this valley. The dip, which has hitherto always been at various steep angles (45° to 90°) to the west side, now becomes much smaller (20° to 35°), so that the ore appears at the surface for some distance down the western slope of the ridge. Then, just before reaching Mánegáon limits the outcrop of the ore-band again curls round so as to strike north-east. At the same time it becomes thinner and much poorer in quality.

The ore-band then gives place to red quartzite and limonite and begins to slope down the hill-side; but soon after it rises again, until it thins out altogether at the point A opposite the phyllite hill to the west, the ore-band not having quite reached the platform leading to this phyllite peak. The overlying phyllite and underlying schistose conglomeratic grit now come into contact and the grit, owing to the small westerly dip now possessed by the rocks, continues as a bold outcrop with the sinuous course indicated between A and D, beyond which I did not follow it. The peak to the west of D consists of phyllites with a very small dip and rises to, say, 800 to 1,000 feet above the plains. On it are numerous walls, doubtless the remains of an old hill fort. It is interesting to notice that the lessening dip of the rocks of this range

Photographed by L. L. Fermor.

Bemrose, Collo., Derby.

CRUMPLED MANGANESE-ORE "BEDS" AT THE BÁLÁGHÁT QUARRY.—BÁLÁGHÁT DISTRICT, C. P.

of hills as one passes from the southern end near Awolajheri to the northern portions at B finds expression in two ways. In the southern portions where the dips are steep the range of hills is comparatively narrow, and the outcrop of the ore-horizon, taken as a whole, is very straight ; but as the dip lessens to the north, so does the width of the range inerease, while the outcrop of the ore-horizon—and after it has died out, of the phyllites and grits—becomes very sinuous.

The phyllites, where they rest on the ore-body, have in this part of the deposit frequently been converted into a mangano-ferruginous laterite, often containing residual fragments of phyllite.

The Bharweli portion.

The ore-band for some 500 yards at the southern end lies on low ground, after whieh it gives rise to the ridge already mentioned, thus eoaleseing with the phyllite ridge towards the northern boundary of the village. The outerop varies in width in different places from 15 to 30 feet and eonsists of fine-grained grey erystalline ore interbanded with the black and red quartzites. At several places the soft whitish sandstone-like quartzite (often serieitie and impregnated with oxides of manganese or iron) erops out to the east of the band, in one plaee being as far as 102 paees to the east, thus showing that a eonsiderable thiekness of these quartzites separates the ore-band from the underlying grits at this end of the deposit. The dips are usually to the west side, but where the band begins to rise on to the ridge it beeomes vertieal and a little further north is overturned so as to dip at 60° to E. 35° S., soon after returning to its normal direction. Although there is plenty of good ore in this part of the band, yet it is only sinee Oetober, 1905, that it has been opened up to any eonsiderable extent.

The Hirapur portion.

The middle (and thiekest and best) portion of the deposit lies within the limits of this village. Soon after erossing the southern boundary the ore-outerop rises to a level of over 300 feet on the erest of the ridge and eontinues at this elevation right to the northern boundary. The outcrop is being aetively quarried throughout this whole length. The total thickness of the ore-band is exposed by one eross-eut only (see page 717), but widths of 25 to 49 feet were measured at various points, eorresponding—the average dip being, say, 60°—to aetual thieknesses of 22 to 43 feet. In one plaee the width aeross the outerop was 83 feet ; but this was due to a sharp anti-elinal and synclinal fold in the ore. At many points the ore-band is either sharply flexed or folded, in some plaees into eomplex eurves (Pl. 20). The dip, whieh is very variable, usually varies between 45° and 80°

to the west side, but near the north end where the strike curls round to north-north-west the dip becomes much smaller (20°—35°), and

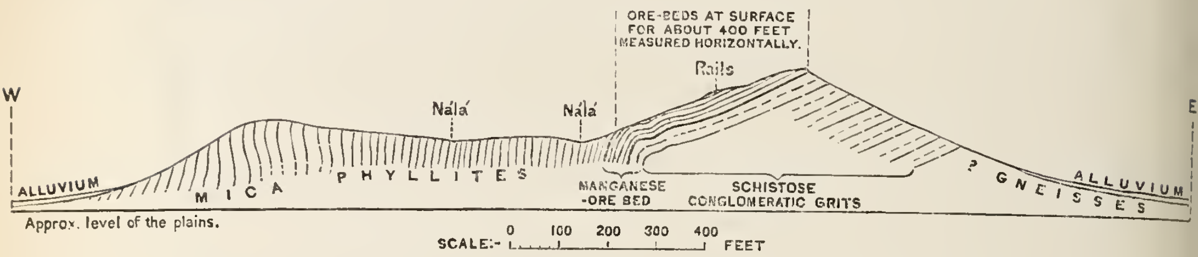


Fig 44.—Section across the Hirapur portion of the Bálághát manganese-ore deposit.

as the ore-band is waved it is kept at the surface for some 400 feet down the west slopes here, really owing to a fold that runs west of south down the hill side. Figure 44[1] is an east and west section across the ore-body at this point (C in figure 42). Throughout this portion of the outcrop there is a much larger proportion of ore than on the Bharweli portion. The ore is partly dull grey psilomelane and partly a very fine-grained light grey crystalline ore that glistens brilliantly in the sun. Owing to its very fine and uniform grain, it has been caused by the earth-movements that have folded and twisted the rocks of this hill to assume structures that are usually imparted only to slates and schists. Thus, many of the divisional planes of the ore when uncovered are found to be waved as if with ripple-marks, while in some places the ore actually shows a sort of slaty cleavage. Besides the divisional planes parallel to the original bedding, the ore-body is often traversed by joint-planes, which in one place are so numerous that the ore breaks up into little rhomboidal fragments. As usual the underlying rock is the jaspery quartzite, resembling sandstone in planes.

The Mánegáon portion.

The ore-band soon curls round to the north-east, first dipping steeply to the north-west and then at an angle, which becomes less and less, to the north-east. At first the outcrop is very bold, consisting of perhaps ½ quartzite and ½ ore, with a thickness of about 15 feet. In one place a huge mass of ore, which I estimated as weighing 180 tons, had fallen over to the east side. Further north the outcrop often consists to such a large extent of red, black, and grey quartzites, and is so veined with quartz, as to be unworkable. And

[1] As will be seen, this figure contains an error; the bracket corresponding to 'manganese-ore bed' has been carried about 0·1 inch too far to the right.

then, as described on page 718, the band becomes much thinner, passing into limonite, so that there is soon only 5 feet or so of limonitic rock (with patches of hematite and manganese oxide) and jaspery quartzite resting on the underlying grit. Finally the band dies out altogether.

Nature and quality of the ores.

Owing to the absence of any spessartite or other manganese-silicates we have here no examples of manganese-silicate rock passing into manganese-ore. True, the quartzites are often replaced by manganese-ore; but the quantity of such rock in which original quartz is noticeable is quite subordinate, and the main mass of the ore, when the bands of quartzite have been separated from it, is good compact ore, although a little of it is spoilt by small veinlets and nests of secondary quartz. On account of the fact, for such seems to be the case, that these ores have not been derived from manganese-silicates by chemical alteration, braunite is to a large extent absent. In a few cases it occurs as sparsely scattered grains in psilomelane, whilst especially towards the Bharweli end of the deposit, the typical mixture of braunite and psilomelane is to be found in places. The main mass of the ore, however, consists of two varieties. One is typical dull grey psilomelane, sometimes containing cavities filled with black powder. The other is the very finely crystalline light grey ore that glistens brilliantly in the sun, and owing to its fine-grained homogeneous character is able to have impressed on it various physical structures resulting from pressure. It can be scratched fairly easily with a knife, the streak being black. A complete analysis of a piece was made by Messrs J. and H. S. Pattinson of Newcastle-on-Tyne, with the result given on page 93 of Part I, which proves it to be hollandite. The constituents of commercial importance are as follows :—

Specimen No. 1146.

Manganese	54·42
Iron	3·10
Silica	1·40
Phosphorus	0·020

At the bottom of the gravity incline No. 1 (see page 725) there was (in March 1904) a huge stack of about 7,400 tons of ore ready for loading into railway wagons. The ore consisted partly of the fine-grained light grey ore, partly of banded psilomelane, and partly of psilomelane with the soft black spots. Several pieces of ore showed films or veinlets or white quartz; but I understand the ore receives a final cleaning when being loaded into the wagons. A sample taken from here was analysed at the Imperial Institute with the following result :—

Sample No. 60.

Manganese peroxide	71·53
Manganese protoxide	9·43
Ferric oxide	7·54
Alumina	2·15
Baryta	3·86
Lime	0·58
Magnesia	0·69
Silica (combined)	1·20
Silica (free)	1·42
Phosphoric oxide	0·12
Arsenic oxide	0·010
Water (combined)	1·33
Water (at 100°C.)	0·12
Carbon dioxide	0·19
	100·17

This is equivalent to :—

Manganese	52·63
Iron	5·28
Silica	2·62
Phosphorus	0·05
Moisture	0·12

An analysis of all the ore stacked on the mine at some time in 1902 was made by Mr. G. M. Prichard, then chemist to the Central Provinces Prospecting Syndicate, with the following result :—

Manganese peroxide [1]	74·71
Manganese protoxide [1]	4·35
Ferric oxide	6·34
Alumina	2·36
Baryta	0·14
Lime	0·26
Magnesia	0·33
Alkalies (soda and potash)	2·05
Silica	4·80
Phosphoric oxide	0·15
Water (combined)	2·13
Moisture	0·57
Carbon dioxide	0·50
Organic matter	1·31

This is equivalent to :—

Manganese	50·60
Iron	4·44
Silica	4·80
Phosphorus	0·065
Moisture	0·57

[1] Calculated from % of Mn on assumption that analysis totals to 100.

In addition to the above Mr. W. H. Clark, Manager of the Syndicate, has kindly supplied the following partial analyses :—

Number.	1	2	3	4	5
Details.	Range of analysis of 6 samples.	Mean of preceding 6 analyses.	Average of ore at the mine.	Sample taken from all the trucks loaded on mine during August 1906.	Sample taken from all trucks loaded on mine during November 1906.
Tonnage represented.	Lots of 50 to 400 tons.	880	897	7,960	6,714
Date	March 1905.	March 1905.	July 1905.	August 1906.	November 1906.
Analyst.	S. A. Jones.	S. A. Jones.	R. D. Connell.	R. D. Connell.	R. D. Connell.
Manganese .	50·58 —52·99	52·35	52·49	50·93	51·36
Iron . .	3·76 — 4·79	4·05	..	..	..
Silica . .	1·24 — 1·82	1·41	1·20	3·05	2·80
Phosphorus .	0·03 — 0·14	0·06	0·05	0·075	0·07
Siliceous residues.	2·41 — 3·23	2·74	..	..	...

The working of the deposit.

The deposit was discovered for the Central Provinces Prospecting Syndicate by an Indian (Zain-ul-abadin), who was given a contract and started work about September 1901. He extracted a considerable quantity of partially cleaned ore, and stacked it indiscriminately so as to interfere to a certain extent with the subsequent working of the deposit. Mr. A. D. Sanders took charge of the deposit in the latter end of 1902 and set about developing it on rational lines.

As the ore is divided by planes parallel to the original bedding into layers averaging six inches to one foot thick, and is usually dipping at a high or fairly high angle, it had not been found necessary up to the time of my visit in March 1904 to resort to blasting. As much of the wall-rock as was necessary was first removed, and then the layers of ore on the footwall (east) side were, by inserting crow-bars into the dividing planes, levered over one by one and allowed to fall, after which they were broken up by sledge hammers; or, when too thick for this, by lighting a wood-fire below the fallen mass, when the unequal expansion of the upper and lower surfaces of the slab caused it to crack. There was often a great difficulty in detaching these slabs, but it was all done with crow-bars, wedges, and sledge-hammers. It was sometimes found necessary to heat the surface of ore with a big wood-fire and then to throw water on the heated surface and thus crack it. Occasionally the hanging wall was attacked first. Then the slabs had to be first levered into a vertical position and thrown over to the west side. The above description still applies, except that blasting is now resorted to and the use of fire has been abandoned.

After the ore so detached has been broken up by the coolies to a convenient size, it is passed to coolie women, who clean it with the usual small cobbing-hammers; but a large number of large pieces of apparently pure ore are sent away without this cleaning. Several levels with rails have been run out on the east side of the ore-ridge to facilitate the disposal of the waste, consisting of poor ore, quartzite, and wall-rock or overburden.

The portion of the deposit to which the most attention has been devoted is that in Hirapur. A level, known as the main level[1], has been run along the west side of the ore-body at about 50 feet below its highest point. The hanging wall of phyllites has been removed from the whole of the deposit above this level, leaving above it an irregularly excavated ridge of ore. The ore-surfaces thus exposed exhibit very well the varying dip, the crumpling, waving, and jointing, characterizing this part of the deposit. This ridge is now being pulled down and the cleaned ore obtained as already described is stacked and passed by the staff of the mine. It is then loaded into 1-ton trucks on the main-level rails, where the gauge, as of all other rails on the mine, is 2 feet. (The northern end of this level taps the Mánegáon portion of the deposit.) The trucks once started travel by gravity southwards along this level, which has a gradient of 1 in 75, the speed being regulated by brakes. At the southern end is a gravity incline (No. 2), down which the trucks are lowered in pairs, the descending loaded trucks hauling up the empty ones. The

[1] See Plate 21.

haulage is controlled by a brake-gear at the top of the incline, the diameter of the brake-wheel being 6 feet. The vertical drop on this incline is 106 feet in a horizontal distance of 750 feet, *i.e.*, the gradient averages 1 in 7. The capacity of this incline is 600 tons a day, but the amount usually transported is less than half this amount. The trucks are then run for a short distance along another level with a gradient of 1 in 75, past the manager's bungalow to the head of incline No. 1. Another gravity incline (No. 3) from the North Bharweli portion of the deposit feeds, when working, which is only occasionally, about 150 tons a day on to the bungalow level. One truck a trip is lowered. The gradient is 1 in 5·35, the drop being 58 feet in 300. Thus all the ore from the Mánegáon, Hirapur, North and South Bharweli, portions of the deposit arrives at the top of the incline No. 1. From there the ore is lowered down the western slope of the phyllite ridge lying to the west of the ore ridge, the bungalow level being on the neck joining the two. The drop is 163 feet in 500 horizontal with a very steep gradient (1 in 2·66 at the steepest). It is controlled by the usual type of brake-gear, the horizontal wheel having a diameter of 5½ feet ; one truck a trip is lowered, the maximum daily capacity being 350–400 tons. As this is not sufficient to take all the ore that could be fed to the top of the incline, another incline (No. 4) is being put in alongside of No. 1. It will have the same drop, but a less steep gradient, and will be able to lower 2 trucks every trip with a daily capacity of 600 tons. The two gravity inclines together will then be able to dispose of 950 tons of ore a day as a maximum.

At the foot of the phyllite ridge the trucks from incline No. 1 are run out on rails supported on trestles, and tipped out on to a dumping ground. This is at a siding put in by the Bengal-Nágpur Railway. The siding is connected by a length of 2 miles of 2′ 6″ gauge rails to the Gondia-Jabalpur branch of the Bengal-Nágpur Railway at a point about a mile north of Bálághát station. The ore thus dumped at the mine siding is inspected by mates whose special duty it is to reject any ore containing quartz or quartzite, such ore not infrequently being put into the bottoms of the mine trucks by the mine coolies and covered by the good ore on top. The ore is loaded by hand into the railway-wagons. During the latter part of 1906 one train a day of 14 wagons, this being the full capacity of the siding, was being loaded. Each wagon takes 16 tons of ore, giving 224 tons per train. Some 4 or 5 extra trains a month were also run, accounting in all for a despatch of some 7,500 tons a month. The tonnage of the ore loaded into these wagons is calculated by measurement, one ton of broken ore being taken as occupying 16 cubic feet.

On arrival at Gondia the ore has to be transferred by hand to wagons on the broad-gauge main line of the Bengal-Nágpur Railway. It is then railed to Bombay. Sometimes hopper-wagons with drop bottoms are supplied at the mine siding; these wagons are run on to an elevated pair of rails at Gondia, and the ore is dropped through a shoot into wagons standing on the broad-gauge line beneath. [1]

A fifth incline is to be put in for the lower Bharweli portion of the deposit. This will discharge ore near the siding put in by the Bengal-Nágpur Railway for the ore brought by Messrs. P. C. Dutt and Burn & Co. from Ukua (now transferred to the Carnegie Steel Co.).

An interesting feature of the work of this mine is that the ore is not usually submitted to analysis before despatch. As soon as the stacked ore has been passed it is loaded direct into the mine-trucks. A certain quantity of ore is taken from each truck as it passes the manager's bungalow. The bulk sample thus obtained does not get analysed until some time after the despatch of the ore.

The number of coolies employed on this mine is very large, sometimes rising to 2,000, but usually about 1,500. About 1,000 of these have been imported, the imported coolies being mostly Kols from the Jabalpur area, and to a small extent Hindus from Raipur. The local coolies are Hindus.

Output. The output of ore from this deposit for the years 1901 to 1907 is shown below:—

Year.	Long tons.
1901	3,839
1902	1,614
1903	7.898
1904	10,323
1905	16,246
1906	78,499
1907	92,182

9a. Laugur.

(INDIAN MANGANESE COMPANY.)

Manganese-ores have been discovered by the Indian Manganese Company about $1\frac{3}{4}$ miles south-south-east of Laugur. The ore found there is doubtless a south-westerly continuation of the Ukua-Ghondi ore-band, which reappears much further to the south-west as the Bálághát deposit.

1 I understand that owing to the damage done to the rolling stock by the falling ore, the use of these wagons, which were really designed for the grain traffic, has been discontinued.

PLAN OF
BÁLÁGHÁT MANGANESE MINE
August 1906
(By H. R. Holmes)

Scale 5 Chains (330 feet) = 1 inch
Blue = Manganese-ore

I am informed by Mr. Hance of the Indian Manganese Company that from the outcrop it was expected that the ore-band would be found to be 16 feet thick. As the result of cross trenches at intervals of 200 yards over 2,000 yards of length however, the width was found to be never greater than 6 feet and to average 4 feet, with a minimum of 2½ feet. At least half of this thickness is waste, due to the intercalation of rocks, not manganese-ore.

1,934 tons of ore were quarried during 1907, but none was sent to the railway.

10. Ghondi.

(P. C. DUTT, BURN & CO.)

Manganese-ore was found at this locality by Lala Kishen Singh of the Geological Survey of India in the field season of 1888-89. This occurrence is on the same horizon as the manganese-ore deposit of Bálághát, namely that mapped by Bose and Kishen Singh as near the junction between the Chilpis and the metamorphic series. Kishen Singh gives no details of this occurrence except that the dips are generally towards the north-west, and that the ore-band can be traced to a good distance in both directions (north-east to south-east). I did not visit this locality myself and so can give no details of the quality or quantity of the ores.

11. Ukua, Gudma and Samnapur.

(CARNEGIE STEEL COMPANY.)

(*See Plate 12.*)

Ukua is situated about 18 miles to the north-east of the Bálághát deposit, and the fact that a band of manganese-ore occurs at the junction between the 'Chilpis' and 'metamorphics' at the same horizon as at Bálághát seems to have been first noticed by P. N. Bose in the field season of 1888-89. The deposit was first held on prospecting license by the Central Provinces Prospecting Syndicate and allowed by them to lapse at the end of the year. Then in 1904 a prospecting license for the same deposit was obtained by Messrs. Burn & Co. and Mr. P. C. Dutt of Jabalpur, who, after despatching a certain amount of ore in 1906, sold the deposit to the Carnegie Steel Company.

Length and situation of the ore-band.

The length of this ore-band, as exposed at the surface, is 3 miles; the strike averages E. 25° N., but is very variable. At its south-west end it disappears under alluvium at a point about ½ mile south of Gudma village and ¼ mile north-east of the Kastur Nálá.[1] Traced towards the north-east the outcrop is seen projecting from the alluvium, and on approaching Ukua village it begins to climb the slope of the mica-schist hills, reaching the summit (△ 2,213 feet) at a point about ¼ mile due north of this village. It next descends to low ground and then gradually climbs up the south-east slopes of a ridge of mica-schists, reaching the top at the north-east end, where the band apparently dies out; the junction here between the overlying mica-schists and underlying gneisses is covered by the huge mass of laterite (both aluminous and ferruginous) resting on Deccan Trap basalt that forms the high hill north-east of Samnapur village and rises further to the north to form Tipagarh Hill, 2,761 feet above sea level, and one of the highest peaks in the Bálághát district.

Dip.

The dip of the rocks is always towards the north-west side of the strike at angles varying from 20° to 60° but usually about 30° to 40°.

Thickness of ore-band.

The greatest thickness of ore-band seen was at a point west-south-west of △ 2,213, where the outcrop was 10 paces wide with a dip of 40°, corresponding to an actual thickness of 19 feet, which is not necessarily the full thickness. On the hill △ 2,213 an actual thickness of 12 feet can be measured from the junction with the overlying mica-schists, but the base of the ore-band is not here exposed.

'Country.'

The overlying rock is mica-schist (composed of sericite and quartz, often with ottrelite, tourmaline, rutile, and magnetite, or some other iron-ore) varying in places to mica-phyllite; while the underlying rock is usually a schistose gneiss (which is evidently only a more metamorphosed form of the schistose grit underlying the Bálághát deposit), this in turn resting on much less schistose gneisses. (See pages 311—314). Between the ore-band and the gneiss there seems to intervene in places a little quartzite, but this is probably to be regarded as part of the deposit, as at Bálághát; moreover, a little pit towards the western end of the deposit, just to the south-west of where the Gudma-Ukua road crosses the ore-band, showed that phyllites at this point also underlie the ore-band. At this point also there is seen a little manganese-laterite resting on the ore-body.

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[1] On the south-west side of this stream (according to Kishen Singh's map) the band reappears and continues to Ghondi, under which heading this part of the band is mentioned (page 727).

Character of the ore-band.

The ore-band is composed of bands of manganese-ore and fine-grained grey, purplish, and red, quartzites, with some of the vitreous black quartzites full of tiny black rods of some manganese mineral. There are also some bands of typical fine-grained spessartite-quartz-rock (gondite), varying in colour from yellowish-buff to purplish (when there is red iron-oxide dust in the spessartite) and often somewhat blackened (Plate 12, fig. 1). Near the south-west end of the band there is one outcrop of rock in which the ore and quartzite has apparently been brecciated and re-cemented by quartz which also veins the ore and quartzite.

Nature and quality of the ores.

The manganese-ores are rather variable in mineral composition. The ores in the part of the deposit to the south-west of the road from Ukua to Gudma consist usually of hard grey, often metallic-looking, psilomelane, frequently containing a certain proportion, often very small, of minute scattered specks of braunite. This ore is often cavernous with a soft black powder in cavities. A sample taken all along this part of the outcrop was analysed at the Imperial Institute with the following result :—

Sample No. 61.

Manganese peroxide	67·76
Manganese protoxide	10·76
Ferric oxide	10·42
Silica (combined)	1·75
Silica (free)	0·42
Phosphoric oxide	0·54
Moisture at 100°C.	0·40

This is equivalent to :—

Manganese	51·23
Iron	7·29
Silica	2·17
Phosphorus	0·24
Moisture	0·40

and indicates that the average ore in this part of the deposit contains 17·5% braunite, the remainder being mostly psilomelane with a little soft black oxide.

In the parts of the deposit to the north and north-east of the Gudma-Ukua road the manganese-ore consists chiefly of the mixture of braunite and psilomelane typical of the Nágpur district, and varies from the very fine-grained variety to that in which the braunite facets are up to ¼ inch across. A sample was taken along this part of the deposit, from the point where the above-mentioned road crosses to a point little to the east of hill △ 2,213. The analysis carried out at the Imperial Institute shows :—

Sample No. 62.

Manganese peroxide	53·02
Manganese protoxide	23·48
Ferric oxide	10·68
Silica (combined)	4·11
Silica (free)	1·44
Phosphoric oxide	0·29
Moisture at 100°C.	0·30

This is equivalent to :—

Manganese	51·85
Iron	7·48
Silica	5·55
Phosphorus	0·13
Moisture	0·30

and indicates a mixture of 41% of braunite with 57% of psilomelane, the remainder being quartz, etc. Much of the manganese-ore contains little films of quartz, which it would be very difficult to clean out except with a very great waste of otherwise good-quality ore.

An interesting feature about this deposit is the fact that the phosphorus increases in amount on passing from the Samnapur to the Ukua end of the deposit. Analyses by Dr. Schulten, kindly supplied by Messrs. Burn & Co., showed the following phosphorus contents :—

Samnapur	0·06
Ukua	0·16
Gudma	0·20

The working of the deposit.

Nearly the whole length of the deposit (except at the extreme north-east end) contains ore of quality equal to that shewn by the above analyses, and in many places probably at least half the thickness of the band will be found to be composed of merchantable ore. Hence there is no doubt of the existence of large quantities of a fairly high-grade ore (albeit somewhat high in phosphorus). It will be, moreover, fairly easy to quarry, for the overlying rock is an easily-removed mica-schist, and the dip is fairly small. The only obstacle then is the question of transport. The parts of the deposit that would probably be worked first, namely from Ukua westwards, are situated about 25 to 26 miles by a fairly good road from Bálághát Railway Station, Bengal-Nágpur Railway. The crossing over the Uskal

Nadi has since my visit been bridged. But there is also a descent of about 1,000 feet of the gháts between Laugur and Pipriatola, and although this is easy enough for the laden carts on their way to Bálághát, yet on the return journey the ascent is a slow piece of work even for empty carts. Hence it is obvious that transport by bullock-carts will be a slow and expensive method, apart from the difficulty of obtaining a large number of carts in this rather sparsely inhabited part of the district; indeed it is probable that this means of transport would be financially possible only when fairly high prices for manganese-ore were obtainable.

There is a scheme under consideration for carrying a branch of the Sátpura Railway from Mandla to Bilaspur, *viâ* Baihar. Should this project be carried out, a branch some 15 miles could be constructed to Samnapur, Ukua, Rupjhar, and even Ghondi. Such a branch would serve, not only to transport the manganese-ores, but also to facilitate the working of the rich bauxite deposits of this area, either for bringing up the plant and raw materials necessary for smelting the bauxite on the spot, or for transporting it to some smelting centre.

Should this scheme fall through it will be necessary to send the ore to Bálághát Railway Station. By means of an assisted siding from the Bengal-Nágpur Railway as far as the foot of the gháts and then a combination of tramway and aërial ropeway, it is estimated that 50,000 tons of ore could be despatched yearly.

Messrs. Burn & Co. and P. C. Dutt have been opening up this deposit during 1905 and 1906 and have succeeded in despatching to England during 1906 over 2,000 tons of ore. They report that the ore-bed was followed for some 80 feet by a drive down the dip-plane, and that at this point the bed suddenly dipped over almost to the vertical. It is interesting to note that this sudden steepening of the dip also characterizes the Bálághát deposit (see page 720). The deposit was transferred to the Carnegie Steel Co. in 1907.

Output.

The output from this deposit during 1906 and 1907 was as follows:—

	Long tons.
1906	2,363
1907	19,400 [1]

[1] Including 5,000 tons extracted by Tata, Sons & Co. at Gudma.

Other Localities.

12. Dharampur.

The Bálághát Ukua ore-band apparently reappears to the east of Ukua, for Kishen Singh in his 1888-89 progress report says that at Dharampur 'it was found precisely at its wonted horizon.' This is somewhat difficult to understand: for, according to the maps of Bose and Kishen Singh, the Wáráseoni-Bhimlat and Hatta-Kanaridha bands of Chilpis have coalesced about 3 miles west of Dharampur; whilst this village is situated so that the nearest area of metamorphics is about 3 miles distant, the "wonted horizon" of the ore-band being at the base of the Chilpis.

13. Kanaridha.

Kishen Singh also mentions finding the ore-bed at Kanaridha, but gives no details, nor does he mark the position on the map. But as Kanaridha is on the southern edge of the Hatta-Kanaridha band of Chilpis, it seems probable that this ore was also found at the base of the Chilpis.

14. Jairási.

Mr. C. E. Low, former Deputy Commissioner of Bálághát, informs me that he has found manganese-ore at Jairási. A reference to the geological map of this area shows that this village is situated on the northern edge of the Hatta-Kanaridha band of Chilpis near its eastern end.

15. Kurthitola.

Kishen Singh also found scattered blocks of manganese-ore about $\frac{2}{3}$ of the way up the ghát near Kurthitola on the road to Baihar. This possibly indicates the presence of an ore-bed at or near the north-west edge of the Wáráseoni-Bhimlat band of Chilpis.

Parsatola (Borapahár).

Pebbles of lateritic ore have been found at this locality by Mr. Low. One specimen I was able to examine consisted of red hematite with veins of psilomelane.

16. Dharpiwára.

On the road to Dharpiwára (presumably from Bálághát) Kishen Singh noticed 'lateritic weathering globules which are black inside.' These are no doubt the pisolitic spherules of mixed oxides of iron and manganese found at so many places in the Nágpur-Bálághát area.

Bodragháț.

A solitary piece of quartz partly replaced by pyrolusite and psilomelane was found by Mr. Low at Bodraghát in the wild country of the Upper Son valley.

CHAPTER XXXIII.

DESCRIPTION OF DEPOSITS—*continued.*

The Central Provinces--Bhandára District.

History—Output and labour—Physical characters and geology—List of deposits—Nature and quality of the ores—Communications and transport—Kosumbah—Síta-pathúr—Sukli—Hatora—Miragpur—Mohugáon Ghát—Pándarwáni—Sálebaddi—Chikhla II—Kurmura (Ponwa Dongri)—Chikhla I—Sitasáongi—Ásalpáni I—Ásalpáni II (Sáya Hurki)—Pach ra.

(*See Plate 43.*)

History.

Manganese-ores were first reported to occur in this district by Colonel Bloomfield, who sometime previous to 1883[1] found loose pieces of ore in watercourse near Ámbagarh. Then, in the field season of 1893-1894, Mr. P. N. Datta of the Geological Survey of India, while geologically mapping parts of this district, discovered several (Nos. 2, 5, 10, 11, 12, 13) of the deposits enumerated below; but his discovery was never made public, and the deposits remained unknown until the opening up of the manganese-ore deposits of the Nágpur district at the beginning of this century led to active prospecting in the Bhándára district with the resultant rediscovery of all the above-mentioned deposits and the discovery of several other deposits not seen by Mr. Datta. During 1901 the Central Provinces Prospecting Syndicate commenced work on the Chikhla I deposit, with the production of 499 tons. In 1905 the Central India Mining Company and Messrs. Jessop & Co. also started work in this district, and Mr. Laxminarayan in 1906.

Output and labour.

The yearly figures of production and average daily number of workers are shown in the following table :—

Year.	Production in long tons.	Average daily number of workers.
1901	499	(*a*)
1902	5,360	300
1903	4,998	75
1904	8,559	64
1905	35,238	300
1906	97,906	973
1907	143,703	2,230

(*a*) Not returned, although work was progressing.

1 Letter dated 3rd September 1883, filed in the Geological Survey Office.

Physical characters and geology of the manganese ore belt.

The manganese-ore deposits occur only in the north-western portions of this district, and are situated partly in the Bhandára (Nos. 1 to 4, 7, and 10 to 14) and partly in the Thirora tahsil (Nos. 5, 6, 8, 9). This area forms, together with the manganese-ore zone of the Bálághát district, an extension of the manganiferous belt of the Nágpur district. The Bhándára manganese area is 20 miles long (Ásalpáni to Chikhla II) and has a maximum width of 18 miles (Pachára to Sítapathúr). The chief topographical feature is the rather high range of quartzite hills starting from the west end of the district at Bhandárbori and running east by a little north to Ámbagarh, where it reaches an elevation of about 700 feet above the plains. It then curls round to the north-east through Chandpur and finally sinks to the plains 4 miles north-east of Rampáili, the total length being thus 34 miles. In addition to this range there are numerous small hills and hill ranges with peaks up to 500 feet above the level of the plains. The plains between and surrounding these hills are at an average elevation of about 1,000 feet or a little more above sea-level. The hills are usually clothed with a fairly thick tree-jungle ; whilst the plains are partly, where alluvial, given up to the cultivation of rice and other crops, and partly, where stony, covered with thin tree-jungle. This area is drained by the Bháwanthari and Chunni rivers ; these discharge their waters into the Wainganga river, which, near Chandpur, comes to within 4 miles of the south-east foot of the above-mentioned quartzite range.

Geologically the manganese area of the Bhándára district is a continuation of the Nágpur manganese belt. The rocks exposed at the surface all over this area are quartzites, gneisses (both acid, epidotic, and pyroxenic), and mica-schists, with pegmatitic intrusions.

The manganese-ore deposits nearly all occur in the hillocks and hill-ranges noted above, the highest outcrop of manganese-ore being on the top of Bhámasur Hill (see Chikhla I), which rises to about 540 feet above the plains. The manganese-ore deposits form, together with the associated manganese-silicate rocks of the gondite series, lenticular bands enclosed parallel to the strike in the quartzites, schists, and gneisses. They are in every way similar in mode of occurrence, origin, and mineral constitution, to those of the Nágpur district.

The deposits of this district will be described in the order shown in the following list :—

List of deposits.

Group	Deposit	Concessionaire
Group I	1. Kosumbah	C. I. M. C. (Central India Mining Company.)
	2. Sítapathúr	C. P. P. S. (Central Provinces Prospecting Syndicate.)
	3. Sukli	C. I. M. C.
	4. Hatora	Do.
	5. Miragpur	Do.
	6. Mohugáon Ghát.	
	7. Pándarwáni	R. H. Richardson.
	8. Sálebaddi.	
	9. Chikhla II.	
Group II	10. Kurmura	C. P. P. S.
	11. Chikhla I	Do.
	12. Sitasáongi	Do.
	13. Ásalpáni I.	
	13a. Ásalpáni II (Kárli)	D. Laxminarayan
Group III	14. Pachára	Jessop & Co.

The deposits are arranged in this list in three groups according to their topographical position. Those of Group I lie to the north of the Bháwanthari river, and to the north-west of the Chandpur-Rámpaili quartzite range ; those of Group II lie to the south of the Bháwanthari and to the north-west of this same range ; while the single deposit in Group III lies to the south-east of the quartzite range.

Nature and quality of the ores.

The ores of this district, like those of the other districts of the Nágpur-Bálághát area, consist typically of the braunite-psilomelane mixtures, varying from ores in which the psilomelane is almost or quite pure to ores in which there is little else but braunite. The 'speckled' variety of ore is also not uncommonly found. For its composition see page 696. At one deposit—Kurmura— a different sort of ore is found. It consists of a mixture of psilomelane and pyrolusite from which there is very gradation to pure psilomelane on the one hand and pure pyrolusite on the other. The thirteen samples taken by me were analysed at the Imperial Institute, and are inserted in their respective places in the descriptions of the deposits following. They show the following limits and mean for the merchantable manganese-ores of the Bhandára district :—

	Limits.	Mean.
Manganese	49·00 to 54·07	51·94
Iron	4·26 to 10·25	7·27
Silica	2·08 to 6·50	4·59
Phosphorus	0·06 to 0·34	0·14
Moisture	0·09 to 1·15	0·44

These analyses indicate, moreover, that the average amount of braunite in the ores is 35% as against 50% in the Nágpur district, the balance in both cases being of course psilomelane.

Communications and transport.

Nearly all the manganese-ore deposits of this district are situated at considerable distances from the Bengal-Nágpur Railway. The nearest to the railway is Pachára, some 8 or 9 miles from Tumsar Road. Ásalpáni is 15 miles from Tumsar Road, and all the others are 18 miles or more distant. There is a road that was once a good one leading from Katangi at the western end of the Bálághát district right through the heart of the Bhandára manganese area to Tumsar Road. Consequently this has been made use of for the carting of the ore to the rail, much to the detriment of the road. The Central India Mining Company has constructed a 2-foot gauge tramway from Tumsar Road to Dongri, a distance of 20 miles. After this the track crosses the Bháwanthari river on a temporary causeway, and soon after branches. One branch goes *viâ* Sukli to Kosumbah (33 miles from Tumsar Road) and the other *viâ* Hatora to Miragpur (29 miles from Tumsar Road). This tramway was first worked by hand trollying, but it has been since converted for steam traction. The Bengal-Nágpur Railway Company has made a survey for a feeder line from Tumsar Road to Katangi, which would pass over very much the same ground as the Central India Mining Company's tramway. But work has not yet been begun on the Bengal-Nágpur Railway line. The tramway is used for the conveyance of the ore, not only of the Central India Mining Company, but also of other firms, on payment of some agreed-upon rate to the Central India Mining Company. Everyone has not, however, taken advantage of its presence and large quantities of ore are still sent by bullock-cart to Tumsar Road.

1. Kosumbah.

(CENTRAL INDIA MINING COMPANY.)

This deposit lies about a mile north-west of the village of the above name towards the north-western limits of the village area or mauza. It is held by the Central India Mining Company who are now actively working it, but at the time of my visit it was practically in its virgin condition. The ore-deposit appears at the surface as a line of 4 hillocks stretched over a distance of $\frac{7}{8}$ mile in a N. 25° E. direction. The most south-western hillock (No. 1) is situated a little to the north of the 'Goordao' Nálá and lies over $\frac{3}{8}$ mile south-south-west of hillock 2, which is joined to hillock 3. From hillock 3 to the most north-eastern hillock (No. 4) it is about 200 yards. Between hillocks 1 and 2, and 3 and 4, there is no ore exposed, so that it is possible that there are here three ore lenticles on one line of strike (hillocks 2 and 3 forming one lenticle). On hillocks 3 and 4 the outcrop of the ore-band was measured as 20—25 feet wide, and at the only place where a decided dip was seen (hillock 3) it was 60° to vertical to the west-north-west. The 'country' was nowhere exposed, unless a small outcrop of mica-quartz-schists on the low ground between hillocks 3 and 4 be considered to represent it; a few yards to the east of hillock 1 biotite-gneisses are seen dipping at 30° to W. 35° N. under the ore-band.

Hillock 1.

On hillock 1 the ore-band, which is not well exposed, consists principally of ore containing in places more or less of the bronze-coloured mica. The ore is a very fine- to medium-grained mixture of braunite and psilomelane; and one piece collected contained a band of the very magnetic manganese mineral (vredenburgite) found at Beldongri. A sample was taken both from the blocks on top and from the pieces down the slopes of the hillock, where a few shallow pits had been dug in the talus. The analysis made at the Imperial Institute showed:—

Sample No. 44.

Manganese peroxide	42·03
Manganese protoxide	30·05
Ferric oxide	14·21
Silica (combined)	2·49
Silica (free)	2·73
Phosphoric acid	0·33
Moisture at 100° C.	0·09

This is equivalent to:—

Manganese	49·90
Iron	9·95
Silica	5·22
Phosphorus	0·14
Moisture	0·09

indicating the presence of about 25 % of braunite.

Hillock 2.

On top of hillock 2 are some fairly large blocks of ore cropping out. Some of the ore is apparently of good quality, but a much larger proportion of it is slightly spoilt by garnet, felspar, or bronze-coloured mica. There is also a fair quantity of spessartite. Besides this there are a number of outcropping blocks of coarsely crystallized white microcline-rock streaked and patched with brown and black owing to the deposition, along cleavage and other cracks, of manganese oxide, and to

Pyroxene-microcline-rock.

the partial replacement of the rock by manganese-ore. This rock also contains a brown pyroxene. In another much finer grained variety of the rock there is a great abundance of this pyroxene, which under the microscope is pleochroic in brownish orange and yellow. The rock also contains a little bronze-coloured mica having an optic axial angle of about 32°.

Hillocks 3 and 4.

The top of hillock 3 is E. 25° N. from that of 2. The outcrop of the ore-band here is prominent, almost forming a wall. The ore itself is a speckled and rather softer variety composed of a small proportion of braunite in a cavernous matrix composed partly of soft black oxides, partly of shiny lead-like psilomelane, and partly of the ordinary dull grey psilomelane; but there is also some of the harder ore. This ore is mostly free from extraneous materials, but in places contains a little spessartite and bronze-coloured mica. The ore on hillock 4 is very similar to that on 3, but a larger proportion of it contains the bronze-coloured mica.

Nature and quality of the ores.

A sample was taken from the outcrop on hillocks 2, 3 and 4, and consisted largely of the above-mentioned speckled variety, with a certain amount of psilomelane and of the hard grey braunite-psilomelane mixture. The analysis made at the Imperial Institute shows:—

Sample No. 45.

Manganese peroxide	53·06
Manganese protoxide	22·91
Ferric oxide ..	14·64
Silica (combined)	2·02
Silica (free) ..	0·67
Phosphoric oxide	0·31
Moisture at 100° C.	0·70

This is equivalent to:—

Manganese	51·33
Iron	10·25
Silica	2·69
Phosphorus	0·135
Moisture	0·70

and indicates the presence of about 20 % of braunite.

The characteristic of these Kosumbah ores is seen to be a low % of braunite and consequent low % of silica, a high % of iron and rather high % of phosphorus.

Mr. H. D. Coggan gives me the following figures as showing the average analysis of the ore raised from this deposit during 1905 and 1906 :—

	1905.	1906.
Manganese	53·76	52·06
Silica	1·81	5·42
Phosphorus	0·082	0·154

Output.

During 1905, 1906, and 1907 this deposit has been worked with the following output :—

Year.	Long tons.
1905	8,105
1906	17,682
1907	29,396½

The ore won here is, after carting to Sukli, sent by means of the Central India Mining Company's steam-tramway to Tumsar Road Station, Bengal-Nágpur Railway, a distance of about 33 miles.

2. Sítapathúr.

(CENTRAL PROVINCES PROSPECTING SYNDICATE.)

This deposit was first found by Mr. P. N. Datta in 1893-94. The ore-band is traceable at intervals for 1⅝ miles in the villages of Sukli and Sítapathúr. A length of ⅝ mile of this lies in Sukli village where it strikes N. 10° W., but a little before reaching the Sukli-Sítapathúr boundary the band curls round to N. 20° E. and continues with this strike for a mile in Sítapathúr limits. The Sukli portion is described separately (page 742). The Sítapathúr portion of the band is held by the Central Provinces Prospecting Syndicate. At its southern end it runs for about ½ mile along the ridge of a hill,[1] perhaps 150 feet high, the most southern part of the hill lying in Sukli limits ; and then, after becoming lost on low ground, it reappears to the north and soon rises to form a long low ridge (No. 2) along which it continues for about ¼ to ⅜ mile. It is again found on low ground a little to the north of this, and finally only scattered

[1] Designated below as Sítapathúr Hill and situated about 1⅜ miles south-south-east of the village.

fragments are visible; but if traced further north the band might be found to reappear at the surface.

The dip of the band is always to the west side, being only 25° in Sukli limits, but about 50° to 60° in Sítapathúr. The width of the ore-band was measured at two points as 12 feet and 15 to 20 feet, respectively. The 'country' is nowhere exposed immediately in contact with the ore, but in two places fragments of mica-quartz-schist were seen, while on the low ridge (No. 2) a granulitic hornblende-gneiss (probably uralitized quartz-pyroxene-gneiss) crops out in large blocks to the west of the ore-band, from which it is separated by some coarse felspathic quartzite.

Character of the ore-band.

The ore-band consists in many places of merchantable manganese-ore, especially on Sítapathúr Hill, where it forms in one place a wall-like outcrop; but in many places the ore is either associated with spessartite-bearing rocks or it gives way almost entirely to them. On the south slope of Sítapathúr Hill is a coarse pegmatite of quartz, pink felspar, and a brown pyroxene that reacts for manganese and sodium and under the microscope is pleochroic in shades of yellow brown. (See pages 135—6.)

Brown manganese-pyroxene.

Manganese-micas.

At one point on top of Sítapathúr Hill there were found, immediately to the west of the ore-band, and forming either a part of it or else its western wall, several loose blocks of a light crimson rock composed chiefly of two species of mica. One of these is a beautiful crimson-pink biaxial mica and the other a rich orange-brown uniaxial mica. (See pages 197—8.)

Spessartite in pegmatite.

This rock also contains scattered grains of a black manganese-ore (braunite?). On the ridge (No. 2) there is some pegmatite containing patches of yellow garnet, presumably spessartite, which it may have taken up from the ore-band at the time of injection. Pieces of white vein-quartz containing magnetite were also found in places.

Nature and quality of the ores.

Most of the ore consists of the hard grey braunite-psilomelane mixture, the braunite tending in places to be rather coarsely crystalline. One specimen, which is very magnetic, looks like a mixture of braunite and psilomelane, but will need chemical investigation on account of the fact that the supposed braunite is as magnetic as magnetite. A sample was broken off the outcrop along the ore-band on Sítapathúr Hill, obviously valueless pieces being as usual rejected. The analysis made at the Imperial Institute shows :—

Sample No. 47.

Manganese peroxide	44·23
Manganese protoxide	30·59
Ferric oxide	11·63
Silica (combined)	5·93
Silica (free)	0·26
Phosphoric oxide	0·22
Moisture at 100°C.	0·17

This is equivalent to :—

Manganese	51·70
Iron	8·14
Silica	6·19
Phosphorus	0·10
Moisture	0·17

and indicates that the average ore contains about 60% braunite, the remainder being psilomelane. It should be noted that several pieces of the ore in the sample contained a little quartz, spessartite, or mica, and that, as is usually done in working a deposit, these were as much as possible cleaned out before crushing the sample.

The working of the deposit.

At the time of my visit the deposit had not been worked; and, even as the crow flies, it is distant 24 miles from Tumsar Road Station, Bengal-Nágpur Railway, the nearest point on the railway. There is no doubt, however, that the deposit contains a considerable quantity of ore of the above quality. During 1906 and 1907, however, the deposit has been opened up, with the following resultant output :—

Output.

Year.	Long tons.
1906	1,791
1907	392

I am not aware if the Central Provinces Prospecting Syndicate has made any use of the Central India Mining Company's steam-tramway for carrying the ore to the railway. This tramway passes the south end of the deposit, and over it, it would be about 29 miles to Tumsar Road.

A subsidiary ore-band.

In the very north-east corner of the village-area just before the road leading from Sítapathúr to Thirori reaches the 'Annapangree Nullah' of the Main Circuit map No. 9, Bhándára district, there is an obscure outcrop of manganiferous rock running across the road in a north-east direction. It extends 140 yards (and possibly more, but I did not follow it up) to the south-west side and 30 to the north-east side of the road. The rock is mostly fine- to medium-grained purplish spessartite-quartz-rock (gondite) partly altered to manganese-ore. Associated with the rock are muscovite-schists and some pegmatite, while both in the 'Annapangree Nullah' and a little tributary joining it at this point the rocks seen are banded biotite-gneisses often penetrated by veins of muscovite-pegmatite. These rocks seem to dip to the south-east. The strike of this band suggests that it may be a reappearance at the surface of the Kosumbah band situated some 4 miles to the S. 30° W. To judge from the outcrop this occurrence is of no economic value.

3. Sukli.

(CENTRAL INDIA MINING COMPANY.)

The deposit of this name is held by the Central India Mining Company and is probably the reappearance at the surface of the Sítapathúr band.[1] The deposit forms a low hillock about 200 yards long; the band continues to crop out on the low ground to the south for another 250 yards, the strike being N. 10° W. with a shallow dip (up to 25°) to the west side. The only place where the 'country' was seen was in a stream-bed at the south end of the deposit, where a granular quartz-pyroxene-gneiss with hornblendic bands was probably resting on spessartite-quartz-rock (gondite). Biotite-gneisses, biotite-schists, and pegmatite, crop out on the low ground separating the Sukli hillock from Sítapathúr Hill.

Character of the ore-band.

The ore-band is very variable in character. At the very south end it is practically fresh spessartite-quartz-rock (gondite), the spessartite being dark reddish and yellowish. Further north the outcrop becomes all manganese-ore with gondite in places, except at the south side of the ore-hillock, where there is an interesting somewhat granular rock composed of spessartite, quartz, microcline, and orthoclase (?), the spessartite, which constitutes $\frac{1}{3}$ to $\frac{1}{2}$ the rock, being often enclosed in plates of felspar.

Nature and quality of the ores.

The ores consist partly of the dirty speckled variety like that of Kosumbah and partly of the hard grey braunite-psilomelane mixture; a considerable proportion of the ore contains a little garnet or bronze-mica. A sample, No. 46,

[1] This Company's concession also includes the southern end of Sítapathúr Hill, which is in Sukli limits.

was broken from the outcrop on the hillock, obviously poor ore being rejected; it consisted largely of the braunite-psilomelane mixture. The Imperial Institute analysis shows:—

Sample No. 46.

Manganese peroxide	60·72
Manganese protoxide	20·18
Ferric oxide	6·15
Silica (combined)	2·05
Silica (free)	0·25
Phosphoric oxide	0·29
Moisture at 100°C.	1·00

This is equivalent to:—

Manganese	54·07
Iron	4·30
Silica	2·30
Phosphorus	0·13
Moisture	1·00

and indicates the presence of some 20 % of braunite, the remainder being psilomelane.

Mr. H. D. Coggan has supplied me with the following figures as giving the average analysis of the ore raised during 1905 and 1906:—

	1905.	1906.
Manganese	52·92	54·61
Silica	4·75	4·40
Phosphorus	0·077	0·072

The working of the deposit.

Output.

This concession, which also includes the very south end of the Sítapathúr deposit, has been worked since 1905. It is connected by the steam-tramway to Tumsar Road Station, 29 miles distant. The yearly output is shown below:—

Year.	Long tons.
1905	3,519
1906	16,529
1907	30,615

4. Hatora.

(CENTRAL INDIA MINING COMPANY.)

This deposit is held by the Central India Mining Company. It crops out as a band striking about W. 10° S. for over ½ mile, the east end of the band being situated about ½ mile north-west of Hatora village. The dip varies between 15° and 40° to the south side. The immediate 'country' on the south side of the band is seen towards the west end only, where in one place it is a quartzite containing abundant grains of iron-ore up to ¼ inch diameter. This iron-ore is rather magnetic, but gives a red streak and is hence probably to be regarded as martite. It is often iridescent in purple and green. Still further west the rock apparently gives place to quartzite free from magnetite and then to a mica-quartz-schist containing magnetite. The immediate 'country' on the north side was nowhere seen, but towards the west end muscovite-gneisses and mica-quartz-schists crop out on both sides of the ore-band. In the nálá cutting across the western end of the ore-band and forming also the boundary to the Hatora village area, the ore-band has disappeared and the rocks exposed are biotite-gneiss, felspar-gneiss, and gneissose mica-schist.

Character of the ore-band.

The ore-band crops out on low ground giving rise to very low ridges and hillocks. Its thickness was nowhere seen, but was apparently not very great. The outcrop consisted mostly of various varieties of spessartite- and spessartite-quartz-rocks (gondite), good ore being apparently very scarce. The spessartite is often quite large, being then of orange colour. In one specimen it is associated with glassy quartz, a brownish fibrous mineral, and a little interstitial microcline. The spessartite is here transparent, of a rich orange colour, and almost always shows hexoctahedral faces modifying the deeply grooved trapezohedra. Another specimen shows rich orange-red spessartite, the colour of potassium bichromate, on hard grey manganese-ore. A third specimen is of a bright yellow rock, almost the colour of sulphur, composed of a very fine-grained aggregate of spessartite, with small prisms of a white asbestiform mineral on the divisional planes. An abundant variety of gondite shows under the microscope the typical arrangement of very abundant small idiomorphic spessartites in a subsidiary quartz mosaic. It is often dark purplish grey in hand-specimens and this is seen under the microscope to be due to red hematite dust clouding the spessartites. At one point near the middle of the ore-band is some intrusive felspar-rock containing abundant orange garnet. In some places the ore-band consists of interbanded light grey quartzite and gondite.

Owing to the fact that so little ore was visible I came to the conclusion that this deposit was of no economic value. Since my visit, however, the deposit has been opened up, and Mr. H. D. Coggan informs me that the operations have disclosed a body of ore which, though of no great extent, is larger than the surface indications led one to expect. He says, that the quality is uniform, the average analyses of the ore raised during 1905 and 1906 being :—

The working of the deposit.

	1905.	1906.
Manganese	53·07	52·33
Silica	6·15	8·05
Phosphorus	0·071	0·072

This indicates that it is unwise to condemn any of the Central Provinces ore-bands merely from surface indications. From the way in which, at various points towards the west end of the outcrop, the 'country' on the south side of the ore-band curls over on to the strike of the ore-band, it seems probable that the outcrop consists of the very upper edge of a lenticular band.

The output from this deposit during 1905, 1906, and 1907, is shown below :—

Output.

Year.	Long tons.
1905	113
1906	2,509
1907	2,121½

The deposit is only a few hundred yards south of the Central India Mining Company's steam-tramway at a point some 2½ miles west of Miragpur.

5. Miragpur.

(CENTRAL INDIA MINING COMPANY.)

Originally discovered by Mr. P. N. Datta in 1893-94, this deposit is now held by the Central India Mining Company. Except where the wording shows otherwise, the following account refers to the deposit as I saw it in March 1904, when but very little work had been done. I have added in the form of footnotes any comments that have been rendered necessary by my cursory visit in December 1907. The manganese-ores occur on hillocky ground, where there are five separate

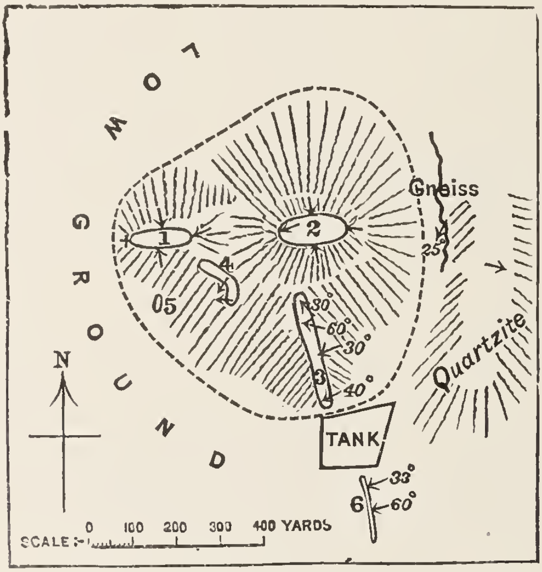

FIG. 45.—Sketch-plan of the Miragpur manganese-ore occurrences. Dotted line is boundary of talus-ore deposits.

exposures, while a sixth lies to the south side of the tank (see Fig. 45). The village lies to the west of this hillocky ground. Exposures Nos. 1 and 2 are almost certainly isolated and apparently consist of two cappings of manganese-rocks, which were once joined together, but are now separated by a small valley eroded between them. If joined together these two patches would form a synclinal strip running about E. 5° N., the folding being very slight and the synclinal axis having a very shallow dip to the west. Exposure No. 2 is almost a perfect shallow synclinal basin, the dip at the west end being, however, in the wrong direction, namely westward instead of eastward. All round the edge of this, which is the highest hillock (perhaps 50 to 80 feet high), the nearly horizontal layers of manganese-rock crop out. Exposures 3 and 6 may really be continuous. The relations of 4 and 5 to the rest are obscured by ore débris. The actual 'country' of the deposit is nowhere exposed; the nearest rocks seen are vein-quartz-like quartzite, found as fragments round the base of this hillocky area and probably *in situ* to the east on the low hills there; and muscovite-gneiss exposed to the east of No. 2. A talus of ore-fragments covers the surface of the ground practically everywhere inside the dotted line of figure 45, except where the ore outcrops are situated.[1]

Characters of the exposures.

The capping on hillock No. 1 is 26 paces across from north to south and 150 from west to east and consists of nearly horizontal layers of ore, quartzite, and spessartite-bearing rock. The dip at the west end is practically horizontal and round the other edges is small and directed towards the interior of the patch. Exposure No. 2, also forming a capping to a hillock, is about 160 paces long and 50 broad; the dip at the west end is very small to the W. 5° S., the dips elsewhere being slight and directed to the interior of the patch. Along the north edge of the patch the ore crops out in massive beds forming a vertical scarp with a thickness of at least 12 feet of ore, the débris on the slopes preventing the full thickness from being seen.[2] The manganese-ore of this patch is very much veined with quartz and patched with yellow garnet, and as seen before work was commenced the quantity of good quality ore seemed very small. When the deposit was opened up, however, it was found that the layers below the capping contained plenty of good ore.

The ore itself is sometimes the hard grey variety and at others is soft and brownish. Exposure 6 on the south side of the tank is 150 paces long with an average strike of N. 10° W., and a width of 22 feet in one place where the dip is 60° to the west side, a dip of 33° being seen in another place. This outcrop consists almost entirely of hard grey ore; but this ore is often to a certain extent impaired by ferruginous and siliceous matter lining cavities. Exposure 3 starts on low ground on the north side of the tank and gradually rises up a low ridge, forming a band over 200 yards long with an average strike of about N. 20° W. and a variable dip, usually 30° to 60°, to the west side; but where the top of the rise is reached both dip and strike are very variable, the ore-band in one place having a local strike of E. 22° N., vertical.[3] A little excavation had been carried out along

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[1] By my second visit—December 1907—sufficient work had been done to show that the 'country' is almost everywhere typical mica-schist, but sometimes so coarsely crystalline as to suggest a muscovite-quartz-pegmatite.

[2] In 1907, the thickness was seen to be at least 15 feet.

[3] The reason for this variable dip was clearly seen in 1907, in the workings. The ore-band is cut off on the south-south-west side by a north-west fault, approximating in direction to a strike fault. The rocks on the south-west side of the fault are mica-schists. At its north-north-west end, the ore-band is violently folded about axes roughly parallel to the direction of dip, and at right angles to the fault.

this ridge and in one place a thickness of at least 8 feet of bedded ore was thus exposed, the ore layers being 1 to 3 inches thick. The ore along this outcrop consisted at several places of the good hard grey variety, but at others was of inferior quality and sometimes interbanded with quartzite. Exposure 4 shows a sharp curve in strike accompanied by a dip in one place at 45° to W. 35° N. and in another at 30° to S. 18° W. It consists of hard grey ore spoilt by various impurities, with also some softer ore. Exposure 5 consists of very garnetiferous rock, runs for 30 paces N. 20° E. and lies on low ground.

Now that I have seen the deposit after extensive work has been done on it, it is evident that each of the separate exposures described above really corresponded to separate masses of ore—except possibly Nos. 3 and 6, which, being on the same line of strike, may be connected underneath the dry tank between them. It seems to me that the probable explanation of the relations of these separate masses of ore is that they were originally all part of one horizontal layer of ore. As the results of violent earth movements the portions Nos. 3, 4, 5, and 6 have been cut off from Nos. 1 and 2, leaving these two portions in a but slightly disturbed condition, their separation one from another being due, not to the earth movements, but to the effects of denudation. The portions cut off from Nos. 1 and 2 were treated variously. No. 3 has been crumpled and faulted, No. 4 has been pinched into a faulted steep synclinal fold surrounded by mica-schists, and No. 6 been made to dip very steeply. In addition to the portions noticed above the work has revealed the presence of some further, not very much disturbed, portions of the ore-bed. These lie between Nos. 3, 4, and 5, and probably actually once connected them together, but have since broken up at the surface into loose fragments of talus-ore more or less *in situ*. Ore *in situ* also seems to run to the south-west of No. 4 on to the low ground, beyond even the limits of detritus shown in figure 45. This was, of course, covered up by detritus, and only became visible when the ground was opened up.

Nature and quality of the ores.

The hard grey ore mentioned above consists of the usual fine-grained mixture of braunite and psilomelane. Some 70 tons of ore had been quarried at the time of my first visit—mostly from outcrop No. 3, but also from other parts—and stacked on the low ground to the west of the ore hillocks. From this ore I took sample No. 54. These stacks consisted largely of the braunite-psilomelane mixture usually more or less cavernous; but a few pieces were psilomelane, sometimes mammillated. The analysis carried out at the Imperial Institute shows :—

Sample No. 54.

Manganese peroxide	50·34
Manganese protoxide	23·17
Ferric oxide	12·49
Silica (combined)	5·07
Silica (free)	0·82
Phosphoric oxide	0·20
Moisture at 100° C.	0·34

This is equivalent to :—

Manganese	49·81
Iron	8·74
Silica	5·89
Phosphorus	0·09
Moisture	0·34

and indicates that the ore contains, on the average, about equal parts of braunite and psilomelane.

Mr. H. D. Coggan has kindly supplied me with the following analyses representing the average quality of the ores extracted during 1906 and 1907 :—

	1906.	1907.
Manganese	51·99	53·24
Silica	5·66	6·03
Phosphorus	0·076	0·078

The working of the deposit.

During 1905, and since, this deposit has been actively worked. From my 1907 visit I see that all the *in situ* portions of the deposit are a source of good ore. But in addition to these all the ground marked in figure 45 as talus-ore is being made to yield large quantities of ore, owing to the fact that the fragments have been formed by the breaking up of the ore-bed in the positions where they now lie, so that the detrital deposits are very rich. The ore is sent to Tumsar Road Railway Station, Bengal-Nágpur Railway, over the Central India Mining Company's steam tramway, a distance of about 29 miles.

Output.

The output of ore from this deposit during 1905, 1906, and 1907 has been as follows :—

Year.	Long tons.
1905	6,554
1906	14,386
1907	34,300

6. Mohugáon Ghát.

Crossing a road in this village is a small outcrop, striking N. 15° E., of very dark spessartite-quartz-rock partly altered to manganese-ore. To the north it is lost amongst houses and to the south disappears almost at once. The outcrop can be only a few yards long, and is 4 feet wide.

7. Pándarwáni.

(MR. R. H. RICHARDSON.)

I saw here no manganese-ore *in situ*, but only a few scattered fragments of hard grey ore and gondite lying on the surface at a point about 350 yards E. 20° S. of the large tank situated on the south-east side of the village. One or two tiny pits that had been dug showed only a little talus-ore. Some deeper excavation work might by chance expose the ore-body from which these fragments were derived; but there was nothing to indicate exactly where to dig. The rock cropping out here is very contorted mica-schist with quartz lenticles, and strikes E. 38° N.

In December 1907 I found that extensive excavations had been made by Mr. R. H. Richardson in the portions of the detritus from the Miragpur deposit lying in Pándarwáni limits. One section showed :—

4″	Clay.
11″	Pisolitic manganese-ore detritus.
9″ to 1′	Pebble ore.
10″	Pisolitic manganese-ore detritus.
2″	Pebble ore.

Resting on altered and manganese-impregnated mica-schist.

These detrital deposits were yielding a considerable amount of ore.

8. Sálebaddi.

At a point about ¾ mile E. 12° S. from the village, a few shallow pits had been dug showing a little detrital manganese-ore mixed with fragments of white quartz. The ore was the hard grey braunite-psilomelane mixture with quartzite bands, while there were also some pieces of the softer speckled ore and of gondite. There were no indications as to the source of this ore, and the occurrence was not of any apparent economic value.

9. Chikhla II.

Just outside the village on its south-west side a couple of small pits showed a little detrital ore, which was also sparsely scattered on the surface. The ore was mostly the hard grey braunite-psilomelane mixture, but a little of it contained quartzite bands. There was also a little of the speckled ore. A small sample of the hard grey ore was analysed at the Imperial Institute with the following result:—

Sample No. 55.

Manganese peroxide	48·77
Manganese protoxide	29·54
Ferric oxide	7·32
Silica (combined)	5·65
Silica (free)	0·82
Phosphoric oxide	0·13
Moisture at 100° C.	0·64

This is equivalent to:—

Manganese	53·76
Iron	5·12
Silica	6·47
Phosphorus	0·06
Moisture	0·64

and indicates that this ore contains 56% braunite. This ore is of sufficiently good quality to justify a moderate expenditure on a search for its place of origin.

10. Kurmura (Ponwár Dongri).

(CENTRAL PROVINCES PROSPECTING SYNDICATE.)

This deposit was first discovered by Mr. P. N. Datta in the field season of 1893-94, and is now held on mining lease by the Central Provinces Prospecting Syndicate. The ore-band crops out along the crest or ridge of a range of hills of which it forms the backbone. One and a quarter miles is the total length of outcrop of this band, which has a south-west to west-south-west strike at its west end, and curls round so as to strike about due east at the east end. At the west end the ore-band is first seen in a low hillock, only vein-quartz and muscovite-pegmatite being seen to the west of this. This part of the deposit is situated within the mauza of Kurmura, which lies just to the south of this end of the band. The band then rises up the main ridge, which has two peaks, the higher, eastern, one rising to about 290 feet above Kurmura pond; at the east end it again descends and then crops out on a series of low hillocks. It is no longer visible when the stream-bed dividing Dongri Buzurg from Lobi is reached.[1] This ore-ridge forms the boundary between

[1] I found a few fragments of spessartite-quartz-rock on the low flat range of hills in the southern part of Lobi situated about east by a little north from this point. It possibly indicates a continuation of this band.

the village areas of Dongri Buzurg or Poṅwár Dongri on the north and the part of Kurmura known as Bálápur Hamesha on the south. The ore-deposit is usually spoken of as Kurmura or Poṅwár Dongri.

No proper development work on the ore-band had been done at the time of my visit; the maximum horizontal outcrop width seen was 40 feet. The average dip of the ore-band is about 50° to the south side.

The 'country' on the north side is mica-schist with numerous veins of white quartz, sometimes as much as 2 feet wide, and arranged parallel to the strike. That on the south side was not seen, but near the base of the range on the south side medium-grained biotitic gneisses crop out. In the nálá at the east end of the band the rock exposed is mica-schist with an intruded epidote-granite.

Character of the ore-band.

At the west end of the band, and for a long way up the ridge to the first or western peak, the ore-band consists of fine-grained spessartite-quartz-rock (gondite), largely altered to psilomelane, and interbanded with pinkish, whitish, and dark grey, quartzites. On top of the west peak there is an outcrop of what looks like good-quality ore; but on being broken it is found to pass into unaltered rhodonite inside. On the descent to the neck between this and the east peak similar rocks are seen, with a little merchantable ore in places. On the neck between the two peaks some good hard ore is exposed, and then on the ascent up to the eastern peak a large quantity of the hard fine-grained braunite-psilomelane mixture is seen, the braunite being subordinate in quantity. The top of the east peak, like most of the range, is heavily jungle-clad, almost the whole jungle there consisting of bamboos; the soil is soft black with rugged blocks of psilomelane projecting up. A few yards east of the top there is a huge upstanding mass of ore 16½ feet high, 15 long, and 8 broad. It is very rugged, without any signs of strike or dip, and composed partly of very fine-grained soft blackish pyrolusite and partly of psilomelane. A little further east an outcrop of this mixture of pyrolusite and psilomelane is 40 feet wide with a sheer drop of 30 feet or more on the south side. This mass is veined with thin lenticular quartz stringers striking S. 28° E. Similar ore (showing bedding in places) or psilomelane alone, crops out down the east slope from this peak and near the bottom of the descent passes into the braunite-psilomelane mixture again and then continues to the east on a line of hillocks, first as psilomelane, and then as various varieties of gondite interbanded with quartzites. In some places the psilomelane seen on the eastern descent from the east peak contains thin layers of radiate-fibrous limonite. In one place this limonite had a surface of a metallic beetle-green colour.

Nature and quality of the ores.

As will be seen from the preceding paragraph, the ores consist partly of a mixture of braunite and psilomelane, the latter mineral predominating, and partly of a mixture of pyrolusite and psilomelane, or of either of these latter minerals alone. The pyrolusite-psilomelane ore is probably more abundant than the braunite-psilomelane ore.

Sample No. 38 was taken from the outcrop of the hard grey braunite-psilomelane ore on the west ascent up to the east peak and was analysed at the Imperial Institute with the following result :—

Sample No. 38.

Manganese peroxide	55·63
Manganese protoxide	19·73
Ferric oxide	8·00
Silica (combined)	3·21
Silica (free)	2·97
Phosphoric oxide	0·36
Moisture at 100° C.	0·23

This is equivalent to :—

Manganese	49·00
Iron	5·60
Silica	6·18
Phosphorus	0·16
Moisture	0·23

and indicates that this type of ore consists of about 1 part of braunite to 2 parts of psilomelane.

Sample No. 39 was broken from the outcrop of pyrolusite and psilomelane, the latter predominating, on top of the east peak, and for some distance down the east descent. The analysis made at the Imperial Institute shows :—

Sample No. 39.

Manganese peroxide	60·74
Manganese protoxide	18·55
Ferric oxide	8·58
Silica (combined)	0·60
Silica (free)	1·48
Phosphoric oxide	0·78
Moisture at 100° C.	0·41

This is equivalent to :—

Manganese	52·81
Iron	6·01
Silica	2·08
Phosphorus	0·34
Moisture	0·41

and indicates the practically complete absence of braunite.

A third sample (No. 40) was taken from about 800 tons of stacked ore quarried from the talus-ore deposits on the northern slopes of the east peak. It consisted of the hard braunite-psilomelane ore with a number of small cavities lined with black powder. The analysis made at the Imperial Institute showed :—

Sample No. 40.

Manganese peroxide	61·44
Manganese protoxide	16·30
Ferric oxide	9·73
Silica (combined)	2·55
Silica (free)	1·45
Phosphoric oxide	0·37
Moisture at 100° C.	0·40

This is equivalent to :—

Manganese	51·52
Iron	6·81
Silica	4·00
Phosphorus	0·16
Moisture	0·40

and indicates that this type of ore contains about 25% of braunite, the remainder being psilomelane with probably a little pyrolusite (the soft lining to cavities).

The three above samples indicate the following mean composition for the Kurmura ores :—

Manganese	51·11
Iron	5·58
Silica	4·09
Phosphorus	0·22
Moisture	0·34

I am indebted to Mr. W. H. Clark for the following analyses by Mr. R. D. Connell of ores from the Bálápur Hamesha end of the deposit :—

	Talus-ore.	Ore-body.
Tonnage.	438	555
Manganese	47·87	46·60
Iron	8·16	10·40
Silica	5·80	5·80
Phosphorus	0·179	0·130

The talus-ore working.

On the northern slopes of the east peak (W. 30° N. from it and towards its base) a considerable amount of excavation had been done, showing 1 to 1½ feet of talus-ore resting on mica-schists with vein-quartz, and the ore extracted had been stacked.

Manganese-ore pisolites.

Thickly scattered on the low bare sandy ground to the south of the ore-range are a large number of round bodies of the size of peas. Many of these were found on fracturing to have a concentric structure and to be rather soft and blackish brown inside. These are doubtless of concretionary origin. But a certain number are probably of detrital origin, for when broken they are found to consist of the hard grey ore without any concentric structure.

The working of the deposit.

It will be seen from the average analysis of the Kurmura ores (page 754) that they are not very high in manganese, but unusually high in phosphorus. Consequently this deposit can probably be worked only when prices are high, for purposes where a somewhat phosphoric ore is not objectionable. The distance to Tumsar Road Railway Station, Bengal-Nágpur Railway, is about 16 miles.

The *output* from this deposit is as follows :—

Year.	Long tons.
1902	248
1905	1,456
1906	4,842
1907	891[1]

11. Chikhla I.

(CENTRAL PROVINCES PROSPECTING SYNDICATE.)

This deposit was discovered by Mr. P. N. Datta in the field season of 1893-94, and is now held on mining lease by the Central Provinces Prospecting Syndicate.[2] The ore-band is traceable for 2½ to 2¾ miles, starting at the west end on Bhámásúr Hill (rising to about 540 feet above the plains), and apparently dying out on Sindia Hill at the east end; these two are connected by a series of seven hillocks lying

[1] Including 499 tons extracted by D. Laxminarayan.

[2] This lease also includes a small portion of the Yedarbúchi village area, probably for the sake of a little talus-ore, as there is apparently no ore *in situ* in this part of the area leased.

on the northern slopes of a range of low hills composed of quartzites and gneisses, and a hill (near the east end) some 500 feet high. The strike is usually about E. 5°—10° S. except at the two ends, where it is rather variable. The dip is as a rule very steep to the south side or even vertical. At its widest point (on Bhámásúr Hill) the ore-band is 80 feet across (measured horizontally). At two places it is separated into two bands, in one place (down the eastern descent from Bhámásúr Hill) by mica-schists, and in the other (towards the eastern end of the band) by micaceous quartzites. At the west end the 'country' is mica-schist on both sides, with micaceous quartzites to the north and a manganiferous gneiss to the south of these schists. In the middle parts of the band the 'country' on the north side is micaceous quartzite and on the south side is either micaceous quartzite or mica-schist, while at the east end, on Sindia Hill, the only rocks noticed were quartzite and vein-quartz; but the immediate 'country' of the ore-band was not visible.

This variation in the character of the 'country' means either that there are lithological variations in the same horizon, mica-schist passing into micaceous quartzite and this into non-micaceous quartzite, on passing from west to east, or that the manganese-silicate band has intrusive relations with regard to the schists and quartzites. I regard the former as the true explanation. The gneiss that occurs a little to the south of the ore-band at the west end seems to have died out at the east end, while the band of quartzite and vein-quartz to the south of the gneiss seems to continue for the whole length of the ore-band.

Character of the ore-band.

The ore-band is nearly always composed of gondite or spessartite-quartz-rock (grey, buff, yellow, and purplish in colour) and manganese-ore, inter-lenticled and inter-banded with quartzite, which itself sometimes contains scattered spessartite crystals or manganese-oxide minerals. It is only on top of Bhámásúr Hill that there is any large quantity of ore. On top of this hill the ore-band forms a sort of broad causeway up to 80 feet wide. The ore is of the hard grey braunite-psilomelane mixture, much banded and streaked with yellow spessartite and spessartite-quartz-rock, with light and dark grey fine-grained quartzite, and with veins and strings of quartz. In one place there is a series of lenticular quartz veins, $\frac{1}{4}$ to 1 inch thick, striking E. 40°S. The ore-band on top strikes E. 15° S. to E. 20° S. and huge masses of ore have fallen down the slopes on both sides. The southern edge of the causeway is like a vertical wall; this continues down the east slope, so that as seen from the east it looks as if a slightly elevated dyke-like wall 80 feet wide were running down this slope. It is doubtful if it could pay to work the ore *in situ* on top of this hill, entailing as it would the rejection of such a large proportion of the ore—except perhaps at times of inflated prices[1].

A sapphirine-bearing rock.

On the third hillock to the east of Bhámásúr Hill the south wall of the ore-band is formed by micaceous quartzite, and on the descent down the eastern side of this hillock these quartzites are seen to curl over on to the strike of the ore-band so as partly to cover it. This indicates that it is practically the upper edge of the ore-band that is exposed there. The interesting feature of this rock is that in places it loses its micaceous character and gives place to a heavy rock (one piece had a specific gravity of 3·03) showing bright blue streaks and bands, and abundant platy crystals of whitish, light greenish, and light greenish-blue, colour. The microscope indicates that the former mineral is sapphirine and the latter enstatite. The rock has all the structure of a metamorphic quartzite with, in addition to the above minerals, abundant tiny scattered crystals of rutile and abundance of ilmenite, occurring in both scattered grains and folia in the rock. There is a distinct arrangement of the minerals in layers, so that the rock may be called a schistose rutile-ilmenite-enstatite-sapphirine-quartzite, or perhaps an enstatite-sapphirine-quartz-gneiss. This is certainly a most unusual type of rock, no doubt to be regarded as the product of dynamo-metamorphism of some pre-existing rock. For the identification of the sapphirine the characters relied upon are the hardness (=about 8), biaxial character, high refractive index, and the following pleochroism scheme :—

$\mathfrak{a}$ = colourless to yellowish-green.
$\mathfrak{b}$ = pale to rich blue.
$\mathfrak{c}$ = do.

The only feature that is different to the characters of sapphirine as usually recorded is the fact that the birefringence is somewhat higher instead of lower than that of quartz. Consequently the identification can be regarded as provisional only, until such time as someone has time to separate this mineral from its intimate association with the other minerals of this rock, test its chemical characters, and take its specific gravity. Similarly the identification of one of the other minerals as enstatite is somewhat doubtful.

[1]During 1908 this ore *in situ* has been opened up; there seems to be a larger amount of good ore inside than was suggested by the outcrop.

The talus-ore deposits.

At the time of my first visit the only work that had been done at this locality was on the talus deposits on the northern slopes of Bhámásúr Hill, near and at its base. These showed a thickness of 3 to 6 feet of talus-ore resting on a débris of white quartzite fragments. On the level this talus consists mostly of a small gravel of manganese-ore with scattered larger pieces, which higher up increase in abundance and size, so that in some places some very large blocks are found in these deposits. There are also a few fragments of quartzite mixed with the ore detritus. The ore is of the hard grey braunite-psilomelane mixture, often spoilt by the presence of thin quartz films and remains of yellow spessartite. Some 5,500 tons of ore were stacked here. The ore in these stacks was as a rule extremely well cleaned and a sample taken from them was analysed at the Imperial Institute with the following result:—

Sample No. 41.

Manganese peroxide	56·41
Manganese protoxide	23·32
Ferric oxide	9·43
Silica (combined)	3·05
Silica (free)	0·55
Phosphoric oxide	0·38
Moisture at 100°C.	0·20

This is equivalent to:—

Manganese	53·78
Iron	6·60
Silica	3·60
Phosphorus	0·17
Moisture	0·20

and shows that the average ore consists of about 30% braunite and 70% psilomelane. The ore is evidently high in manganese, and low in silica, but somewhat too high in phosphorus.

Mr. W. H. Clark has kindly supplied me with the following analyses of Chikhla ores:—

Date	13th Nov. 03	13th Nov. 03	6th Apl. 05	6th Oct. 06	6th Oct. 06	6th Oct. 06	6th Oct. 06	6th Oct. 06	6th Oct. 06
Tonnage represented	A fair quantity	A fair quantity	1,085	428	3.000	2,000	300	440	210
Analyst	C. Fawcitt		S. A. Jones	R. D. Connell					
Manganese	51·04	51·04	50·01	50·32	48·84	50·56	52·28	51·63	50·52
Iron	10·02	9·69	7·26	7·32	8·70	6·96	6·78	7·56	7·2[illegible]
Silica	8·10	10·05	6·86	9·10	7·15	8·15	7·85	8·80	7·40
Phosphorus	0·193	0·205	0·101	0·119	0·095	0·083	0·076	0·086	0·068

These figures correspond to the following limits and mean :—

——	Limits.	Mean.
Manganese . . .	48·84 to 52·28	50·69
Iron	6·78 to 10·02	7·95
Silica	6·86 to 10·05	8·16
Phosphorus . . .	0·068 to 0·205	0·114

The working of the deposit.

At the time of my second visit to this deposit—in December 1907—I found that it had been worked to a large extent, but that this work had been confined to the talus deposits. The excavations in this talus showed that the talus-ore is as much as 10 feet thick in places; it is said to have been found to be 16 feet thick in exceptional cases. The underlying rock is seen in these workings to be mica-schists traversed by quartz veins. To aid in the systematic working of these talus deposits a gravity incline was under construction down the north-east corner of Bhámásúr Hill. The total fall on this incline is 320 feet, with a length of 1,100 feet to the rail-crossing at the base. The gradient of the top 600 feet is 1 in 3, after this gradually decreasing to horizontal at the unloading station, and then sloping slightly up. These figures are on the authority of Mr. J. J. Freund, Assistant Manager in charge of this deposit. The object of this ropeway is the easy removal of the ore being worked on the east-north-east face of Bhámásúr Hill. The ore here is being worked in a series of levels, said to be about 80 feet apart. When the ropeway is ready it will be used first to carry the ore of the lowest level; when all this has been shifted the effective length of the hauling rope will be lessened and the ore of the next higher level removed, and so on, right to the highest level. By working systematically up the hill-side in this way a fairly clean sweep of the talus deposits will be made. The only point where any appreciable waste comes in is in the treatment of the smalls. Many thousands of small pebbles of high-grade manganese-ore below about 1½ to 1 inch diameter are being thrown on the waste dumps. At the time of my visit the amount of ore stacked on the levels was said to be 40,000 tons; this was waiting, of course, for the completion of the incline. At the top of the incline an adit was being driven into the hill-side to intersect the ore-body *in situ*.

The ore from this locality was being carted to Tumsar Road Railway Station, a distance of 20 miles, in spite of the proximity of the Central India Mining Company's steam tramway.

The *output* from this deposit from 1901 to 1907 is as follows :—

Year.	Long tons.
1901	499
1902	5,112
1903	4,998
1904	8,559
1905	14,791
1906	27,678
1907	38,840

12. Sitasáongi.

(CENTRAL PROVINCES PROSPECTING SYNDICATE.)

The main ore-band was first found by Mr. P. N. Datta in 1893-94 ; this area is now held by the Central Provinces Prospecting Syndicate.

There are four parallel ore-bands in Sitasáongi, the southern and most important of which forms the ridge of Dholi Hill, while the other three occur on the northern slopes facing Bhámásúr Hill. Dholi Hill is situated due south of Bhámásúr Hill and not south-south-east of it as shown on the map. It is also not so high as Bhámásúr Hill, but is probably only 300 to 400 feet high.

In making a north to south transit across the rocks here, starting from the Chikhla ore-band and going southwards, the following succession of rocks was found, much of the ground being obscured either by the dense jungle, or by the rock débris on the hill slopes.

North.—The Chikhla ore-band (1).
Obscured.
Muscovite-gneiss with felspathic augen and lenticular bands of pink quartz-felspar-rock.
Vein-quartz.
Muscovite-gneiss.
Vein-quartz fragments.
Do. *in situ*.
Muscovite-gneiss.
Vein-quartz fragments and micaceous quartzite.
Obscured.
Mica-schists.
Sitasáongi ore-band (2).
Obscured.
Mica-schist.
Sitasáongi ore-band (3).

Obscured.
Sitasáongi ore-band (4).
Muscovite-gneiss.
Obscured.
Sitasáongi ore-band (5). *Summit of Dholi Hill.*
Obscured by talus of ore, and spessartite-quartz-rock (gondite), with some mica-schist and gneiss.
Contorted mica-schist.
Magnetite-muscovite-quartz-schist.
Obscured.
Vein-quartz.
Obscured.
Biotite-gneiss with felspar-quartz augen.
Base of Dholi Hill on south side.
Obscured.
White gneiss.
South.—Biotite-gneiss with a band of garnet-gneiss.

Ore-bands 2, 3, and 4.

Ore-bands Nos. 2, 3, and 4 were seen only in making this cross-section and were not followed along their strike, but they do not crop out at the surface at either the west or east end of the hill, where I crossed the main ore-band 5; they can hence be regarded as of much shorter length. The characters of these three ore-bands where crossed were as follows:—

Ore-band 2.—2-3 yards wide and composed of the usual mixture of manganese-ore, spessartite, and quartzite.

Ore-band 3.—3 yards wide and composed of buff-coloured fine-grained gondite altered in patches to ore.

Ore-band 4.—2 yards wide forming a wall-like outcrop striking E. 5°N. and composed of both hard grey ore and gondite.

Bands 2 and 3 are of no apparent economic value; band 4 contains a little ore that is possibly merchantable, but this is largely spoilt by quartz veins, etc. It is quite possible, however, that if these three bands were followed along their strike, they would be found to be sufficiently altered to ore in places to be workable.

The main ore-band.

The main ore-band (5) is traceable for about 1,200 yards and varies in width at the outcrop from 12 to 53 feet. It is nearly or quite vertical all the way, showing in places, however, a very steep southern dip. Its strike averages east to west; at the west end it strikes east, changes to E. 20° N. on approaching the summit and then curls round through east to E. 10°—15° S. at the east end. The extreme west end of the band is probably in Yedarbuchi village limits. The top of Dholi Hill consists of two peaks with a depression between. The ore-band as it runs up the western end of the ridge to the western peak forms a very bold dyke-like outcrop, in one place 34 feet high. This is often split open in an extraordinary fashion by the roots of a species of fig-tree (the *pákar*) which grows in abundance on it. It is here composed of interbanded grey quartzite, yellow gondite, and massive yellow spessartite-rock, there being very little manganese-ore. On the slope down from the western peak to the depression between this and the eastern peak there is a certain quantity of good hard grey ore, as also on the ascent up to the eastern peak. Similar ore crops out all down the eastern descent from the eastern peak and down this slope I took sample No. 43 by chipping pieces off the outcrop at regular intervals. The pieces included in the sample consisted of the braunite-psilomelane mixture with a little spessartite in one piece. The analysis carried out at the Imperial Institute showed :—

Nature and quality of the ores.

Sample No 43.

Manganese peroxide	44·51
Manganese protoxide	33·02
Ferric oxide	7·73
Silica (combined)	5·54
Silica (free)	0·96
Phosphoric oxide	0·16
Moisture at 100° C.	0·19

This is equivalent to :—

Manganese	53·76
Iron	5·41
Silica	6·50
Phosphorus	0·07
Moisture	0·19

and indicates that the average ore contains about 55% of braunite and 45% of psilomelane. Such ore is evidently well worth working, but it will require some actual quarrying to show whether the quantity available is sufficient.

On the southern slopes of Dholi Hill there is a fair quantity of talus-ore, but whether there be a sufficiently high per cent. of merchantable ore in this débris is doubtful. A few shallow excavations had been made on the nearly level ground at the south base of the hill. They showed a thickness of 1 to 2 feet of débris of ore and quartzite, most of the ore being valueless. A small proportion of good ore had been

Talus-ore.

collected and from this I took sample No. 42, which was analysed at the Imperial Institute with the following result:—

Sample No. 42.

Manganese peroxide	46·57
Manganese protoxide	30·13
Ferric oxide	6·09
Silica (combined)	5·20
Silica (free)	0·83
Phosphoric oxide	0·22
Moisture at 100° C.	0·24

This is equivalent to:—

Manganese	52·83
Iron	4·26
Silica	6·03
Phosphorus	0·10
Moisture	0·24

and shows that the ore consists of about equal proportions of braunite and psilomelane. The quality of this ore is evidently somewhat inferior to that of the ore *in situ*.

Mr. W. H. Clark has kindly supplied me with the following analysis by Mr. R. D. Connell of ore obtained from some trial pits here:—

Manganese	48·05
Iron	9·18
Silica	6·75
Phosphorus	0·091

Ottrelite.

To the east of where the ore-band has disappeared on low ground there are, near a pillar marking the boundary between the village-areas of Sitasáongi and Chikhla, some masses, 10 feet high, of a very coarse silvery mica-schist, with the dip about vertical, the strike being about east. This rock, which contains ottrelitt, garnet, tourmaline, rutile, and ilmenite (?), is noticed in more detail on page 313.

13. Asalpáni I.

This deposit was discovered in the field season of 1893-94 by Mr. P. N. Datta. The outcrop can be traced for about ¾ mile, of which the western portion striking east-north-east lies in the limits of the village of Gárkár Bhúngá, while the eastern portion striking about due east lies in Ásalpáni limits. It is possible that the band may reappear at the surface further to the west at any point between here and the Guguldoho deposit (see page 947). The outcrop lies mostly on low ground, but in one place towards the western end it rises to the top of a hillock, perhaps

50 feet high, this hillock being situated on the south slope of a small hill of micaceous quartzites. Fig. 46 gives a section across the deposit here. The 'country' on the footwall of the deposit is nowhere visible, but is probably mica-schist; for this rock was exposed in a trench made at the north-east corner of the Ásalpáni pond. The dip is everywhere towards the south side, at angles varying from 35° to 65°.

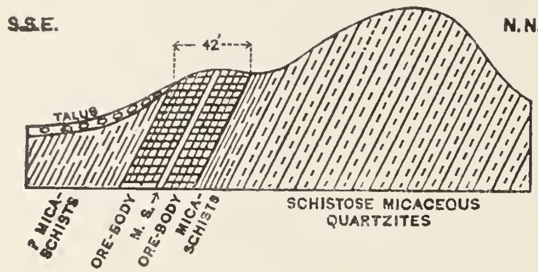

Fig. 46.—Section across the Gárkár-Bhúngá portion of the Ásalpáni manganese-ore deposit.

The ore-band consists of spessartite-quartz-rock of various colours, greyish, brownish, reddish, and purplish, sometimes quite fresh and sometimes partly altered, and often interbanded with quartz and quartzite and in some places with rhodonite-rock. The maximum width seen was 14 paces across the outcrop at the point where the section in Fig. 46 was drawn; the outcrop here is divided into two by an intercalated band of mica-schist.

The ore-band is nowhere sufficiently altered to manganese-ore to be workable. At one place, I found a little very magnetic manganese-ore composed of a mixture of psilomelane and braunite (?) with remains of rhodonite and garnet.

An analysis of some manganese-ore, probably from this deposit, carried out by Mr. E. Riley for Messrs. Ogilvy Gillanders & Co. of Calcutta showed:—

Manganese	.. 20·90
Iron	.. 4·26
Silica	.. 37·92
Phosphorus	.. 0·079
Moisture	.. 0·53

No work had been carried out except for one or two shallow pits, and, as far as one can judge from the outcrop, this deposit is of no present economic value; but judging from the case of the Hatora deposit there might be some marketable ore below the surface.

13a. Asalpáni II (Sáya Hurki).

(D. LAXMINARAYAN.)

This deposit was discovered in 1905 and is now being worked by D. Laxminarayan of Kámthi. It lies at the south-east corner of a hill known locally as 'Sáya Hurki'[1] (Syudka Hoorkee on the 1-inch map of this area). This hill is situated about 1¼ miles in a north-easterly direction from Ásalpáni village and lies in Government forest. It is about 1 mile north-west of Kárli village, on which account the deposit is often referred to as the Kárli deposit, although it lies within a part of the forest formerly belonging to Ásalpáni. The hill is composed of mica-schists, very schistose micaceous quartzites, sericitic quartz-schists, and schistose quartzites, the dip varying from south-south-east to east. The manganese-ore band crops out along the eastern slope or edge of the southward projecting spur of the hill-mass shown on the 1-inch map. The general direction is northerly at the southern end changing to north-north-west further north; the band can be traced for a total length of about 3 furlongs.

The excavations at the southern end of the outcrop gave a thickness of 8 to 12 feet to the ore-band, whilst in the most northerly excavation the band was only 2 feet thick. As no ore or manganiferous rock was to be seen cropping out immediately to the north of this point, but only crinkled mica-schists, it may be supposed that the band probably thins out to the north in a lenticular manner. As shown by the workings on the southern portions of the outcrop, the dip is fairly constant at about 45° to the east to east-south-east. There workings show, however, that the ore-band is not a flat sheet, but is crumpled about axes having the dip of the ore-band. The consequence is that the actual plan of the ore-band is a sinuous curve of which the average direction is the strike given above.

In the workings as seen in December 1906 many surfaces of the ore-band had been uncovered by the removal of the easily-quarried overlying mica-schists, and these were seen to be deeply grooved and fluted parallel to these dip-axes, *i.e.*, down the dip planes.

The overlying rock is a fairly coarse silvery mica-schist, crumpled and separated in one place from the ore-band by a 2-inch layer of very fine-grained mica-schist. The underlying rock is a white friable fine-grained schistose quartzite passing down into fine-grained mica-quartz-schist.

---

[1] This means teak-tree hill

The joint planes of these underlying rocks often show dendritic growths of manganese oxide.

The ore-band itself is of very variable composition. It consists of (1) hard grey crystalline ore, (2) soft and dirty ores, (3) yellow spessartite-rock changing to ore, (4) rhodonite-rock largely changed to manganese-ore, and (5) vitreous white and black quartzites. The proportion of good ore is very variable owing to the variable amount of change that the rhodonite- and spessartite-rocks have undergone; indeed it is often easy to trace the passage of layers of either spessartite- or rhodonite-rock into manganese-ore. In the most northern excavation the rock exposed was almost entirely rhodonite-rock partly changed to ore.

On the low ground to the south of the southern end of the ore-outcrop a considerable quantity of loose fragments of ore has been found in the clayey soil by means of shallow excavations. They are sufficiently large and angular to indicate the probable extension of the ore-body beneath. Talus-ore has also been found on the lower ground to the west of the southern part of the ore-outcrop.

Nature and quality of the ores.

The hard fine-grained grey crystalline ore is composed of the usual mixture of braunite and psilomelane. There is also a more friable variety of similar appearance, probably, as at Kándri, owing its more friable character to a smaller amount of the cementing psilomelane and a consequent larger proportion of braunite. Besides some softer and dirtier ores, there is also a little cavernous psilomelane showing mammillated surfaces in cavities. It seems to be confined to the surface outcrop, where it occurs as numerous veinlets in the rhodonite-rock, manganese-ore, etc.

The working of the deposit.

This was of a very crude nature in December 1906, and, as so often happens, the waste was being dumped very close to the workings on the dip side, so that it would all have to be shifted later on, in order to follow the ore-band down. Owing to the hard nature of parts of the ore-band—especially the rhodonite-rock and vitreous quartzites—blasting is resorted to, country powder being used. Sometimes also large masses of rock are split by burning a fire against them and then throwing water on the heated surface.

The ore extracted has to be carted 4 miles or more over rough cart tracks to the main road from Tumsar to Katangi, which is struck at Chicholi, 11 miles from Tumsar Road Station. The ore is at present (December 1906) carted to Tumsar Road, but may be later carried by the light railway of the Central India Mining Company, which passes Chicholi.

The *output* of ore from this deposit is as follows :—

Year.	Long tons.
1906	11,873
1907	2,844

14. Pachára.

(JESSOP & CO.)

This deposit, the only one in Group III (page 735), is held by Messrs. Jessop & Co. and lies in Government Forest about a mile west-north-west of Pachára village. The ore occurs as a practically horizontal ' bed ' of varying thickness intercalated between vitreous quartzites, which are possibly felspathic. Owing to the practically horizontal stratification of the rocks, the outcrop of this deposit, instead of being moderately straight, is very sinuous, following the contour of the quartzite hills on the southern and south-eastern slopes of which it occurs. I traced it in all for about half a mile along the flanks of these hills, but the length measured along the curves of the outcrop was about $1\frac{1}{2}$ miles. The outcrop may reappear again to the east-north-east. Had the ore-'bed' been continuous it might have been expected to crop out again on the northern flanks of this range of quartzite hills, but a search made there failed to reveal its presence, so that, as the bedding of the quartzites appears to remain approximately horizontal, it is evident that the ' bed ' of ore thins out to the north in the same way as it seems to do to the west, south, and east.

The ' bed ' of ore is mostly about $1\frac{1}{2}$ feet thick, but the thickness increases to 5 feet in some places and becomes as low as 4 inches in others. The 'bed' is not sharply separated from the overlying and underlying quartzites. The overlying quartzites are usually more or less broken where they rest on the ore and sometimes partially replaced by limonite near the contact ; and there are also thin manganiferous layers, probably secondary replacement products, here and there in these overlying quartzites. The underlying quartzite is sometimes separated from the ore by an argillaceous layer. The ore-band is composed largely of very dirty ore, some of which is a psilomelane-braunite mixture with soft black spots and patches, and some of which is psilomelane passing in places into soft wad-like ore. tiny braunite octahedra being often scattered through both the hard and soft portions of the ore. There is also some cavernous boryoidal psilomelane, which sometimes passes into red ochre and contains reddish clay in the cavities.

Nature and quality of the ores.

No manganese silicates were seen in this deposit, and this fact, taken in conjunction with the sooty nature of the ores, their admixture in places with red and yellow ochres and the evident replacement of the quartzites in places, indicate that this deposit is to a large extent the result of replacement of the quartzites along their bedding planes.

Some few hundred tons of ore had been extracted and from the ore-heaps I took sample No. 37 consisting mostly of cavernous and dirty psilomelane with a small proportion of the psilomelane-braunite mixture. The analysis made at the Imperial Institute is as follows :—

Sample No. 37.

Manganese peroxide	57·46
Manganese protoxide	20·25
Ferric oxide	5·52
Silica (combined)	1·81
Silica (free)	0·80
Phosphoric oxide	0·38
Moisture at 100°C.	1·15

This is equivalent to :—

Manganese	52·09
Iron	3·86
Silica	2·61
Phosphorus	0·166
Moisture	1·15

and indicates that the average ore consists largely of psilomelane and soft oxides with only a small proportion (18%) of braunite. The percentage of manganese shown by this analysis is somewhat higher than I expected, judging from the nature of the ores.

As the deposit is situated only 8 or 9 miles from Tumsar Road Railway Station, Bengal-Nágpur Railway, it is obvious that, if much ore of the above quality could be obtained, it would pay to work this deposit. The ore-band is, however, of small and irregular thickness, and as it goes

The working of the deposit.

into the hill-sides, it is covered by an ever-increasing overburden of quartzites. Consequently it will probably be found, after the extraction of a few thousand tons (if so much) of ore, that it is no longer practicable to work the deposit, even if it continue far into the hill-sides. Such ore as is extracted will need very careful cleaning before despatch to the railway station.

Output.

The following figures are given as representing the output of this deposit :—

Year.	Long tons.
1905	700
1906	600
1907	*Nil*

CHAPTER XXXIV.

DESCRIPTION OF DEPOSITS—*continued*.

The Central Provinces—Chhindwára District.

History—Output and labour—Geology—List of deposits—Nature and quality of the ores—Communications and transport—Kachi Dhána—Lakhanwára—Gaimukh—Sitapár—Bichua—Alesur—Devi—Ghoti—Wagora—Gowári Warhona—Dudhára.

(*See Plates 11, 22, and 43.*)

History.

The fact of the existence of manganese-ores in this district seems to have been first noticed by Mr. P. N. Datta [1] of the Geological Survey of India, who, while mapping the valley of the Kanhán river in the cold season of 1893-94, discovered the deposit of Kachi Dhána, the most valuable in the district, and noticed fragments of ore on the ground ¾ mile south-west of Khairi on the Kelod-Sausar road. This latter deposit is here dealt with under Gowári Warhona. Nothing more was heard of these deposits till the late Mr. A. M. Gow Smith, when prospecting in the year 1902, rediscovered both the above, and in addition found seven other deposits. His activity led Rai Sahib Mathura Prasad of Chhindwára to find manganese-ore at Devi.

At the time of my visit in December 1903 no work had been done on any of these deposits, except a little clearing of jungle, and digging of trial-pits and trenches. I was, however, able to revisit, hurriedly, Kachi Dhána, Lakhanwára, Gaimukh, Sitapár, and Gowári Warhona, in December 1907, when all these deposits had been more or less opened up. I have made such additions and alterations to this account as seemed necessary. The deposits discovered by Mr. Gow Smith have now become the property of the Indian Manganese Company, formed in 1904.

Output and labour.

The figures of production and labour for this district for the years 1906 and 1907 are as follows :—

Year.	Production in long tons.	Average daily number of workers.
1906	7,486	..
1907	30,728	416

[1] M. S. Progress Report, 1893-4, Part I.

Geology.

A brief account of the area in which the manganese-ore deposits occur has been given by Mr. Datta [1], whilst I have given an account of the petrology and manganese-ore deposits of the same area [2]. In the 1-inch map of this area published with the latter paper (Plate 20) I have marked in all the known manganese-ore deposits.

The manganese-ores of the Chhindwára district are confined to a portion of the valley of the Kanhán river situated in the Sausar tahsil. This river has cut its way down through the thick basaltic lava-flows of Deccan Trap age that once covered the whole country in this part of India, and now pursues a tortuous course over the metamorphic and crystalline rocks, which it has often obscured with its alluvium. This metamorphic valley, which is well cultivated, varies from 3 to 9 miles wide in the portions where the manganese-ore deposits lie and is flanked on each side by flat-topped basalt hills, which often rise to as much as 600 feet above the valley. Intervening between the trap and the metamorphics is a thin layer of Lameta limestones and sandstones, usually 10 to 50 feet thick, but sometimes absent. The strip of metamorphic and crystalline country in which the manganese-ore deposits occur is 17 miles long from north to south, with an average width of about 6 to 8 miles from east to west. The strike of the rocks in this area varies from about south-east in the southern part of the belt, to east in the northern part. The rocks of the metamorphic and crystalline complex are described in the paper cited above and consist of interbanded granulites, gneisses, schists, quartzites, pyroxenic gneisses, calciphyres, and crystalline limestones, with granites and abundance of intrusive pegmatite. As lenticular bands intercalated between these rocks occur the manganese-silicate-rocks and associated manganese-ore deposits. The strikes and dips of these manganiferous bands conform to those of the associated rocks. The dips are consequently very variable, but are usually steep.

List of deposits.

As in the Nágpur district, the manganese-ore deposits are genetically connected with manganese-silicate-rocks of the gondite series, the chief being various varieties of gondite and rhodonite-bearing rocks. The origin of the ores is the same as in the case of the Nágpur district and is considered on pages 357—364. There is no need to group the deposits as is done in the case of the Nágpur district. They will be described in the order given in the sub-

[1] *Rec. G. S. I.*, XXXIII, pp. 221—228, (1906).
[2] *Ibid.*, pp. 159-220.

pended list, in which the deposits are numbered roughly from north to south. It should be remarked, however, that Nos. 6 and 7 correspond to Class II of the Nágpur deposits and the remainder to Class I.

List of the Chhindwára deposits.

1. Kachi Dhána.
2. Lakhanwára.
3. Gaimukh.
4. Sitapár.
5. Bichua.
6. Alesur.
7. Devi.
8. Ghoti.
9. Wagora.
10. Gowári Warhona.
11. Dudhára.

The nature and quality of the ores.

The ores found in this district consist typically of the fine-grained mixtures of braunite and psilomelane, characteristic of the manganese-ore deposits of the gondite series. In this district I have not seen any coarsely crystalline varieties of this ore. Crystalline manganates, to be grouped as hollandite, are, however, found in some quantity at two different deposits. These are Sitapár and Gowári Warhona. At Sitapár the ore is a coarse-grained crystalline mixture of this manganate with braunite, a bronze-tinted ore (sitaparite), pyrolusite, and an arsenate. As none of the deposits were being worked at the time of my first visit I was compelled to take my samples from the outcrops of the deposits. The samples collected were analysed at the Imperial Institute and are inserted in their places under the descriptions of the different deposits. The limits and mean of 8 of these, No. 8 being omitted as it was obviously much too siliceous to be of any use, are shown below :—

	Limits.	Mean.
Manganese	48·95—54·97	52·72
Iron	5·00—11·77	7·08
Silica	4·98—10·63	7·16
Phosphorus	0·06—0·28	0·141
Moisture	0·00— 1·27	0·38

In addition to the analyses of my own samples I am able, by the kind permission of the directors of Indian Manganese Company, Limited, to publish analyses of samples collected by Messrs. H. Kilburn Scott and Selkirk, both of whom reported on the Chhindwára deposits, Mr. Scott before, and Mr. Selkirk after, the formation of this company.

Communications and transport.

The deposits are all situated at distances not greater than 4 miles from the main road from Nágpur to Chhindwára. The most southern of the deposits, namely Gowári Warhona, is situated 31 miles from Nágpur by road, and 45 miles from Chhindwára; and the most northern, Gaimukh, 27 miles from Chhindwára and 50 miles from Nágpur. Until the great rise in prices that characterized 1906 this long lead prevented the despatch of any ore to the rail either at Chhindwára, or Nágpur. During 1906 and 1907, however, a considerable quantity of ore has been extracted. That from Kachi Dhána, Gaimukh, and Sitapár, has been carted north to the railway at Chhindwára, and despatched to Calcutta *viâ* Nainpur and Gondia, Bengal-Nágpur Railway; whilst that from Gowári Warhona has been carted to Nágpur and thence railed to Calcutta. But it is very probable that any considerable drop in the price of manganese-ore will stop this despatch of ore, and although the ores in this district are some of the best in India it is improbable that any very active working of the deposits can take place until a railway is constructed from Nágpur to Chhindwára through the valley of the Kanhan.[1] The relative merits of such a railway and one from Nágpur to Betul are under consideration, and it is to be hoped for the sake of the manganese industry that the former route will be chosen.

1. Kachi Dhána.[2]

(INDIAN MANGANESE COMPANY.)

This is probably the best deposit in the Chhindwára district, and was originally found by Mr. P. N. Datta in the field season of 1893–94, as already noted (page 770). It is 4 miles from Rámákona, which is 28 miles from Chhindwára by a good road. There are here five separate hillocks on the same east to west line of strike, numbered 1 to 5 from east to west.

Hillock No. 1.

The largest hillock—No. 1, situated immediately to the south of the village of Kachi Dhána—is 360 paces long, 130 broad, and, say, 40 feet high. The ore-body crops out all along the back or ridge of the hill. The width of the outcrop of ore, at the time of my first visit, seemed to vary from 20 to 200 feet at various places, but could not be measured owing to the jungle-clad

[1] The drop in prices has come (at end of 1907) and work in this district has consequently been slackened.

[2] *Rec. G. S. I.*, XXXIII, p. 209, (1906).

character of the hill, on which no work had been done. Fifty to 100 feet, however, seemed to be a probable true figure for the thickness of the deposit. In 1907 there was a trench across the top of the ridge. This indicated a horizontal width of 115 feet, corresponding, with a dip of 45° to the south side, to 80 feet of true thickness; but even this section was not conclusive and the above figure may be slightly too large or too small. A length of about 40 yards of the east end of the deposit seemed quite worthless at the outcrop, the ore being mixed with gondite and magnetite-spessartite-rock, both chalcedonized. By December 1907 a trench had been cut across the ridge at this point. Two ore-bands were exposed. One of these, probably corresponding to the main mass of the ore in the hill further west, was 7 paces wide, with a dip of 35°-40° to the south by east. The other band was a subsidiary one, some 19 paces north of the one noticed above. The 'country' exposed in this trench consisted of biotite-gneiss, gondite, and a decomposed rock that might be a spessartite-gneiss. This series, including the main ore-band, is traversed by coarse felspathic intrusives. Except for this trench the 'country' of the deposit was obscured by the débris of the ore.

Hillock No. 2.

Hillock No. 2 is 140 paces long, and perhaps 15 to 20 feet high. At the eastern end it is composed largely of chalcedonized quartz-microcline-spessartite-rock; but the remainder of the hillock, as far as could be judged from the outcrops, seemed to be composed of ore. In December 1907 the north edge of this hillock had been a little opened up. The ore exposed probably corresponds to the subsidiary band in hill No. 1. The section showed abundance of a light brown rock (probably pyroxene-felspar-rock), sometimes apparently interbedded with the manganese-ore layers, and sometimes clearly cutting across them. The thickness of the ore in this hill cannot be stated until it is better opened up.

Hillock No. 3.

Hillock No. 3 is about 130 paces long, and 35 broad, with a height of perhaps 15 to 20 feet. The whole hillock seems to be composed of ore mostly of rather good quality, but containing in places a fair amount of pink felspar as impurity, together with some spessartiferous bands.

Hillock No. 4.

The next hillock, No. 4, is 140 yards long and 60 broad, with a height of 15 to 20 feet. Here clearings, which had been made along and across the deposit, showed that ore cropped out *in situ* only for 66 paces from the eastern end, fragments, only, being seen for the rest of the length, though the deposit is probably continuous. The 'country' shown by the cross-clearing was a very interesting rock composed mainly of albite, and a manganese-pyroxene with pinkish brown to pale greenish brown pleochroism. The width of the ore deposit was seen to be possibly 50 feet.

Hillock No. 5.

The last hillock, No. 5, is simply a slight rise in the ground. When I first saw it, it showed an outcrop of spessartite-quartz-rock (gondite), passing under cherty Lameta sandstones to the west. Later on Rai Sahib Mathura Prasad of Chhindwára secured this hillock, which had been neglected by the Indian Manganese Company, and opened it up a little. This development did not, as I saw it in December 1907, indicate the presence of any workable ore, but it was of considerable interest. One trench showed a central mass of pyrolusite 4 paces wide, spotted with geodes and patches of calcite and quartz; when the geodes were empty, these two minerals showed definite crystal terminations in the cavities. Sometimes however, the cavities were filled with pink opal. The presence of calcite is of considerable interest, because its occurrence in this way is unique in the Indian manganese-ore deposits, as far as my experience of them goes. It has possibly been derived from the Lameta rocks, which are often calcareous. The rock seen to the north of the pyrolusite is extremely coarse felspar-rock, cutting across the strike of the pyrolusite —which is conformable to that of the crystalline rocks of this neighbourhood—at its west end. On the south side of the pyrolusite are massive chalcedonized spessartite-bearing rocks.

From the way in which these five hillocks of ore crop out in a line, there seems little doubt that they are genetically connected. But whether they are all joined to one another in the low ground between by ore, or whether there are two or more lenticular bands on the same line of strike, can be determined only when the deposits are opened up further.

It is interesting to note here the occurrence a mile or so to the west, near the head of the nálá that flows past the south of the deposits, of an outcrop of spessartite-quartz-rock (gondite) showing no signs of change to manganese-ore. This outcrop is not on the line of strike of the above deposit.

Nature and quality of the ores.

There are two kinds of ore at Kachi Dhána. One is the compact mixture of psilomelane and braunite, in which the psilomelane is usually rather small in amount and often absent, the ore then being finely crystalline; the other is dark-grey finely crystalline braunite with fairly numerous black spots about $\frac{1}{8}$ inch in diameter. The former variety of ore characterizes hillocks Nos. 1 to 3, while hillock No. 4 shows both varieties.

In December 1907 I saw one block of quarried ore consisting of a mixture of hollandite, braunite, and psilomelane, with a squarish patch of bronze-tinted ore, probably the same as sitaparite found at Sitapár.

The ores will everywhere need careful cleaning, as they contain in various places spessartite, quartz, chalcedony, magnetite, albite, and pink felspar.

I picked out for analysis a piece of ore that seemed to be composed entirely of finely granular braunite. In places it tended to be slightly more coarsely crystalline. The specimen was analysed at the Imperial Institute with the following result:—

Specimen No. 797 (17·4).

Manganese peroxide	42·86
Manganese protoxide	35·45
Ferric oxide	6·70
Alumina	0·26
Baryta	0·00
Lime	1·31
Magnesia	3·15
Combined silica	8·75
Free silica	0·00
Phosphoric oxide	0·03
Arsenic oxide	0·002
Combined water	0·91
Moisture at 100°C.	0·09
Carbon dioxide	0·06
	99·572
Manganese	54·60
Iron	4·69
Silica (total)	8·75
Phosphorus	0·013
Specific gravity	4·71

At first I attempted to re-arrange this analysis in terms of its mineralogical composition on the assumption that it contained braunite of the formula $3Mn_2O_3.MnSiO_3$, with a small amount of interstitial psilomelane. The analysis was found not to correspond to any such mixture and it was found necessary to assume that the formula of the braunite present corresponded to $7Mn_2O_3.2MnSiO_3$. On this assumption the composition of the ore works out as follows :—

Braunite :—		
Mn_2O_3	73·54	
Fe_2O_3	6·70	
MnO	4·33	
MgO	2·53	
CaO	1·20	
SiO_2	8·75	
	97·05 . . .	97·05
Apatite		0·07
Calcite		0·13
Al_2O_3		0·26
MgO (surplus)		0·62
As_2O_5		0·002
H_2O (combined)		0·91
Moisture at 100°C		0·09
		99·132
Surplus oxygen		0·44
		99·572

The closeness of this analysis to braunite of the formula $7Mn_2O_3.2MnSiO_3$ is perhaps best seen if the ferric oxide be converted into Mn_2O_3, and the protoxides MgO and CaO into MnO and the whole then calculated to 100. The result is as follows :—

MnO	45·15
MnO_2	46·17
SiO_2	8·68
	100·00
Manganese	64·17
Available oxygen	8·48

If now these figures be compared with the figures for the different varieties of braunite given on page 70, it will be seen that there is a very close correspondence with the braunite of the formula $7Mn_2O_3.2MnSiO_3$. The silica is of course the chief criterion in deciding which formula the braunite agrees with, but there is also a close agreement in the amount of manganese. The divergences in the amounts of the two oxides of manganese are evidently due to the fact that there is a slight excess of available oxygen over that required by the formula. This is within the limits of error in the determination of oxygen, and the difference may be due either to such an error, or it may indicate that there is a very small amount of interstitial psilomelane. The specific gravity of the ore is 4·71. This is only just outside the limits for this mineral, namely 4·75–4·82. The difference may be another indication of the presence of a very small amount of psilomelane, or it may point to the presence of cavities between the individual grains of braunite, some of which did not become filled with water when the determination was made.

A sample was taken from the outcrops on hills 1 and 2 by breaking off pieces of ore at regular intervals all along the ridge and from each side. The sample thus obtained was analysed at the Imperial Institute with the following result:—

Sample No. 9.

Manganese peroxide	45·84
Manganese protoxide	33·19
Ferric oxide	7·15
Baryta	0·98
Combined silica	5·12
Free silica	1·87
Phosphoric oxide	0·16
Moisture at 100°C.	0·17

This indicates a mixture, assuming all the braunite present to have the formula $7Mn_2O_3. 2MnSiO_3$, of 58% of braunite with 42% of psilomelane or other manganates. The analysis is equivalent to:—

Manganese	54·73
Iron	5·00
Phosphorus	0·070
Silica (total)	6·99

showing that the ore is of very high quality.

The following analyses, published with the kind permission of the Directors of the Indian Manganese Company, are taken from reports made by Mr. H. Kilburn Scott and Mr. W. Selkirk for this Company.

Analyses from Mr. Scott's report.

Number.	1	2	3	4	5	
Manganese	55·51	55·85	56·82	53·05	51·87	All dried at 212°F.
Iron	4·39	5·03	4·92	2·82	4·92	
Silica	8·40	6·83	8·76	1·10	16·27	
Phosphorus	0·035	0·135	0·115	0·004	0·033	

No. 1. From outcrop along the summit of hillocks Nos. 1 and 2.
No. 2. From hillock No. 3 taken at different parts of the outcrop.
Nos. 3. to 5 are characteristic types from outcrop of which:—
No. 3. Finely crystalline and almost amorphous.
No. 4. Highly crystalline, supposed to be braunite.
No. 5. Highly crystalline, supposed to be braunite, included some glassy quartz.

Analyses from Mr. Selkirk s report.

Number.	6	7	8	9	
Manganese . . .	54·17	55·08	54·54	55·21	All dried at 212°F.
Iron	5·30	4·90	4·75	4·93	
Silica	6·00	6·70	8·70	9·02	
Phosphorus	0·132	0·127	0 037	0·031	

Nos. 6 and 7 were taken across the outcrop of hillock 3.
Nos. 8 and 9 ,, ,, ,, ,, ,, hill 1.

Another partial analysis carried out by Mr. Blyth for Mr. Datta in 1894 yielded :—

MnO	=68·75 %	= 53·25 % Mn.
P_2O_5	= 2·10	
Moisture	= 0·26	

This deposit must contain a large quantity of high grade ore. It is 4 miles from Rámákona, which is 28 miles from Chhindwára.

The working of the deposit.

The inconstant manner in which the good ore occurs in these hillocks, as in many of others of the deposits of the Central Provinces, makes it a matter of impossibility to give even a bare approximation to the amount of ore available. The outcrop evidence was, however, sufficient to justify extensive work at this deposit, and such work as had been carried out to the end of 1907 confirmed the evidence of the outcrops as to the presence of large quantities of merchantable ore. The ore is carted direct from the deposit to Amla, 3 miles north of Rámákona and thence to Chhindwára, a total distance of about 28 miles.

Output.

The output of ore from this deposit during 1906 and 1907 was as follows :—

Year.	Long tons.
1906	3,713
1907	8,720

2. Lakhanwára.[1]

(INDIAN MANGANESE COMPANY.)

When I saw this deposit in December 1903 it was visible at the surface as three very small outcrops of rather fine-grained hard grey crystalline ore, very largely braunite ; these are shown at the west end of the sketch-map, fig. 47 on page 782, from which it will be seen that they are only 200 to 250 yards to the west of the Gaimukh deposit. In spite of the considerable difference between the ores of Lakhanwára and Gaimukh, it seems probable, in view of their proximity and situation roughly on the same line of strike, that there must have been some genetic connection between them.

When I revisited these occurrences in December 1907, I found that they had been worked out. No. 1 extended to a depth of only 3 to 4 feet, the rock below this being pegmatite and schists (?) largely converted into soil. A trench put across the strike near No. 3 showed only soft schistose micaceous gneisses with vein quartz, with a dip to the south by west at 70°. The ore extracted was lying by the side of this trench and had evidently been found close to the surface only. From this it seems that we had here examples of the lowest parts of bodies of manganese-ore, the upper parts of which had been completely denuded away.

Nature and quality of the ores.

I took a small sample from outcrop No. 3. It was analysed at the Imperial Institute with the following result :—

Sample No. 11.

Manganese peroxide	40·86
Manganese protoxide	31·75
Ferric oxide	16·82
Combined silica	1·47
Free silica	3·39
Phosphoric oxide	0·46
Moisture at 100°C.	0·39
Carbon dioxide	0·14

This is equivalent to :—

Manganese	50·41
Iron	11·77
Silica (total)	4·86
Phosphorus	0·39

[1] *Rec. G. S. I.*, XXXIII, page 211, (1906).

The analysis of the Lakhanwára ore in Mr. Scott's report is as follows :—

Dried at 212° F.

Manganese	57·51
Iron	6·02
Silica	4·63
Phosphorus	0·153

The Lakhanwára ores vary from crystalline-granular, in which the quantity of psilomelane must be small, to ores showing a crystalline mineral in a psilomelane matrix. There is probably a certain proportion of braunite in these ores ; but the crystalline mineral is to a large extent one of the strongly magnetic minerals, either mangan-magnetite or vredenburgite. The bronze tint visible in places probably indicates vredenburgite.

Mathura Prasad's deposits.

Perhaps 300 yards west of the Lakhanwára outcrops noticed above, some openings made by Rai Sahib Mathura Prasad have revealed the presence of further masses of manganiferous rock. The two workings are situated on the two banks of the Gehra Nálá of the map. The opening on the east bank of the nálá shows soft schistose gneisses pierced by masses and veins of granite and pegmatite ; the ore-band is not properly exposed, but is probably a mixture of quartz, spessartite, and manganese-ore, intercalated in the schists. A little to the south-west of this on the west bank of the nálá is a run of coarse spessartite in vein-quartz in a 'country' of the usual schistose gneisses. The ore seems to occur as a lenticle in this rock, and is softish and mixed with spessartite. Traversing the schists is some pegmatite composed of quartz, felspar, and muscovite. Most of the ore stacked from these two occurrences was small in quantity, showed various impurities, and did not strike me as being of much commercial value.

3. Gaimukh.[1]

(INDIAN MANGANESE COMPANY.)

The deposit known by this name is situated in the area marked 'SEETAPAR JUNGLE' on the 1-inch sheet, No. 54, Central Provinces Survey, and about $1\frac{1}{4}$ miles west-north-west of Sitapár village, marked as 'Pangree' on the map. It takes the form, as far as the outcrop is concerned, of a lenticular body of ore 60 yards long and 20 yards wide, forming a small hillock 30 to 40 feet high, situated on the south side of a low

1. *Rec. G. S. I.*, XXXIII, p. 211, (1906).

hillocky ridge of white quartzite, usually very like vein-quartz in appearance.

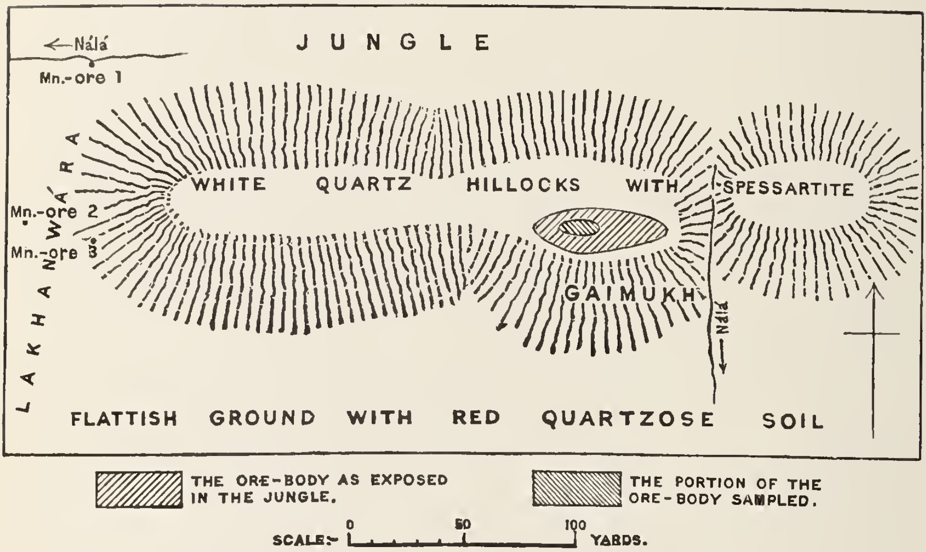

Fig. 47.—Sketch-plan of the Gaimukh and Lakhanwára deposits.

The ore is hard, black and crystalline, probably braunite, the crystal individuals showing faces averaging $\frac{1}{4}$ inch across. But nearly always there is mixed with the ore a dark brown mineral with interstitial patches of white to pale flesh-pink colour showing a pearl lustre. Under the microscope it is seen that the ore is an altered rhodonite-rhodochrosite ($MnCO_3$) rock, the former being the brown and the latter the white to pink mineral, and both these minerals will unavoidably find their way into cargoes of the ore. The same is the case with the sample taken by me, shown in the analysis No. 12 (page 784).

The rhodonite is of course objectionable on account of its high silica content, but as rhodochrosite contains nearly 48 per cent. of manganese, and the CO_2 is easily removed by calcination, it will probably be found advisable to retain it in the cargoes, even though its presence may slightly lower the manganese percentage.

As will be seen from the sketch-map, figure 47, only the central portion of the deposit was considered worth sampling; the peripheral portion was mostly fairly fresh spessartite-rhodonite-rock with a little rhodochrosite. Thus it will be noticed that the core of the lenticle, only about 20 yards long and 7 yards broad, is composed chiefly of ore formed by the alteration of rhodonite and rhodochrosite, while the external part is not only less altered, but is composed of a different rock, namely rhodonite-spessartite-rock, and in fact is more siliceous. This probably means that the original manganiferous sediments were more impure in the outside layers than in the layers forming the central portions of the deposit.

The presence of carbonate suggests that the centre of the deposit has been the pathway of subterranean waters, which have partly altered the rhodonite to ore and also formed the manganese carbonate; on the other hand the carbonate may be an original mineral.

On the continuation of the ore-deposit to the east of the small nálá shown on the sketch-map, there were seen a good number of fragments of white quartz containing dark reddish brown spessartite trapezohedra. Similarly, to the west the quartz was also often seen to contain these trapezohedral crystals.

'Country.'

None of the 'country' could be seen at the time of my first visit. North of the white quartz hillocks the ground is obscured by heavy jungle-covered soil, while to the south occurs a reddish quartzose soil separating the ore-deposit from some hills of crystalline limestone.

By December 1907, however, a little work had been done on the deposit. A cross-cut trench revealed a 'country' of soft micaceous and extremely schistose gneisses (almost schists) with decomposed pegmatite. The dip seen was steep to the south side. The work further showed that at least a portion of the larger shaded area in figure 47 does not correspond to rock *in situ*, but to huge masses of manganiferous rock detached from the ore-body *in situ*. The work done did not indicate the existence of an ore-body of more than moderate size.

Nature and quality of the ores.

As already mentioned, the ore in the central portion of the deposit consists of a black ore, probably braunite, mixed with a certain proportion of rhodonite and rhodochrosite. A sample taken by breaking pieces from the outcropping blocks over the whole of this area was analysed at the Imperial Institute with the following result :—

Sample No. 12.

Manganese peroxide	22·51
Manganese protoxide	52·42
Ferric oxide	8·85
Combined silica	10·63
Free silica	0·00
Phosphoric oxide	0·10
Moisture at 100° C.	0·32
Carbon dioxide	0·41

This is equivalent to :—

Manganese	54·98
Iron	6·19
Silica (total)	10·63
Phosphorus	0·044

The high percentage of silica is doubtless an expression of the fact that there is a certain proportion of rhodonite in the ore. The low percentage of peroxide of manganese compared with what is customary and the correspondingly high percentage of protoxide are also indications of the presence of rhodonite in fair proportion. Hence it is not possible to say what proportion of braunite this analysis indicates. The amount of carbon dioxide returned is, however, smaller than I anticipated, as it indicates the presence of only just over 1 per cent. of rhodochrosite. The large amount of manganese in the ore came as a surprise to me, and it means that the ore is of considerably better quality than one would suspect from its appearance.

The following analyses were taken from the reports of Messrs. H. K. Scott and W. Selkirk, respectively :—

	Mr. Scott.	Mr. Selkirk.	
Manganese	56·68	54·20	Dried at 212° F.
Iron	6·21	5·00	
Silica	7·68	9·75	
Phosphorus	0·078	0·036	

Mr. Scott's sample was taken from the outcrop with the rejection of any ore that did not look good, whilst Mr. Selkirk's sample represented the 'general run of the ore neglecting, however, the siliceous portions.'

It is evident from the analyses that the ore of this deposit is well worth quarrying, as it is high in manganese and low in phosphorus, the only feature against it being the somewhat high percentage of silica.

During 1906 a start has been made in opening up this deposit. The deposit is less than a mile east of the main road at a point about 26 miles from Chhindwára.

Output. The output from this deposit during 1906 and 1907 was as follows:—

Year.	Long tons.
1906	205
1907	177

4. Sitapár.[1]

(INDIAN MANGANESE COMPANY.)

(See Plate 22.)

This deposit is situated about ¾ mile due west of Sitapár village, which is erroneously located on the 1-inch topographical map, being really the village shown as 'Pangree', while Pángri is a very small hamlet about ½ mile east by north from Sitapár. It is about 1 mile east of a point on the main road 26 miles from Chhindwára. The ore deposit takes the form of a small elliptical hillock 27 yards long from east to west by 23 broad and perhaps 20 to 25 feet high. It rises from a cultivated field so that all the associated rocks are completely concealed by alluvium and the whole outcrop consists of huge blocks (see Plate 22) of ore, which contain a variety of minerals, amongst which not a trace of either spessartite or rhodonite is visible. The mineral assemblage on the other hand, is unique.

The foregoing description applies to the deposit as I saw it in 1903 in the virgin state before any work had been done on it. When I revisited it in December 1907 the deposit had been largely worked. The overburden had been stripped on all sides exposing a conical mass of ore standing up in the middle of the quarry. The strike of the ore-band was seen to be east-south-east, with a steep dip to the south side (average of about 80°). The width of the deposit as exposed—for it was not certain that the full width had been exposed—was 135 feet, which, at a dip of 80°, corresponds to a true thickness of 133 feet. This thickness includes a small proportion of partings or intrusions of pegmatite. The

[1] *Rec. G. S. I.*, XXXIII, pp. 211, 232, (1906).

length exposed was 158 feet. At the west end there were a few small pegmatitic intrusions, and at the north-east corner a much larger one. This varied from very coarse-grained felspathic rock (felspar up to 2 inches long) to comparatively fine-grained rock suggesting a medium-grained granite in texture. Much of the felspathic intrusions in this quarry contains either braunite or a pyroxene. On the south side of the east end of the quarry there was exposed a big mass of soft, very schistose, micaceous gneiss, apparently faulted into the ore-body. Its strike and dip were roughly at right angles to that of the ore-body on either side of it.

Minerals in the ores.

The ores are coarsely crystalline and composed of a mixture of six minerals. Of these one is a pale pinkish white to white *arsenate* (with phosphate), for which see page 218. Another is the bronze-coloured micaceous mineral which I have provisionally designated *manganchlorite* (see page 195). The other four are manganese minerals containing high percentages of manganese. One is *braunite*, an analysis of which is given in Part I (page 76). It occurs in lustrous black granules, which sometimes show faces that may be interpreted as those of the tetragonal octahedron, there being occasionally a small truncating basal plane. Another is a crystalline manganate occurring in rough prismatic crystals that do not show definite crystal faces, probably owing to lack of freedom during growth of the mineral; this mineral is closely allied to *hollandite* and may be provisionally included under that species, although it contains a considerably higher percentage of calcium than the typical hollandite of Kájlidongri (see pages 87—91). The third of these manganese ores is *pyrolusite* in pseudomorphs showing the outward form of manganite[1]. It is not abundant. The fourth mineral, sitaparite, is a dark grey one with a bronze tinge suggesting that it is the same as vredenburgite found at Beldongri in the Nágpur district. The difference between the two minerals lies in the fact that whilst vredenburgite is strongly magnetic the Sitapár mineral is only slightly magnetic; also, the Sitapár mineral contains 6 per cent. of lime. As shown on page 50 this mineral is composed essentially of oxides of manganese and iron, the percentage of iron being high, namely about 19%. To this mineral I have given the name *sitaparite* after the deposit.

This deposit is worth a special visit to see the ores as quarried. The most characteristic ore is a sparkling, coarsely to rather finely crys-

[1] *Rec. G. S. I.*, XXXIII, p. 232, (1906).

Photographed by L. L. Fermor.

Bemrose, Collo., Derby.

HILLOCK COMPOSED ENTIRELY OF MANGANESE-ORE. SITAPÁR, CHHINDWÁRA DISTRICT, C. P.

talline, prismatic grey hollandite, often with patches and streaks of bronze-tinted sitaparite, the contrast between these two minerals being heightened by the sunlight. The only ores that can compare with these for beauty are the beautiful blue-grey psilomelane of Kumsi in Mysore, and the sparkling finely crystalline hollandite of Bálághát. But neither of these are so attractive as the ore of Sitapár. It almost makes one shudder to think of the thousands of tons of these two beautiful and elsewhere rare minerals, hollandite and sitaparite, that are being shipped and used for the manufacture of ferro-manganese !

Quality of the ores.

In working this deposit it will be necessary carefully to clean out the white mineral, for otherwise the cargoes are likely to run high in arsenic. I took a sample in 1903 by breaking pieces off the outcropping blocks over the whole of the hillock. As a fair proportion of the pieces of ore thus obtained contained the white mineral, I separated the sample into two, 10 and 10A; 10 being composed of the four manganese-ores, and 10A of all the pieces of ore that contained either the arsenate or the bronze micaceous mineral. The weights of the two samples were 59 lbs. and 38 lbs., respectively. The analyses were carried out at the Imperial Institute with the following results :—

	Sample No. 10.	*Sample No. 10A.*
Manganese peroxide	42·41	39·58
Manganese protoxide	36·28	38·08
Ferric oxide	9·85	10·05
Baryta	1·03	0·31
Combined silica	6·86	7·90
Free silica	0·09	0·00
Phosphoric oxide	0·14	0·27
Arsenic oxide	0·003	0·095
Moisture at 100°C.	0·00	0·04

These are equivalent to :—

Manganese	54·97	54·57
Iron	6·89	7·03
Silica (total)	6·95	7·90
Phosphorus	0·061	0·118
Arsenic	0·002	0·062

The interesting feature of these analyses is the difference between the arsenic in the two samples. If the sample had not been divided into two portions the combined sample would have shown about 0·025 of arsenic. It is a fortunate thing that the arsenate is so different in colour from the manganese-ores that the coolies can easily clean it out.

The analyses given above may be compared with those of samples taken by Messrs. Scott and Selkirk, respectively, when they reported on this deposit. They are as follows :—

——	Mr. Scott.	Mr. Selkirk.
Manganese	54·94	53·94
Iron	5·28	6·10
Silica	7·33	8·37
Phosphorus	0·072	0·055

During 1906 and 1907 this deposit has been opened up and a considerable quantity of ore carted to Chhindwára and thence railed to Calcutta *viâ* Nainpur and Gondia. Mr. Henry M. Hance, Manager of the Indian Manganese Company, has kindly supplied the following figures of cargo analyses of Sitapár ore :—

——	1.	2.
Manganese	54·42	53·83
Iron	6·00	5·60
Silica	7·00	6·85
Phosphorus	0·077	0·053
Moisture	0·16	0·16

The remarkably close agreement between these analyses of large quantities of quarried ore and those of the outcrop samples taken by Scott, Selkirk, and myself, show that a good idea of the value of the ore in a deposit can sometimes be obtained from outcrop samples. It is evident, moreover, from these analyses that the ores f this deposit are of very high grade and equal to the best of the Nágpur ores.

The working of the deposit.

This deposit has been opened up in the usual form of an open quarry, a fine conical mass of ore having been uncovered. As at so many other manganese quarries, it is now found necessary to shift spoil that was originally dumped too near the edge of the pit. The amount of waste so dumped is, however, not nearly so large as at many other deposits. The ore is carted to Chhindwára station, 26 miles distant, by a good road involving, however, a steep ghát ascent on to the Sátpura plateau.

Output. The output from this deposit during 1906 and 1907 was as follows :—

Year.	Long tons.
1906	1,699
1907	9,869

5. Bichua.[1]

A little to the south of Burár Hill is a ridge of crystalline limestones containing many accessory minerals, such as essonite, epidote, and pale green pyroxene [2] ; just to the south of this is a series of five small hillocks, the most eastern of which is about 100 feet high. They have a practically east to west strike and are composed mainly of spessartite-quartz-rock (gondite). The Rámákona-Devi road crosses the outcrop so that the most western part is just to the south and the remainder to the north of the road. The total length of the manganiferous band is a little over half a mile ; but it is not continuous over this length, the two eastern hillocks being separated from the three western ones by nearly a quarter mile. At the west end the band is cut off by a pink tourmaline-granite tending towards a granulite [3], whilst in the second hillock from the west end the manganese-band is interrupted by a coarse pegmatite of quartz and felspar containing large spessartite crystals up to an inch in diameter [4] ; this pegmatite may possibly be an intrusive cutting across the strike of the manganiferous band at right angles.

The main mass of the spessartite-quartz-rock is fine-grained and partially altered to ore, but nowhere sufficiently so to be of any commercial value. At the western end the gondite commonly takes the form of a coarse rock of vein-like quartz and trapezohedral spessartite crystals up to an inch in diameter. On the two eastern hillocks some rhodonite was also seen. The manganiferous band shows in two places, where it crosses nálás, widths of about 20 and 40 yards respectively. The dip is nearly vertical, being to the south on the most western hillock and to the north on the next hillock to the east.

As will be judged from the foregoing remarks this band of manganiferous rock is much too fresh and unaltered to be of any commercial value. at least as far as one can judge from the outcrops.

[1] *Rec., G.S.I.*, XXXIII, p. 212 (1906).
[2] *Ibid.*, p. 199.
[3] *Ibid.*, p. 176, (1906).
[4] *Ibid.*, p. 179.

6. Alesur.[1]

Due west of Devi village, a low outcrop of white crystalline limestone[2] runs up from the west to the 'Ghondee' nálá of the 1-inch map. At the east end, on approaching the nálá, the crystalline limestone gradually changes to the black variety[3], with included spessartite and rhodonite, and this passes along the strike into the ordinary spessartite-quartz-rock (gondite) partially changed to ore. The total length of the outcrop of manganiferous rock is 52 paces, and at the east end the greatest width is 5 or 6 yards with a calciphyre as 'country.' The ore-band reaches the nálá and is there cut off by a complex of pegmatite injecting a garnetiferous biotite-gneiss in all directions. Both limestone and spessartite-quartz-rock contain lenticles of quartz parallel to the strike.

This occurrence is not mentioned as having any economic value, but because of its interest, in showing a gradual passage from a white crystalline limestone to spessartite-quartz-rock or gondite. The blackening of the limestone is, as explained elsewhere[4], due to the deposition of a black dust of manganese oxide along the cleavage and twinning planes of the calcite.

7. Devi.[5]

(RAI SAHIB MATHURA PRASAD.)

This deposit was discovered by an agent of Rai Sahib Mathura Prasad of Chhindwára, who holds the property on prospecting license. The ore occurs as an irregular, interrupted band traceable at intervals for about a mile along the northern side of a run of small hillocks of crystalline limestone[6] and calciphyre[7], which stretches east from the village of Devi and terminates at the eastern end in a hill over 150 feet high. At the western end the ore-band lies at the base of the hillocks, but at the eastern end it gradually climbs to the top of the above-mentioned hill. Again, at the western end the associated rocks have a steep dip to the north, while at the eastern end a dip of 25° to the south is shown in the accompanying crystalline limestone.

The ore-band consists largely of rocks composed of spessartite, rhodonite, and rhodochrosite, the last-named being the least common of the three minerals. Amongst these rocks is a beautiful coarse-grained one,

1 *Rec. G.S.I.*, XXXIII, p. 212, (1906).
2 *Ibid.*, p. 198.
3 *Ibid.*, p. 200.
4 *Ibid.*
5 *Rec. G.S.I.*, XXXIII, p. 212, (1906).
6 *Ibid.*, p. 198.
7 *Ibid.*, p. 190.

composed of rose-pink rhodonite and orange spessartite. There is, moreover, much quartz banding in the ore and manganese-silicate-rocks; and in places this quartz contains manganese-garnets up to half an inch in diameter. These rocks are often blackened owing to the partial conversion of the rock into manganese-ore; but the alteration has only in a comparatively few places proceeded sufficiently far for the alteration product to be an ore of manganese; even in those places the amount of ore is small. This ore is partly hard and partly soft and is brownish black in colour. The limestone adjoining the ore-band is often of the black variety, which, as usual owes its colour to manganese oxide deposited along the cleavage and twinning planes of the calcite. It also contains small altered grains of rhodonite [1].

I collected a sample along the outcrop to the east of the nálá bisecting the ore-band, from any points where it looked as if the ore was of possible value. The sample was assayed at the Imperial Institute with the following result:—

Sample No. 13.

Manganese peroxide	38·87
Manganese protoxide	32·70
Ferric oxide	10·05
Combined silica	4·98
Free silica	0·00
Phosphoric oxide	0·65
Moisture at 100°C.	1·27
Carbon dioxide	0·04

This is equivalent to:—

Manganese	48·95
Iron	7·03
Silica (total)	4·98
Phosphorus	0·283

Judging from this analysis it seems as if a small quantity of phosphoric manganese-ore, which is not quite up to first grade as regards manganese, may be obtained from this deposit. But until a railway has been constructed through the valley of the Kanhán it is not probable that it will pay to extract this small quantity of inferior ore, even when the prices rule as high as they did in 1906.

[1] *Rec. G.S.I.*, XXXIII, p. 201, (1906).

To the east this deposit is probably cut off by a fault, for microcline and other quartzites appear on the line of strike. It seems probable that this is a continuation of the Alesur manganese-ore band, which also occurs in crystalline limestone ; but if this be the case there is probably a fault possibly connected with the pegmatite intrusion noted on page 790, between the two, this accounting for the lateral shift of one relative to the other.

During 1906 some 600 tons of ore were extracted from this deposit.

Output.

I do not know if this ore has ever been despatched to the railway.

8. Ghoti.[1]

(INDIAN MANGANESE COMPANY.)

This deposit is situated within the limits of a village, called Bharkúm, no longer existing, the site of which is about 1¼ miles north-east of Ghoti.

There are two parallel bands of ore having a strike about E. 10° N. Of these the southern band is about 750 yards long as seen at the surface, and the more northern one only 440 yards. For 150 yards at their western end these two bands form the north and south edges, respectively, of a hillock about 50 feet high, and are separated by some cultivated ground occupying the flattish top of the hillock between. Judging from scattered fragments, this ground must be composed of micaceous felspathic schists with some pegmatite of muscovite, white felspar, and quartz, probably intrusive in the schists. To the east of this hillock the ore outcrop takes the form of a very low hillocky ridge, and where a nálá crosses the deposit about its middle it is seen that the dip is either very steep to the N. 10° W. or is vertical, and also that the southern band is really composed of two bands, of which the most southern is 143 paces south of the most northern of the three bands.

The ore-band consists partly of fairly good ore, partly of grey and white quartzites and felspathic bands, and partly of mixtures of ore, spessartite, and quartz. A little rhodonite was also seen at the eastern end, near which was also a pegmatite-like rock of pinkish white felspar (microcline), quartz, and yellow spessartite. The relations of this pegmatite to the ore-body could not be made out. The garnet varies from bright

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[1] *Rec. G. S. I.*, XXXIII, p. 213, (1906).

yellow to deep orange and red in colour ; while the ore varies in character from hard steel-grey finely facetted ore and soft very crystalline friable grey ore to grey ore patched with black and mixed with quartz, garnet, and ferruginous patches ; these ores are various mixtures of braunite and psilomelane. The quantity of good ore does not seem very large. The northern band contains, on the whole, the better ore.

Nature and quality of the ore.

An outcrop sample was taken by me from wherever the ore looked to be of possible value. The pieces of ore showed braunite and psilomelane and sometimes a little yellow garnet. The analysis carried out at the Imperial Institute is as follows :—

Sample No. 14.

Manganese peroxide	42·24
Manganese protoxide	29·42
Ferric oxide	11·02
Combined silica	5·60
Free silica	3·14
Phosphoric oxide	0·64
Moisture at 100° C.	0·52

This is equivalent to :—

Manganese	49·55
Iron	7·71
Silica (total)	8·74
Phosphorus	0·279

Making allowance for the small amount of garnet present, the analysis shows that the ore consists of about equal proportions of braunite and psilomelane.

The two following analyses are taken from reports by Messrs. H. K. Scott and W. Selkirk, respectively :—

	Mr. Scott.	Mr. Selkirk.
Manganese	48·62	49·48
Iron	8·17	8·25
Silica	6·28	4·60
Phosphorus	0·276	0·306

The first sample is described as composed of merchantable ore from the whole length of the deposit. Mr. Selkirk's sample was taken from the best-looking ore on the property.

From these various analyses it will be seen that the ore of this locality is highly phosphoric, whilst it is hardly up to first grade in its manganese percentage. Measured in a straight line this deposit is about 5 miles south-east of the road to Chhindwára at a point about 30 miles from that town. Hence until a railway has been constructed through this area it cannot pay to work such ore. Even when such a line has been constructed it is not likely that this ore will be worked except at times of very high prices. when it often pays to ship second grade ores as well as first.

9. Wagora.[1]

The metamorphic rocks at Wagora consist chiefly of biotite-garnet-granulites[2], gneisses, and schists, having a general strike of about W. 35° N. with an average dip of 60° to the south side. By traversing the various nálás it is seen that there are at least six parallel bands of spessartite-quartz-rock (gondite) intercalated in the above rocks. These bands vary in thickness from 15 inches to 60 yards, and the same band is seen to expand and contract in a lenticular fashion to a very marked degree, the most noticeable case being that of the most north-easterly band (A)[3], which in one place is 60 yards and in another only 6 yards wide. Though there is such an abundance of manganiferous rock, yet in no case is it of any commercial value. The only two places where the rock is to any extent altered to manganese-ore are at the points marked A and B on the map, Plate 20, *Rec., G. S. I.*, Volume XXXIII.

At A is a hillocky ridge 270 yards long passing to the south-east under the Lameta rocks; in places this manganiferous band seems to be 60 yards wide. In this outcrop occurred a little rhodonite as well as spessartite; and it is the rhodoniferous rock that is furthest changed to ore. A sample was taken of a few pieces of as good ore as could be found. It showed rhodonite, spessartite, and quartz, besides the ore, which consisted of psilomelane with some braunite.

It was analysed at the Imperial Institute with the following result:—

Sample No. 8.

Manganese peroxide	31·05
Manganese protoxide	12·16
Ferric oxide	9·83
Combined silica	6·57
Free silica	30·06
Phosphoric oxide	0·34
Moisture at 100°C.	0·86

[1] *Rec. G. S. I.*, XXXIII, p. 213, (1906).

[2] *Ibid.*, pp. 179, 180.

[3] *Ibid.*, map, Plate 20.

This is equivalent to :—

Manganese	29·08
Iron	6·88
Silica (total)	36·63
Phosphorus	0·148

The analysis demonstrates the worthlessness of the ore and shows that the sample contained 30 per cent. of quartz. The combined silica was probably present largely as spessartite and rhodonite, perhaps about 15 per cent. of these minerals being present, leaving 55 per cent. for the psilomelane (and a little braunite).

At B there is a very low hillock about 100 yards long and 30 broad. It shows no rhodonite, being entirely of gondite, with some brown cherty rock formed by the silicification of the manganese-rock. Here I could not find any material worth assaying.

The specimen of gondite of which an analysis is given on page 349 was obtained from the outcrop in the nálá immediately to the west of Wagora village. (Also see Plate 11, fig. 2).

10. Gowari Warhona.[1]

(INDIAN MANGANESE COMPANY.)

(*See Plate 40.*)

This village, marked on the 1-inch map as 'Gowaree Wandona', is about $\frac{3}{4}$ mile south-west of Khairí. The ore-deposit occurs to the north-west of the village, and Mr. P. N. Datta in the season of 1893-94 found fragments of ore scattered on the ground there, though he did not see the ore *in situ.* The late Mr. A. M. Gow Smith in 1903 independently discovered the deposit, and located it by means of pits and two outcrops seen in nálá-beds. The accompanying sketch-plan (Plate 40, fig. 1) shows the position of the ore-band and of the pits and trenches. The deposit has been thus proved for a total length of nearly 1,600 feet. Its average thickness seems to be $5\frac{1}{2}$ to 6 feet, with a strike of W. 35° N., and a dip to the south side of the strike at an average angle of about 50°.

The ore-band seems to be composed of very good material, being best at its north-west end, as seen in pit 1, where it is crystalline in two or three varieties, and is—like the whole of the deposit—divided by planes parallel to the bedding so as to cause the ore to separate into tabular pieces averaging 1 to $2\frac{1}{2}$ inches in thickness, but ranging between $\frac{1}{2}$ and 4 inches.

[1] *Rec. G. S. I.*, XXXIII, p. 214, (1906).

At the south-east end, where exposed by the four trenches, Nos. 1 to 4, there is a quantity of intercalated schistose, quartzose and felspathic material, and the 'country' is seen to be partly soft spessartite-quartz-rock (gondite) and partly felspathic schists secondarily impregnated with manganese. The ore seen in these trenches, and in the nálá exposure (B) immediately to the south-east, is still fairly good, but shows evidence of deterioration in quality, which is further shown by an outcrop in another nálá about 300 yards to the south-east of this exposure where the ore-band has taken the form of an outcrop 9½ feet wide, consisting of alternating layers of yellow-brown gondite—altered to soft ore in bands and patches—, schists, and fine-grained biotite-gneiss, with some vitreous quartz-rock.

Regarding the distance to which this ore-band may be expected to extend, it will be seen from map, Plate 20, *Rec. G.S.I.*, Volume XXXIII, that about ¼ mile to the north-west of pit 1 the ore is cut off by crystalline limestone, possibly due to faulting, and that the same thing occurs about ¼ mile to the south-east of exposure B. Hence the total distance to which the ore-body may extend is ¾ mile.

About 750 feet to the north-east of the above ore-band, pit 7 exposes another inferior band, which is possibly further represented by a 5-inch band of gondite in the nálá flowing to the east of the village.

The rocks in which these two ore-bands occur are mainly soft grey biotite-gneisses, biotite-felspar-schists, and muscovite-gneisses, the whole with thin intercalated bands of soft quartz-felspar-rock.

Quantity of ore available.

We have here a case in which it is possible to make an estimate of the quantity of ore available; for the main ore-band, simulates a coal seam in its regular strike, dip and thickness between pit 1 and nálá exposure B, though probably not in constancy of composition. We will take the total length between the above points as 1,600 feet, the average thickness of the deposit as 6 feet, and the specific gravity of the ore as 4½. Owing to the diminishing quality of the ore at the south-east end, where it will need careful cleaning, and to allow for wastage, etc., we will reject 30 per cent. of the ore. Then if the ore continue in depth of the same quality and thickness as at the surface for 20 feet, the quantity of ore available is—

$$\frac{1{,}600 \times 6 \times 20 \times 62{\cdot}5 \times 4{\cdot}5}{2{,}240} \times {\cdot}7$$

$$= 16{,}875 \text{ tons.}$$

or say 17,000 tons.

Hence for every 10 feet, measured down the dip of the rocks, that the ore extends in depth with the above thickness and quality, 8,500 tons of ore might be extracted. Taking 40 feet as the maximum depth to which it might be profitable to extract the ore under present conditions, we see that there is a possible yield of 34,000 tons of ore from this deposit; *if the deposit continue in depth of the same quality and thickness as at the surface.*

Since the foregoing was written I have been able to revisit the deposit (December 1907). By this time a considerable amount of work had been done on the deposit, in the form of the usual opencast excavations. This work has shown that the ore-band is much less regular than one would suppose from the outcrops and prospecting pits and trenches first constructed. Thus to the east of the nálá section (B) a dyke of a coarsely crystalline rock, composed of pinkish felspar with a little quartz, has been exposed, cutting across the ore-band nearly at right angles. It strikes E. 40° N., is practically vertical, and has a width of 3 to 4 feet. In some places the ore-band is doubled on itself and sharply folded. Towards the west end the ore-band is often broken, disappearing in places owing to pegmatitic intrusions. In one place the ore-band has apparently been faulted horizontally for a few feet.

Nature and quality of the ores.

Three sorts of ore are found in this deposit. One is the usual very fine-grained braunite-psilomelane mixture, another is a mixture of these two minerals in which the braunite predominates and is in crystals up to $\frac{1}{4}$ inch in diameter; the third is made up of small parallel prisms of a manganate, to which the name hollandite may be extended. This type of ore tends to form the outside of layers of ore, of which the inside is composed of the first variety.

I selected a piece of the last variety for complete analysis at the Imperial Institute. It showed a layer of the crystalline prismatic mineral of a shining light steel-grey appearance resting on ore that seemed to be composed of a mixture of this crystalline mineral with braunite. The analysis is as follows:—

Specimen No. 752 (16·998).

Manganese peroxide	70·84
Manganese protoxide	14·21
Ferric oxide	4·91
Alumina	0·36
Baryta	6·18
Lime	0·47
Magnesia	0·30
Combined silica	1·23

Free silica	0·48
Phosphoric oxide	0·07
Arsenic oxide	0·002
Combined water	0·39
Moisture at 100°C.	0·07
Carbon dioxide	0·04
	99·552

This is equivalent to :—

Manganese	55·94
Iron	3·44
Silica (total)	1·71
Phosphorus	0·031

In calculating this ore into terms of its mineral composition I found that the best interpretation is to assume that the braunite has the customary formula $3Mn_2O_3.MnSiO_3$, and that the crystalline prismatic mineral is a manganate allied to hollandite, which it resembles in appearance, the high percentage of baryta being an especially good indicator of the presence of a manganate. The mineralogical composition can be stated as follows :—

Apatite		0·16
Calcite		0·09
Braunite ($3Mn_2O_3.MnSiO_3$)		12·32
Hollandite :—		
$Fe_4(MnO_5)_3$	9·65	
$Al_4(MnO_5)_3$	0·91	
Ba_2MnO_5	8·25	
Ca_2MnO_5	0·63	
Mg_2MnO_5	0·68	
H_4MnO_5	1·50	
Mn_2MnO_5	63·96	
	85·58	85·58
Free Silica		0·48
Moisture		0·07
As_2O_5		0·002
Surplus oxygen		0·85
		99·552

The surplus of 0·85 % of oxygen, may be due to experimental errors in its determination, or perhaps more probably it can be taken as indicating that a portion of the manganese manganate is in the manganic form $Mn_4(MnO_5)_3$ and not all in the manganous form as represented.

I took a sample of the ore from the two outcrops and all the pits and trenches along the main band of ore. From pit No. 1 and the two outcrops the ore was broken from *in situ*, whilst from the other pits and trenches it was taken from the small heaps of ore that had been extracted. The ore in the sample consisted of various pieces of the braunite-psilomelane mixtures with a fair amount of ore containing the crystalline manganate. The analysis was carried out at the Imperial Institute with the following result :—

Sample No. 7.

Manganese peroxide	54·02
Manganese protoxide	25·02
Ferric oxide	7·15
Combined silica	4·55
Free silica	1·66
Phosphoric oxide	0·17
Moisture at 100°C.	0·31

This is equivalent to :—

Manganese	53·59
Iron	5·00
Silica (total)	6·21
Phosphorus	0·074

and indicates that the ore is composed of about 45 per cent. of braunite, with the balance largely made of the two manganates, psilomelane and hollandite.

For comparison with the foregoing analyses I give below some others extracted from the reports of Messrs. H. K. Scott and W. Selkirk :—

Analyses of samples taken by Mr. Scott.

Number.	1	2	3	4	
Manganese . .	53·87	51·82	54·15	56·45	Dried at 212°F.
Iron	2·76	3·10	2·56	1·31	
Silica	2·65	10·15	1·45	6·37	
Phosphorus . .	0·041	0·090	0·030	0·072	

No. 1. From test pits at west end of property and mostly of beautiful crystalline appearance.
No. 2. From cross-cuts at east end of property and containing some decomposed felspar and kaolinic matter.
No. 3. Mineral from outcrop with crystalline structure.
No. 4. Do. , but of massive and amorphous character.

Analyses of sample taken by W. Selkirk.

Number.	5	6	7	
Manganese	47·45	51·94	53·66	Dried at 212°F.
Iron	3·55	3·60	3·83	
Silica	13·65	8·30	5·30	
Phosphorus	0·122	0·039	0·064	

No. 5. From outcrop in stream-bed at east end (nálá exposure B).

No. 6. From outcrop in stream-bed at 200 yards further west (nálá exposure A).

No. 7. From pit 2.

The working of the deposit.

Judging from the analyses above there is no doubt that some at least of the ore of this deposit is of very good quality, and it can only be a question of transport and prices as to whether it will pay to work it. During 1906 and 1907 the deposit has been actively worked by the usual opencast methods. Considering the narrowness of the ore-band and the large amount of dead-work that will be necessary to win the ore as the depth of the working increases, it originally seemed to me that this was a deposit that should be mined from the very beginning, and not quarried, provided of course the result of boring tests justified this. The way in which the ore-band has been crumpled in places, and broken by pegmatitic rocks, as noticed above, and the extreme softness of the 'country' renders it doubtful, however, if it would have been economically possible to actually mine this deposit. Nevertheless, as a result of not mining the deposit, it will probably be abandoned when the workings have reached a depth of 40 feet (20 to 25 feet was the greatest depth reached by the time of my visit in December 1907); and unless some boring be then done it will not be known whether or not a large quantity of valuable ore has been left in the ground.

The deposit is situated about one mile south-west of the main Nágpur-Chhindwára road at a point 31 miles from Nágpur. The ore despatched from this deposit during 1906 and 1907 was carted over this route.

The output of ore from this deposit during 1906 and 1907, before which it was not worked, is shown below :—

Output.

Year.	Long tons.
1906	1,269
1907	11,962

11. Dudhara.[1]

On the south-east side of 'Dudara H' are two bands of spessartite-quartz-rock (gondite), both of them much too fresh to be of any commercial value. The strike is south-east with a dip of 50° to the south-west, whilst the 'country' consists of soft biotite-gneisses and schists. At their north-west ends, where they pass under the Lametas and trap of Dudhára Hill, they are in the Chhindwára district, while at the south-east end they run into the Nágpur district and are there lost in the jungle. The more south-westerly of the two bands is extremely interesting; for it is a fine example of the lenticular thickening and thinning of bands of gondite. At its widest point it is 75 feet across; whilst it thins out to practically nothing at its N. W. end, and also disappears when traced to the S. E. After this it reappears as a thin band and runs into the Nágpur district.

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[1] *Rec. G. S. I.*, XXXIII. p. 214, (1906).

CHAPTER XXXV.

DESCRIPTION OF DEPOSITS—*continued.*

The Central Provinces—Hoshangábád and Jabalpur Districts.

Hoshangábád district.—Sontulai.

Jabalpur district.—History—Geology—The Sihora beds—Hematite-jasper—Manganiferous hematite—Psilomelane—Source of the manganese—Formation of the ores—The Gosalpur quartzites—Pyrolusite—Manganiferous limonite—Lateritoid—Manganese in laterite—Economic value of the deposits—List of localities.

Kuan—Kasái Hill—Darshani—Ponra Hill—Mansakra—Mangela—Ghogra and Dhanwáhi—Sakri—Khatola—Paharewa—Mangeli—Bhátádon—Gosalpur—Dharampura.

Hoshangábád District.

During the field season of 1902-03 I found several occurrences of manganese-ore in this district. Since that time, however, the boundaries between this district and Nimár have been altered, with the result that all the occurrences now lie within the Nimár district—under which heading they are noticed—with the exception of Sontulai in the Harda tahsil.

Sontulai.

In December 1902, I found, in the middle of the road at the west end of the village, an outcrop of some impure black wad, weathering brown, and apparently interbedded with some quartzose and brecciate rocks, presumably of Bijáwar age. The strike is E. N. E. with a moderate dip to the south side. The outcrop was of small extent, but the ore may continue under the soil in either direction along the strike. A specimen was sent to the Geological Survey office and found by Mr. Blyth to contain

21·43 per cent. of manganese. Later, when at head-quarters, I made a complete analysis of another sample with the following result[1] :—

Sample M. 4.

MnO_2	24·13
MnO	1·91
$Fe_2O_3 + Al_2O_3$	2·28
BaO	0·67
MgO	trace
SiO_2	69·18
P_2O_5	0·03
CoO	0·17
NiO	0·38
CuO	0·47
H_2O (combined)	0·88
Moisture	0·53
	100·63

This is equivalent to :—

Manganese	16·73
Phosphorus	0·014

This ore is of course of no economic value, and I would not recommend anyone to spend any money on opening up the occurrence. I do not know what is the origin of the deposit; I imagine that it is not a true bed, but is more probably the result of the surface replacement of some very siliceous rock. For a calculation of the foregoing analysis into terms of manganates, see page 112. The possibility of making this re-arrangement points to the mineral's being psilomelane; but from its physical characteristics, especially its softness, it had better be called wad. The presence of the quantities of oxides of cobalt, nickel, and copper, shown is consistent with the mineral being called wad, some wads being rich in these constituents.

Jabalpur District.

History.

The manganese-ores of the country round Gosalpur and Sihora in this district have at one time or another aroused a great amount of interest, and they

[1] *Rec. G. S. I.*, XXXI, p. 48.

were well known long before much attention was given to manganese-ore deposits in other parts of India. Mr. Olpherts in 1875 first brought the Gosalpur pyrolusite to the notice of Government. In 1879 it was examined by Mr. H. B. Medlicott, the then Superintendent of the Geological Survey, and a note on the ore, with an analysis, published by Mr. Mallet.[1] In his paper on the iron-ores of the north-eastern portion of the Jabalpur district [2] published in 1883, Mr. Mallet describes the manganiferous hematite with associated psilomelane of Ghogra, Dhanwáhi, Khatola, and Gosalpur. In a second paper[3] immediately following he gives his views on the origin of the Gosalpur pyrolusite.

In 1884, Mr. C. W. McMinn, then Deputy Commissioner of Jabalpur, sank a number of pits to ascertain the extent of the Gosalpur manganese-ores, and Dr. King, who had succeeded Mr. Medlicott as Director of the Geological Survey, paid a hurried visit in the same year. In the Durga Puja holidays of 1887, Mr. E. J. Jones of the Geological Survey continued the exploration of the ores, and immediately after Mr. P. N. Bose, also of the Geological Survey, was deputed to make a thorough examination of the manganese-ores of this district. Mr. Bose's work led to the discovery of many additional localities for pyrolusite, psilomelane, and manganiferous hematite; and to test several of them he had numerous pits and trenches dug. The result of his labours is published in two separate papers, the first [4], in 1888, giving a detailed description of the various deposits, with, in many cases, estimates of the quantities of ore available, and the second[5], in 1889, dealing with the geological relations and origin of the ores.

During 1904 I paid a visit to this district and examined several of the principal deposits, cleaning up a few of Mr. Bose's trenches and pits. As the result of this examination I find myself in fairly good

[1] 'On Pyrolusite with Psilomelane occurring at Gosalpur, Jabalpur District.' *Rec. G. S. I.*, XII, pp. 99, 100, (1879).

[2] *Rec. G. S. I.*, XVI, pp. 94—115.

[3] 'On Lateritic and other Manganese Ore occurring at Gosalpur, Jabalpur District.' *Ibid.*, pp. 116—118.

[4] 'The Manganese-Iron and Manganese-Ores of Jabalpur.' *Rec. G. S. I.*, XXI, pp. 74—89, (1888).

[5] 'The Manganiferous Iron and Manganese Ores of Jabalpur.' *Rec. G. S. I.*, XXII, pp. 216—226, (1889).

agreement with Mr. Bose's descriptions and conclusions, except on the one point of the quantity of ore available. With regard to this, I think Mr. Bose has in most cases overestimated the amount of merchantable ore that the evidence obtained from the pits and trenches dug justifies one in expecting to be present.

Geology.

Mr. Bose has given an excellent geological sketch of this area, and published with his first paper a geological map of the manganese area showing the distribution of the various manganese-ores. The geological part of this map is largely based on a map made by Mr. C. A. Hacket in 1871. But certain alterations were made by Mr. Bose, and the localities for manganese-ore are, of course, all his own additions; and for most of the localities mentioned in this chapter I will refer the reader to Mr. Bose's map.

The manganese- and manganiferous iron-ores occur in two formations, namely, in laterite and in 'transition' rocks. The 'transition' rocks have been previously described as Bijáwars; but in view of their extremely metamorphosed condition and general lithological resemblances, there is reason to suppose that these rocks are really of Dhárwár age, and as such they will be referred to here. These so-called Bijávars were divided by Mr. Hacket into four groups as follows:—

1. Chanderdip group.
2. Lora ,,
3. Bhitri ,,
4. Majhauli ,,

Practically all the ores occur in the Lora group, though Mr. Bose gives three localities for pyrolusite in his Majhauli-Bhitri group. Mr. Bose subdivides the Lora group into two divisions:—

1. Sihora beds,
2. Gosalpur quartzites,

the Sihora beds being the overlying rocks.

The manganese-bearing area of the Lora rocks stretches S. S. W. from the E. end of the Lora range of hills to Sihora and Paharewa, a distance of nine miles. Here alluvium supervenes for about two miles, and then the same rocks appear at Naigain, with a marked shift in their alignment, due either to a fault or a very sharp change in strike, and extend S. W. for another nine miles through Gosalpur to Marhásan and Chindamani. The width of this strip of rocks varies from three to five miles. Roughly speaking the outcrop takes the form of a lenticular patch of slaty shales and banded hematite-quartzites, flanked on both sides by massive quartzites.

'The shales and micaceous hematite-banded quartzites form a distinct synclinal (which we shall call the Lora syncline) just west of Gosalpur, their dip at Gosalpur pointing north-north-west and at Ghugri in the opposite direction. In the south-western direction the syncline is traceable to Murhasan and Khorawul, the micaceous,—hematite-banded quartzites, or hematite-quartzites, as they may be more conveniently called, forming two broken parallel ridges, and the shales superposed on them, the valley between. North of Gosalpur, the syncline is more or less distinctly traceable to the Lora range proper, where the rocks are greatly folded and contorted.'[1]

The Sihora beds.

The above-mentioned beds constitute Bose's *Sihora beds*, and the massive flanking quarzites are his *Gosalpur quartzites*; he supposes them to pass under the Sihora beds, though signs of bedding are very difficult to find in the Gosalpur quartzites. According to Bose the sequence of the Sihora beds is as follows (in ascending order) :—

'1. Slaty shales.

2. Thin laminated quartzites usually of a jaspery type, and often parted by layers of micaceous iron ore interstratified with shales.

3. Slaty shales, usually sheeny and tinted red.'[2]

White talcose shales occur interlaminated with the other shales and hematite-jaspers, and also in separate beds.

Hematite-jaspers.

The banded hematite-jaspers are most strongly developed in the Lora range. The typical rock is composed of alternating bands of a reddish, lavender, or whitish, jasper or jaspery quartzite, and of a schistose micaceous hematite splitting easily along the schistosity planes so as to show a shining satiny lustre (see Plate 9). The rock is often extraordinarily contorted, and when this is the case bands of jasper or hematite are frequently seen to thin or thicken in a lenticular fashion, or even to pinch out entirely, this being possibly a result of the contortion. This

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1 Bose, *Rec. G. S. I.*, XXII, p. 218.
2 *Ibid.*, p. 220.

contortion has occasionally produced a cleavage in the hematite which cuts the lamination planes at an acute angle, though the cleavage usually coincides with the lamination.

Frequently the hematite contains scattered octahedral magnetite crystals varying in size from a pin's head to ⅛ inch or ¼ inch in diameter, and these stand out on the cleavage planes as tiny elevations or pimples over which curve hematite films; the crystals weather out in their typical octahedral shape.

A much less common rock is one composed of bands of very finely granular magnetite alternating with jaspery bands, usually whitish or brown in colour.

The siliceous bands that separate the hematite or magnetite layers are seen microscopically to consist usually of microcrystalline quartz, sometimes almost cryptocrystalline, and at other times slightly more coarsely crystalline; they may accordingly be termed jasper or jaspery quartzite according to their degree of fine-grainedness. The varying colours are due to varying impurities. When white the impurities are, of course, very small in amount, but when reddish there is usually a certain amount of crystalline hematite in tiny scattered grains or of opaque red ochre, while the brown jasper associated with the magnetite bands is seen to contain clouds of minute scattered magnetite cubes or octahedra. The quartz, when in sufficiently large grains, often shows undulatory extinction; further the rock commonly shows minute quartz veins traversing the various bands of jasper and iron-ore indiscriminately.

The hematite bands vary in thickness from mere partings of the thickness of a hair in the jasper or quartzite, up to solid ore in layers as much as two or three inches thick, with the siliceous bands quite subordinate, or even absent, *e.g.*, at Dhanwáhi, Dharampura, and Gosalpur. This hematite is often very fissile, splitting into thin laminæ, which are not very friable, but which show a brilliant satiny lustre, sometimes with fine waves due to minute contortions. At other times the hematite is not nearly so fissile, but is more friable, readily yielding to the fingers abundant tiny scales of micaceous hematite. This latter is more like a schist of micaceous hematite, while the former variety more resembles a well-cleaved slate in structure, and it is possible that the difference is due to the cleavage corresponding with the banding or original bedding in the former case, and to the cleavage cutting the banding obliquely in the latter case. The accompanying figure shows an actually observed case. In either case the rock is probably best described as a micaceous hematite-schist, or, when banded with silica, as a banded micaceous hematite-jasper or quartzite or more simply as *banded hematite-jasper or quartzite.*

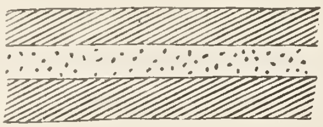

Fig. 48.—Banded hematite-jasper showing slaty cleavage. Natural size.

Manganiferous hematite.

In several places these hematites have been greatly altered at the surface with the production primarily of manganiferous hematite and later of psilomelane. Quite fresh micaceous hematite has a bright red streak, but as it becomes more and more manganiferous the streak changes through dull red, chocolate, brown, and brownish-black, to the black colour characteristic of psilomelane. This change is also accompanied by a gradual loss of lustre (and of hardness, in the case of the harder variety of hematite) and texture, with the production of a dull black soft rock still retaining the abundant signs of the original schistosity. In the later stages of the change thin veins of psilomelane appear both parallel to and cutting across the lamination of the hematite, and as irregular segregations; but at the earlier stages it is not possible to see what is causing the change of character. It may possibly be a replacement or coating, scale by scale, of the original hematite by psilomelane, so that the hematite individuals still remain separate; whilst later they unite to form visible psilomelane in places. Such ore, in which traces of the original structure still remain, and in which visible psilomelane may or may not have appeared in any quantity, is what has been described as *manganiferous hematite.*

The following analyses of samples taken by me show that this ore still contains a very large proportion of iron :—

Locality.	Dharampura.	Sakri.
Number of sample.	A. 17.	69
Manganese peroxide (MnO_2)	32·28	24·12
Manganese protoxide (MnO)	2·50	2·13
Ferric oxide (Fe_2O_3)	35·28	37·39
Baryta (BaO)	1·19	..
Combined silica (SiO_2)	4·15	2·51
Free silica (SiO_2)	15·50	7·22
Phosphoric oxide (P_2O_5)	0·355	0·05
Arsenic oxide (As_2O_5)	0·008	..
Combined water (H_2O)	2·60	..
Moisture at 100° C.	0·30	0·14
These are equivalent to—		
Manganese	22·34	16·91
Iron	24·70	26·17
Silica	19·65	9·73
Phosphorus	0·155	0·02

A. 17.—Analysed by J. and H. S. Pattinson.

69.—Analysed at the Imperial Institute.

An analysis by Mallet of a sample from Ghogra and Dhanwáhi is given on page 825. It shows :—

Manganese (trace of cobalt)	12·26
Iron	46·43
Silica (insoluble residue)	9·55
Phosphorus	0·12

Psilomelane

As a final stage the whole rock may become converted into psilomelane, often containing remains of original hematite jasper, shale, or talc; then, of course, except for these remnants, the original rock structure has been entirely obliterated. As an example of such final concentration of the manganese as psilomelane may be mentioned an analysis of psilomelane from Gosalpur by Mr. Mallet, which yielded 83·20% available peroxide =52·53% Mn [1], and of a sample (A. 18) of psilomelane collected by me at Dharampura (see page 834).

[1] *Rec. G. S. I.*, XVI, p. 118.

Source of the manganese.

As to the source of the manganese that converts apparently non-manganiferous micaceous hematite into manganiferous hematite at the outcrops in certain localities--for this manganiferous hematite is not to be found in every place where hematite occurs—Mr. Bose says [1] :—

'There can be hardly any doubt that the original source of the manganese ores of the Jabalpur ground is to be sought for in the micaceous,—iron-banded quartzites of the Lora group. The hematite usually assumes the form of micaceous iron ore, and has manganese disseminated in it, though in very minute quantities.'

This latter appears to be an assumption based on probability; for no analytical or other evidence is given in support of the statement. That this assumption is probably correct, however, is indicated by the two following partial analyses by Messrs. J. & H. S. Pattinson. Sample A. 7 is of apparently non-manganiferous hematite from hill 1520 at Mangela, in the manganese area, and sample A. 10 represents the soft red hematite of similar age worked by native iron smelters at Jauli, outside the manganese-area :—

Locality.	Mangela.	Jauli.
Number of sample.	A. 7.	A. 10.
Ferric oxide	69·86	85·57
Ferrous oxide	*nil*	*nil*
Total silica	20·40	5·80
Combined water	1·40	2·50
Moisture at 100° C.	0·35	0·30
Iron	48·90	59·90
Manganese	1·70	0·16
Phosphorus	0·479	0·043

Formation of the ores.

Assuming that we may take it as settled that the fresh micaceous hematite does contain manganese in minute quantities, then it seems that, when the outcrop of the hematite-quartzites is subjected to weathering, both iron and manganese go into solution, and that the solution, percolating through the cracked surface rock, deposits its manganese in a state of fine dissemination in the unaltered hematite. Some of the manganese also replaces the bands of quartzite, jasper, phyllite, and shaly slate,

[1] *Rec. G.S.I.*, XXII, p. 222.

often present in the hematite, all these substances being carried away in solution, and the interchange being probably, at least in part, metasomatic. This process of concentration of manganese and removal of iron continuing for a long time results in the final change of the whole outcrop into psilomelane boulders and nodules, resting upon manganiferous hematite veined with psilomelane, with this passing gradually downwards into unaltered hematite.

The Gosalpur quartzites.

Turning now to the Gosalpur group, which Bose supposes to underlie the Sihora beds, we find it to be composed principally of quartzites varying greatly in colours, various shades of white, brown, grey, yellowish, and reddish prevailing. In texture they are usually very fine-grained, sometimes fine enough to be called jaspers, and typical red jasper is not an uncommon rock in this group, *e.g.*, at Mangeli. Occasional thin partings of micaceous hematite are also found in these quartzites at places. The Gosalpur quartzites show bedding but seldom, and are very frequently brecciated at the surface, showing angular fragments of quartzite set in a matrix that may be limonite, pyrolusite, psilomelane, ochre, or chert. In some cases this brecciation strongly suggests the fault breccias that are so common in the Dhár forest and elsewhere; this especially applies to the breccias with a chert matrix. But in the majority of cases this brecciation is only superficial and is due to chemical changes affecting the rock, and possibly taking advantage of cracks. A very common way in which this change takes place is as follows. In the white quartzite, for example, tiny round yellow spots appear, often arranged in bands, and these spots become more and more numerous, finally joining together so as to produce a soft sandy yellow rock in which are enclosed unaltered areas of the original quartzite. These being usually angular in area impart to the rock the aspect of a fault breccia of white quartzite set in a soft sandy or ochrey yellow matrix. This rock is seen in many of Mr. Bose's pits at Gosalpur and elsewhere to pass downwards in the course of a few feet into unbrecciated, and but slightly altered, quartzite.

Pyrolusite.

It is in association with the Gosalpur quartzites that the pyrolusite of this district is usually found. The relationship of the pyrolusite to the quartzite is well seen in many of Mr. Bose's pits at Gosalpur.

The following section [1] recorded by Mr. Bose is a typical one :—

2′ Soil.

2′ 8″ Abundant nodules of *pyrolusite*, ¼ inch to 6 inches in diameter, mixed up, as usual, with nodules of iron-ore. A little *psilomelane* and *wad* occurs in association with the *pyrolusite*.

4′ 10″ Fragments of decomposed yellowish, and yellowish-white, mottled quartz-rock, becoming larger and more abundant towards bottom. *Pyrolusite* occurs in the interstices in larger blocks than in the preceding stratum and with cavernous spaces containing the decomposed quartz-rock.

Decomposed quartz-rock with veins and nests of *pyrolusite*.

In some of the other pits this quartz-rock or quartzite is seen to pass down into similar decomposed rock free from pyrolusite, and doubtless this passes still lower down into fresh quartzite. The iron-ore is limonite.

Occasionally psilomelane predominates over pyrolusite in this decomposed quartzites, as in the following section noted by me in one of the old pits :—

6″ Soil.

3′ 6″ Small nodules and flat pieces of psilomelane with granules of the same. Also a few remains of quartzite and a little limonite. But nearly all more or less good psilomelane; which, however, often shows soft yellowish remains of quartzite. Occasionally there is a little pyrolusite, which either occurs filling or lining cavities in the psilomelane, or, occasionally, in thin radiated crusts on the psilomelane.

4′ Decomposed white to yellow crumbly Gosalpur quartzite with fairly numerous veins of psilomelane in cracks or cavities.

It will be judged from these sections, and is very clearly seen in the field, that the manganese-ore has been introduced into the quartzite by a process of replacement; in which the silica of the quartzite has been taken into solution and manganese-ore, usually pyrolusite, deposited in its place. This replacement has been effected at the surface, so that there is a passage downwards from the ores containing very little residual quartzite at the surface to the decomposed quartzite containing scattered veins and nests of the pyrolusite, and from this into the blotched quartzite, in which ochre has appeared in spots as described on page 811; but in which manganese-ore has not yet appeared. This rock passes still lower down into quite fresh quartzite. The ores thus formed by this superficial replacement are of course similar in origin to those found in many other parts of India, as, for example, in Mysore, Singhbhum, and the Panch Mahâls.

[1] *Rec. G. S. I.*, XXI, p. 79.

It depends on the degree of completeness to which the replacement has been carried as to whether the ore is of commercial value or not. When the replacement has not been pushed far enough the ore is apt to be very siliceous owing to the large proportion of the grains of quartz that have escaped replacement. When, however, the replacement has been pushed to its utmost limit, an ore may be produced that is practically free from quartz. This is well illustrated by the analyses given below. The pyrolusites they represent are from four different localities, and have all been formed at the surface by the replacement of quartzites. It will be noticed that in the sample from Gosalpur the process of replacement has been pushed nearly to completion, so that there is now only 1·85% of silica left, whilst the percentage of manganese has risen to 56·80. In the Mansakra sample the replacement has been carried nearly as far, but replacement by iron in the form of limonite has accounted for a somewhat larger proportion of the change than has replacement by manganese. In the Paharewa and Mangeli sample the replacement is much less complete, 17·30% of silica being left in the former case and 11·35% in the latter. Here also about half of the replacement has been effected by iron and about half by manganese, although the presence of iron in such large amount would not have been suspected from the physical aspects of the ore. These two latter samples showed residual siliceous matter in quantity, whilst even the Gosalpur sample showed occasional quartz.

Number of sample.	63	68	A.6	A. 16
Locality.	Mansakra.	Paharewa.	Mangeli.	Gosalpur.
Character of the ore.	Pyrolusite with limonite.	Pyrolusite.	Pyrolusite with psilomelane and limonite.	Pyrolusite.
MnO_2	34·92	37·07	37·90	88·58
MnO	2·46	1·53	2·13	1·03
Fe_2O_3	44·96	38·06	37·42	2·28
BaO	trace	..	0·10	1·61
SiO_2 (combined)	2·13	2·48	5·35	1·75
SiO_2 (free)	2·27	14·82	6·00	0·10
P_2O_5	0·50	0·31	0·655	0 355
As_2O_5	..	..	..	*nil*
H_2O (combined)	..	..	7·00	2·60
Moisture at 100° C. . . .	0·44	0·12	0·60	0·40

These are equivalent to:—

Number of sample.	63	68	A.6	A. 16
Locality.	Mansakra.	Paharewa	Mangeli.	Gosalpur.
Character of the ore.	Pyrolusite with limonite.	Pyrolusite.	Pyrolusite with psilomelane and limonite.	Pyrolusite.
Manganese	24·00	24·65	25·60	56·80
Iron	31·47	26·64	26·20	1·60
Silica (total) . . .	4.40	17·30	11·35	1·85
Phosphorus. . . .	0·22	0·135	0·286	0·155

Sample No. 63 was taken along the Mansakra ridge. It consists of pyrolusite with a certain amount of chert-like limonite, and some residual quartzite. Analysed at the Imperial Institute.

Sample No. 68 was taken from a gravel pit on the south side of the hill to the east side of the Mirzapur road, where there were exposed numerous bands of pyrolusite in a laminated sandstone-like rock, which was probably really a decomposed form of the Gosalpur quartzite. Some of the pieces in the sample showed siliceous bands. Analysed at the Imperial Institute.

Sample A.6 was taken from two of the pits on south side of the small hill just to the west of Mangeli village. Besides pyrolusite the sample included a few pieces of psilomelane; and some of the pieces of pyrolusite showed some limonite and hematite; and a little siliceous remains. Analysed by J. and H. S. Pattinson.

Sample A.16 was taken from one of the sides of one of the large irregular pits at Gosalpur. It consists of fine-looking pyrolusite, which occurred as a bed about 1 foot thick at a depth of 4 feet from the surface. The bed was apparently composed entirely of pyrolusite nodules from ½″ up to 6″ in diameter; but did not continue far laterally, the pyrolusite giving way to psilomelane and limonite in one direction. It is overlain by 6″ to 1′ of limonite nodules and this by soil containing scattered fragments of limonite and quartzite. Analysed by J. and H. S. Pattinson.

Manganiferous limonite.

In some places at the surface the ridges of both the Sihora or Gosalpur divisions of the Lora group (as mapped by Mr. Bose) are capped by masses of limonitic rock, which is usually somewhat manganiferous. I am inclined to think, however, that at Mansakra the rocks mapped as Gosalpur by Mr. Bose may be Sihora. If this be the case, these limonitic cappings are restricted to the Sihora beds. The limonite itself often shows a sort of slaty structure when resting on the outcrops of Sihora beds, as at Sakri and Kasai Hill, and it seems probable both from this circumstance, and because of residual fragments sometimes found in the limonite, that these limonites have been formed by the replacement at the surface of the interbanded shaly slates and hematite-jaspers, the resultant limonite retaining the slaty structures of the replaced rocks. These limonite are sometimes, however, free from this slaty structure and are then chert-like in appearance, and vary in colour from ochreous brown to liver-brown. The limonite is often traversed by veins of psilomelane; which is also often present in the limonite in irregular concretionary masses, sometimes of considerable size, as on Kasái Hill. Should iron smelting on European lines ever start anywhere near this district, these limonites could probably be worked profitably and sorted as worked into iron-ore comparatively free from manganese, manganiferous iron-ores, and manganese-ores. The quantity obtainable at Darshani Hill, Kasái Hill, and the Mansakra ridge, and other localities in this area, is probably not inconsiderable, although it must be remembered that by its very origin this ore is only found superficially. As examples of the quality of these ores the following analyses of samples taken by myself are interesting :—

Analyses of manganiferous limonites.

Number of sample.	64	65	A.8
Locality.	Mansakra.	Sakri.	Kasái Hill.
MnO	0·05	0·00	8·64
MnO_2	1·48	0·91	0·95
Fe_2O_3	73·03	60·12	67·28
BaO	..	..	0·11
SiO_2 (combined)	1 22	2·05	4·30
SiO_2 (free)	3·99	9·58	0·80
P_2O_5	0·74	1·03	1·91
H_2O (combined)	..	..	10·36
Moisture at 100° C.	0·38	0·29	0·65
These are equivalent to :—			
Manganese	1·29	0·71	6·20
Iron	51·12	42·08	47·10
Silica (total)	5·21	11·63	5·10
Phosphorus	0·323	0·044	0 853

Sample No. 64 was taken all along the outcrop on the Mansakra ridge. It consisted mainly of the chert-like limonite, which often showed a certain quantity of manganese-ore in streaks and in cavities, the ore consisting of both psilomelane and pyrolusite. Some of the ore was rather clay-like and one piece consisted of soft yellow limonite with streaks of psilomelane and included angular quartzite. Analysed at the Imperial Institute.

Sample No. 65 was taken from the outcrop of limonite on the ridge situated about 1 mile E. N. E. of Sihora railway station, at the north end of the ridge. The sample consisted of limonite, often with psilomelane veins; one or two pieces showing remains of original micaceous hematite; and one piece red earthy hematite. Analysed at the Imperial Institute.

Sample A.8 was taken all along the top of Kasái Hill. The original sample was divided into two, one consisting of the manganese-ore (sample A. 9, not analysed), and the other (A. 8) of limonite rendered manganiferous by the presence of a certain number of psilomelane veins. The limonite shows the usual slaty structure, and, sometimes, stringers of radiated hard shining limonite. Analysed by Messrs. J. and H. S. Pattinson.

Lateritoid.

It will now be necessary to refer to the rock I have called lateritoid in the second part of this Memoir. The term *lateritoid*, it may be remembered, was introduced to describe those forms of manganese and iron-ore—formed on the outcrop of the rocks of the Dhárwár formation—that have some resemblance to the rocks usually called laterite; but which are nevertheless distinct from what is usually referred to as laterite by most geologists. Lateritoid is usually distinguished by containing residual fragments of the rock from which it has been derived by replacement, these fragments being merely the portions of the original rock that have escaped replacement at the time of formation of the lateritoid. From this point of view, therefore, all the pyrolusite, psilomelane, and manganiferous limonites and hematites to which reference has been made in the preceding pages should be classed as lateritoid.

Manganese in laterite.

In addition to the occurrences of manganese-ore that may be grouped under the term lateritoid, there are also some in what must be regarded for the present as true *laterite*. Some of the pyrolusite near Gosalpur occurs in the laterite that obscures a portion of the Dhárwár (Gosalpur) rocks of that neighbourhood. The manganese-ore that occurs in the laterite is not, however, of much importance as compared with the lateritoid occurrences of manganese-ore. The most notable occurrence is at

Bhátádon, where there is some manganese-laterite composed mainly of wad, for an account of which see page 830. This laterite is, however, closely associated with the surface-brecciated Gosalpur quartzite, and is hence only doubtfully to be regarded as true laterite. Also see Mallet, *Rec. G. S. I.*, XII, p. 99; and XVI, pp. 116-118.

Economic value of the deposits.

Turning now to the economic prospects of the ores of this district, and taking no account of the lateritic ores, which are of little value, there are the following ores to be considered:—micaceous hematite, manganiferous hematite, manganiferous limonite, psilomelane, and pyrolusite. As far as I could tell from the evidence it did not seem probable that any one of these ores was obtainable in large quantity. The *micaceous hematite*, which is the only ore not of secondary origin, is very much interbanded with jasper, although sometimes present in beds or layers of sufficient thickness to be of possible value. The *manganiferous hematite* being derived from this is naturally present in still smaller quantities. The *manganiferous limonites* occur in some quantity capping some of the ridges, and are to be considered as the best examples of lateritoid in this area. The *psilomelane* is the final product of the series of changes, of which the first is the conversion of ordinary hematite into manganiferous hematite, and as such is not found in any very large quantity, although it is possible that a considerable accumulation of this mineral may be found at one or two spots. The *pyrolusite* seems to be present in fair quantities at one or two localities, notably Mansakra and Gosalpur, and it is possible that a fair amount of it may be obtained if these deposits are ever carefully opened up. Apart from their irregular mode of occurrence, these ores suffer from a great variability of composition, due to the way in which they have been formed. They are also in many cases extremely phosphoric. The best prospect of their being worked at a profit would exist if iron works were set up to treat the iron ores of the Agaria and Jauli areas of this district.[1] The ores of the Sihora and Gosalpur areas could

[1] The report made by Mr. E. P. Martin and Prof. H. Louis on the prospecting operations that were carried out in this district under their direction were distinctly unfavourable with regard to the possibility of the success of such a project. See *Agricultural Ledger*, No. 3 of 1904, pp. 19—23.

then be worked as a whole and sorted into three products, iron-ore manganiferous iron-ore, and manganese-ore. Any attempt to work the manganese-ores alone is likely to be a source of loss to the operator, except at times of very high prices. It is also likely to lead to a loss of iron-ore that would be considered worth saving were any iron works in existence in the neighbourhood. As regards transport, none of the deposits are situated more than three miles as the crow flies from the Jabalpur-Katni branch of the E. I. R. During 1907, Mr. J. Kellerschon has opened up the Mansakra pyrolusite on behalf of the Carnegie Steel Co. with an output of 7,100 tons. See page 824 for the analysis of this ore.

List of localities.

The following is a list of the localities, arranged in groups according to their geographical situation, at which manganese-ore and manganiferous iron-ore have been found in this district:—

1	Emelia.	
2.	Hardua Khurd.	Sleemanábád Group.
3.	Kuan.	
4.	Bara Chhapra.	
5.	Kasái (Kashi) Hill.	Sihora Group.
6.	Darshani.	
7.	Ponra (Ponda) Hill.	
8.	Chhota Chhapra.	
9.	Mansakra.	
10.	Sihora	
11.	Mangela.	
12.	Ghogra.	
13.	Dhanwáhi.	
14.	Kurru (Kuro).	
15.	Lora Hill.	
16.	Sakri.	
17.	Khatola.	
18.	Paharewa.	
19.	Deori.	
20.	Mangeli.	
21.	Daroli.	
22.	Hargarh.	
23.	Bhátádon.	
24.	Muret (Muraith).	Gosalpur Group.
25.	Naigain.	

26. Chandnota.
27. Dhangáon.
28. Kailwás.
29. Chindámani.
30. Gosalpur. } Gosalpur Group—(*contd*).
31. Dharampura.
32. Hirdenagar.
33. Marhásan.
34. Keolári.
35. Nargáon.
36. Pararia (Pandaria). } Panagarh Group.
37. Nonsar.
38. Gangai.

I do not intend to give a detailed account of the occurrence of manganese at each of these localities. In the first place, I have not visited them all. Those to which I have been are Nos. 5-7, 9-14, 16-18, 20-23, 30, 31. In the second place, ample accounts of most of these occurrences have been given by Mr. Bose in the two papers already cited, while most of the localities are marked on the map accompanying the first of these papers. Hence I shall in most cases merely refer to Mr. Bose's papers, adding remarks of my own where it seems necessary. Of the two papers by Mr. Bose, the one in volume XXI of the Records has a pagination of 71 to 89, and the one in volume XXII of 216 to 226. Hence in referring to these I shall merely mention the page.

1. Emelia.

This place lies about 4 miles S. S. W. of Katni. Mallet gives an analysis of laterite from here containing 1·54% of Mn_2O_3, containing traces of cobalt [1].

2. Hardua Khurd.

See Bose, page 87.

3. Kuan.

A piece of pyrolusite, said to have formed part of a nodule weighing originally 5 or 6 lbs., was sent to the Geological Survey office by Lieutenant-Colonel H. F. Loch in 1906. It was found in the jungle 4 or 5 miles north of Kuan, which itself lies about 8 miles north of Sihora.

4. Bara Chhapra.

See Bose, page 86.

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[1] *Rec. G. S. I.*, XVI, p. 108, (1883).

5. Kasái (Kashi) Hill.

See Bose, pages 77, 86.

This is the hill marked on the 1-inch map as ·1523. On top of this hill are massive outcrops of limonite, apparently in horizontal columns striking W. 20° S. On the very top of the hill the limonite strikes E. 25° N., and at this point it is 36 feet across the limonite outcrop. The limonite shows a slaty or schistose structure, is brown in colour, and in places contains remains of yellow shale-like material, probably representing the rock that has been replaced with formation of the limonite. At the N. W. edge of the top of the hill the limonite is somewhat quartzose, containing remains of white quartz. The grain of the limonite is usually extremely fine, so that the ore looks amorphous, except for the slaty structure. It usually contains a number of tiny cavities, and is often traversed by strings of radiated hard shining limonite and of psilomelane, the latter sometimes filling cavities bounded by radiated limonite. In general, the psilomelane has been deposited subsequently to the limonite. Sometimes the veins of psilomelane are very numerous, forming a network ramifying through the limonite, and occasionally the rock is entirely psilomelane. This latter feature is especially noticeable a little way down the S. W. slope, where I saw quite a lot of psilomelane, one mass being about a yard cube as judged from the exterior. At this point the width of the outcrop of iron- and manganese-ore is about 45 to 50 feet.

The evidence obtained indicates that the limonite and psilomelane form merely a capping to the hill, being the result of the surface replacement of some underlying rocks striking about W. 30° S. and dipping at about 45° to the N. W. side. These rocks were possibly banded hematite- and magnetite-quartzites. If the cap of this hill were to be worked and sorted into two products, iron-ore and manganiferous ores, a fair quantity of ore might possibly be obtained; but I do not think it could be profitably worked as a source of manganese-ore alone. I took a sample by breaking off pieces of ore at intervals all along the top of this hill. This sample I subsequently divided into two, one of them (A. 8) consisting of limonite more or less manganiferous due to the presence of psilomelane veins, and the other (A. 9) of cavernous botryoidal psilomelane, with a little attached limonite and occasional remains of white quartz. The former sample only was sent for analysis and the result is given on page 815, from which it will be seen that the ore is a manganiferous iron-ore of good quality, except for the phosphorus. It would, however, make a valuable basic ore.

On the S. E. side of the Kasái Hill there is a low range of hillocks of magnetite-quartzites with a little hematite. These are brecciated at the surface, owing to the rock being partially replaced by limonite and psilomelane; but no ore of economic value is exposed. On the top of the most western hillock there is a good example of pyrolusite-cemented quartzite breccia, this rock being a result of the partial replacement of a quartzite that may belong to the Gosalpur division.

6. Darshani.

See *Bose*, page 77.

Darshani Hill is situated about $\frac{5}{8}$ mile north of the village of the same name, and is the one marked on the map as ·1418. It is perhaps 120 feet high referred to the surrounding plains. At first sight it seems to be composed entirely of the limonite seen on Kasái Hill. But it is probable that here also the ore occurs as a capping, perhaps extending part of the way down the slopes. The ore consists mainly of limonite, but contains a number of veins and patches of psilomelane, and in places the rock is entirely psilomelane. The ore often shows angular quartzose remains. Round the base of the hill there is a considerable amount of talus-ore, consisting of limonite and psilomelane, the latter often being rather pyrolusitic. It is probable that a considerable amount of limonite and manganiferous ore could be won from this hill, as at Kasái Hill, if it were worked for both sorts of ore.

I understand that some work was done on this hill during 1907 by a syndicate styled the Multiore Syndicate. But I have not heard the result of the work.

7. Ponra (Ponda) Hill.

See Bose, pages 76, 77, 225, 226.

This is the Ponri Hill of Bose (·1396 on map), and is apparently of no value as a source of either manganese- or iron-ore, except perhaps for some talus-ore. An interesting specimen obtained here was a piece of psilomelane retaining the original laminated structure of the shale or slate from which it had resulted by replacement, and also containing remains of the shale or slate, although in an altered condition. On account of its laminated character this ore resembles in appearance some of the ores of the Sandur Hills, especially those of Rámandurg.

8. Chhota Chhapra.

See Bose, page 84.

9. Mansakra.

See Bose, pages 85, 223.

The ridge in which these ores occur runs for about 2 miles in an E. N. E. direction, through the village areas of Mansakra, Silondi, and Majhgáon. A little ore seems to have been found in Majhgáon, but none in Silondi. All that follows refers to the Mansakra portion. It is difficult to say what is the predominant rock in the ridge, because of the secondary cappings of ores. But judging from fairly numerous exposures of the underlying rocks I think it probable that the ridge consists mainly of jasper or quartzite, with a band of hematite-jasper. Mr. Bose maps the ridge as belonging to the Gosalpur group, but on account of the presence of this hematitic band, it might seem more reasonable to include it in the Sihora group; except that there is no reason why the Gosalpur group should not include hematitic bands. At the west end of the ridge the quartzites have the appearance of having been brecciated and subsequently cemented by limonite, psilomelane, and pyrolusite. This brecciated appearance is really the result of replacement, although it is probable that the rock was to a certain extent brecciated during the earth movements that crumpled the rocks of this area. On the main portion of this ridge the replacement has often been carried further than on the western portions. I took a sample by breaking off portions of the rock all along the ridge, wherever it looked sufficiently good. The sample I divided into two. One of these (No. 63) consisted of pyrolusite containing a certain amount of residual quartz, and of chert-like limonite. The other (No. 64) consisted mainly of the chert-like limonite, often showing more or less manganese-ore in cavities and in streaks, this ore consisting of both psilomelane and pyrolusite. The results of the analyses of these samples are given on pages 814 and 815; it will be seen that the sample No. 63 is to be classed as manganiferous iron-ore rather than as manganese-ore.

In their report on the iron deposits of this district Messrs. Martin and Louis notice this occurrence as follows [1]:—

'It contains certain small deposits of iron ores which are different in every sense from those hitherto described; they consist of a couple of bands of siliceous brown hæmatite, striking about E.-W., and dipping southwards at an angle of about 60° into a low ridge some 600 yards long, rising to a height of about 70 feet above the surrounding plain. One of these bands seems to be about 40 feet thick and the other about 20 feet, but their persistency has not yet been proved. The ore as shown by the subjoined analyses, is of inferior quality, though its physical condition is satisfactory.

	Fe.	Mn.	SiO_2.	S.	P.	Moisture.
Wider band . . .	52·15	0·36	14 70	0·022	0·385	0·10
Narrower band . .	44·95	6·28	14·55	0·027	0·352	0·27

'The deposit is well situated, being about one mile from the railway line over fairly level ground.

'In the same ridge there are also small patches of manganiferous iron-ore, a sample of which gave the following analysis:—

Fe.	Mn.	SiO_2.	S.	P.	Moisture.
24·45	21·47	19·60	0·022	0·163	0·80

'With regard to these Silondi ores, it can only be said that if such a deposit were found close to existing iron works, it might possibly prove worth working, but under actual conditions, its highly siliceous character and the small quantity available deprive it of all value.'

Mr. Bose was led to conclude, as a result of his prospecting operations, that at one place about 900 feet west of the Mansakra-Silondi boundary there were some 9,000 tons of pyrolusite available. In the course of their prospecting operations Messrs. Wynne and Jones, working for Messrs. Martin and Louis, cut a trench across the ridge at about this point. The length of the trench as I saw it was about 206 paces, and the width about 7 feet. It is said to have been 10 to 30 feet deep, but by the time of my visit had all been filled up, except for the most southern 14 paces of it, where the ore exposed was manganese-ore and

[1] *Agricultural Ledger*, No. 3 of 1904, p. 23.

not iron-ore. The ore thus exposed was pyrolusite intimately associated with the chert-like limonite so common on this ridge. I am indebted to Mr. P. C. Dutt of Jabalpur for the following analysis by Mr. F. W. Harbord of a sample of ore taken from a trench situated a little to the east of the trench noticed above.

Manganese	40·78
Fe_2O_3 and Al_2O_3	12·46
Silica	18·04
Sulphur	0·004
Phosphorus	0·160
Moisture	0·40

During the year 1907 Mr. J. Kellerschon has worked this deposit on behalf of the Carnegie Steel Co. The ore-body opened up was found to be about 10 feet thick, 240 feet long, and 120 feet wide. The amount of ore won to the end of 1907 was 7,100 tons. Of this, 5,000 tons has been taken to Sihora Station, E. I. Ry., ready for despatch. The analysis of ore from three different pits where the thicknesses of the ore layer were 8, 10, and 11 feet, respectively, and of 6,000 tons of ore after sorting, are shown below, the figures having been supplied by Mr. Kellerschon :—

	Pit 8 feet deep.	Pit 10 feet deep.	Pit 11 feet deep.	Sorted ore, average of 6,000 tons.
Manganese . . .	37·38	38·14	36·60	42·03
Iron	15·40	15·80	16·00	13·10
Phosphorus . .	0·221	0·189	0·171	0·182
Silica . . .	10·89	11·21	11·00	8·84

10. Sihora.

See Bose, pages 84, 85, 223, 225.

11. Mangela.

See Bose, page 75.

On the southern slope of the hillock marked on the map as ·1520 I took a sample (A. 7) of micaceous hematite. The pieces in the sample consisted of micaceous hematite with occasional thin jasper bands, and some yellow shaly bands. That the ore once contained magnetite is shown by the pimple-like elevations on the hematite, but these pimples are now soft and decomposed. This ore, although apparently non-manganiferous, contains 1·70% of manganese, as shown by the analysis given on page 810.

12. Ghogra and 13. Dhanwáhi.

See Bose, pages 75, 87, for Ghogra, and pages 75, 77, 84, 87, for Dhanwáhi.

The best account of the manganiferous iron-ores of this area, lying on the southern side of the Lora range, is the one by Mallet. According to him[1] :—

'The hill half a mile north of Gogra is formed mainly of jasper-hematite. Near the base of southern slope there are a number of shallow ore pits[2], but they are only in talus, not in the rock *in situ*. The miners seek for the small bits of ore which can be used at once in the furnaces, and leave the large lumps, which would require the labour of breaking up. The ore is a manganiferous micaceous hematite, containing a varying proportion of interbanded jaspery quartz. It is a siliceous ore, although not very highly so. As the manganiferous band is entirely concealed beneath the talus, no estimate can be made of its thickness. Judging, however, from the large amount of *débris*, it seems probable that the thickness is considerable. As the loose ore must either lie directly over that *in situ*, or else have come down hill, and as the pits extend 20 or 30 feet (vertically) from the base of the hill, probably a large amount of ore is obtainable by dry open workings whether these be through a deep mass of talus or into solid rock.

'The proportion of manganese varies much, as can be seen from the outward appearance of the ore. In some specimens of the micaceous iron, the presence of manganese is scarcely apparent to the eye; in others, the ore shows by its dark colour that it contains a large amount, and in the highly manganiferous portions psilomelane occurs in irregular segregations. A carefully chosen average sample, made up of a large number of small pieces taken from different pits, yielded—

Ferric oxide	66·33	=Iron 46·43
{ Manganese (with traces of cobalt) . . .	12·26	
{ Oxygen	6·83	
Phosphoric oxide	·27	
Sulphuric acid	·03	
Sulphur	trace	
Ignited insoluble residue	9·55	
Lime, alumina, water and undetermined . .	4·76	
	100·00 (*sic*)	

'The manganese exists, in large part at least, in the form of psilomelane, occurring in irregular segregations, or more minutely disseminated through the rock.'

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1 *Rec. G. S. I.*, XVI, p. 101, (1883).

2 'Those to the west belong to the village Gogra, and those to the east to Danwai.

An analysis of manganiferous micaceous hematite from Ghogra by Messrs. Gilchrist and Riley [1] gives the following:—

Manganese	6·37
Iron	28·15
Siliceous matter	45·00
Phosphorus	0·03
Sulphur	trace
Moisture	0·32

These ores have long been smelted locally with the production of a superior steely iron, known as *kheri*. When I visited the locality in November 1904, furnaces were being built for the ensuing season at Ghogra only. For an account of the industry see the first of Mr. Bose's papers, pages 87, 88; and for an analysis of the *kheri*, see page 596 of Part III of this Memoir.

14. Kurru (Kuro).

Manganiferous ores, either manganiferous hematite or psilomelane, are marked by Bose as occurring near this village. See the map attached to the first of his papers.

15. Lora Hill.

See Bose, page 225.

Manganiferous ores are marked in the map attached to the first of Bose's papers as occurring at the N. W. foot of Lora Hill (·1923 on the 1-inch map).

16. Sakri.

See Bose, page 75.

Mr. Bose records a section seen in a trench constructed by him in Sakri *mauza* near the boundary with Sarda, at a point about 1½ miles E. N. E of Sihora station. Cleaning out this trench has led me to conclusions somewhat different from those of Mr. Bose. Thus he records a length of 230 feet of manganiferous hematite at the N. W. end of the trench. This figure seems to have been arrived at by opening up only parts of the whole length, intermediate portions to a total of 60 feet

[1] *Iron*, XXVII, p. 476, (1886).

being left untouched. And most of the ground opened up shows talus only, the trench not having been carried deep enough to reach rock *in situ*. Consequently, only a very small proportion—about 50 feet-of the 230 feet of manganiferous hematite recorded by Mr. Bose, can be regarded as *in situ*; and the value of this occurrence is not therefore as great as Mr. Bose's description might lead one to expect. I took a sample (No. 69) from each of the sections of the trench, except the last recorded by Mr. Bose. The result of the analysis of this sampie is given on page 809. The sample included some pieces showing visible residual quartzite, which could have been cleaned out so as to give a better result. A little of the ore showed visible psilomelane.

The trench noticed above is situated on the eastern side of the N.—S. ridge at this place. The chief rock visible on this ridge is the banded jasper-hematite, the strike of which is E. by a little N., with a fairly steep southerly dip. On the portions of the ridge lying to the west of the trench the rocks have been replaced at the surface with the formation of limonite, as at Kasái Hill and Mansakra. This limonite often contains the small magnetite grains that presumably once formed a part of the rock that has undergone replacement, and usually retains the original schistose or slaty structure of the rock that has been replaced; but some of it is of the chert-like variety. The limonite is often traversed by thin veins of psilomelane. From this limonite I took a sample (No. 65), an analysis of which is shown on page 815. To the north of this portion of the ridge there is a band of rock very rich in magnetite. It shows bands of jasper, magnetite-bearing hematite, magnetite-bearing argillaceous rock, and very often of magnetite alone.

On the S. W.-running spur from the north end of the ridge mentioned above there are hematite-quartzites and hematite-schists, and various coloured slaty shales. The hematite is often highly manganiferous, and in some cases has been converted into psilomelane. The shales are also often blackened, owing to the impregnation and partial replacement of the rock by manganese oxide. A portion of the completely blackened shale was found to have a specific gravity of 3·33, so that evidently it has not all been replaced, but must contain a considerable amount of residual shaly matter, in spite of the black colour of the rock. I took here a sample (No. 66) of the psilomelane and the blackened shale. The analysis was made at the Imperial Institute with the following result :—

Sample No. 66.

MnO_2	30·92
MnO	3·33
Fe_2O_3	27·39
SiO_2 (combined)	3·79
SiO_2 (free)	19·61
P_2O_5	0·14
Moisture at 100° C.	0·34

This is equivalent to :—

Manganese	22·14
Iron	19·17
Silica (total)	23·40
Phosphorus	0·06

The manganized shale and psilomelane together are hence of no value. The psilomelane alone might give a fairly good analysis, but without the manganized shale would not be abundant enough to be worth working.

17. Khatola.

See Bose, pages 75 and 83.

Mallet, also, refers to the occurrence of manganiferous hematite at this locality. [1]

The only point of particular interest at this locality is the occurrence, on the hill immediately to the west of the gap where the railway cuts through the ridge, of psilomelane containing small crystals of magnetite, the presence of which shows that the original rock contained magnetite as one of its constituents, the magnetite alone having escaped replacement. In this respect this ore resembles some of the psilomelane of the Sandur Hills, which often contains similar residual crystals of magnetite.

The small hills on either side of Sihora Railway station are the most easily accessible of any in this area, to the geologist who wishes to examine typical banded hematite-jaspers.

18. Paharewa.

See Bose, pages 75, 83, 224.

[1] *Rec. G. S. I.*, XVI, p. 102, (1883).

A portion of the ores noticed by Mallet under the heading of Khatola (Kuthola) belongs to this area. Within this *mauza* are found psilomelane, pyrolusite, and manganiferous hematite ; but none of them seems to be of any value, as far as one can judge from surface indications. Along the south base of the hill to the east of the Mirzapur road there are a number of murram quarries. Underneath the surface gravel a section was exposed showing 6 to 8 feet of vertical friable sandy quartzites, with some pyrolusite bands, probably formed by the replacement of the silica, and often continuous from the top to the bottom of the section, disappearing at the bottom beneath the soil. The analysis of a sample (No. 68) taken here is given on page 813. From this it will be seen that, even if the ore were present in quantity, it would probably be too poor to be worth working under present circumstances.

19. Deori.

See Bose, page 84.

20. Mangeli.

See Bose, page 84.

The small hill just to the west of the village is, as far as one can judge from loose fragments, composed of red jasper, with some of grey and brown colour, and also some thin films of micaceous hematite in some of the red jasper. I had the pits dug by Mr. Bose at the south foot of this hill opened up. From two of these I took sample A. 6 of which an analysis is given on page 814. The pits did not offer any hope of any considerable quantity of pyrolusite being present.

21. Daroli.

See Bose, page 84.

22. Hargarh.

See Bose, page 84.

23. Bhátádon.

See Bose, page 84.

The small hillock on which the ores occur lies about one mile E. S. E. of Sihora station, about 200 yards south of the Hiran river. It is composed partly of brecciated Gosalpur quartzite and partly of a lateritic rock. This rock may be called *manganese-laterite* and consists of an aggregation of small concretions of wad. This breaks with a dull fracture, and is of a marked blue-black colour. It does not readily soil the fingers, but can be scratched easily with production of a brownish-black streak. There are also some limonite concretions in the same rock, showing radiate limonite externally, and massive chert-like limonite internally. These limonite concretions are made up to 3 or 4 inches diameter. Only a small proportion of the 8-foot thickness mentioned by Mr. Bose consisted of ore, and as the total visible area at the surface of this manganese-laterite was 108 square feet, it is difficult to see how a few hundred tons of ore could be obtained. A sample of ore taken from this pit was analysed at the Imperial Institute with the following result :—

Sample No. 67.

MnO_2	48·62
MnO_2	4·86
Fe_2O_3	3·53
SiO_2 (combined)	2·35
SiO_2 (free)	2·44
P_2O_5	0·06
Moisture at 100° C.	0·39

This is equivalent to :—

Manganese	34·53
Iron	2·47
Silica	4·79
Phosphorus	0·03

It will be noticed that the constituents estimated total up to 62 % only. Doubtless combined water accounts for an important proportion of the remainder ; but even allowing for this there is probably a considerable balance. This may perhaps be made up by baryta, but the possibility of considerable amounts of oxides of copper, cobalt, nickel, lead, and zinc should be borne in mind, and it is evident that this mineral is well worth careful analytical examination.

24. Muret (Muraith).

See Bose, page 87.

25. Naigain.

See Bose, page 85.

26. Chandnota.

See Bose, page 85.

27. Dhangáon.

See Bose, page 86.

28. Kailwás.

See Bose, page 86.

29. Chindámani.

See Bose, page 86.

30. Gosalpur.

See Bose, pages 71-87, 221-226.

The existence of manganese-ore at Gosalpur seems to have been known for a long time to the local glass makers, although they did not of course, call it by this name. Its occurrence was first brought to the notice of Government by Mr. W. G. Olpherts in 1875. Later it was described by Medlicott in a paper by Mallet[1], who makes further reference to it in a latter paper.[2] According to Bose,[3] who gives a large scale plan of the Gosalpur pyrolusite area,—

'Except in the ground just in front of the dâk bungalow (some 50 yards to south-east of it), the *pyrolusite* occurs here in and among the Gosalpur quartzites, usually soft, decomposed, and blue-coated at the outcrop. Sometimes the rock is hard, and either white or red in colour, assuming in the latter case the appearance of jasper. Wherever such is the case, manganese-ores are wanting. Frequently the rock appears as a conglomerate or breccia, fragments of soft, decomposed (sometimes almost powdery) quartzite being cemented together, as it were, by a matrix of *manganese* or iron-ore. Wherever such a rock crops out, *manganese* or iron-ore is found in some quantity by digging close to it through the soil-cap under which it passes, the nature of the ore being determined by that of the "matrix" at the outcrop.

'The quartzites have the general. . .strike of the area, *viz.*, N. E.—S. W. The dip is obscure; it was found to be very high (about 80°) pointing S. E., some 150 yards north of the dâk bungalow.'

After this Mr. Bose gives the details of a number of pits dug by himself. The ones given on page 812, may be taken as typical of the sections recorded by Mr. Bose. Further, he sub-divides the ore-bearing area

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1 *Rec. G. S. I.*, XII, pp. 99, 100, (1879).

2 *Op. cit.*, XVI, pp. 102, 103, 116-118, (1883).

3 *Op. cit.*, XXI, p. 77.

and estimates the amount of pyrolusite available in each division, arriving at the figure of 50,000 tons as a rough estimate of the amount of pyrolusite at Gosalpur. He makes the following comment (*l.c.*, page 83) on this :—

'It must be remembered, however, that it is almost invariably associated with a little *psilomelane*, and that a good portion of this quantity consists of very small grains, mostly coated red outside by oxide of iron.'

As anyone working this pyrolusite would probably take the larger pieces of ore only, it is evident that the amount of ore actually available must be much less than the above figure. And of the large pieces of ore originally available a large proportion has by now probably been removed by the glass workers and the succession of prospectors and geologists that have given their attention to this place. Were the pyrolusite of high quality, however, so that the ore could be sold at a special price for chemical purposes or glass working, then it is possible that it would pay to extract what is left.

As regards the quality of the pyrolusite, it will be seen from the analysis of a sample (No. A. 16) taken by me and given on page 814 from the following analysis made by Mallet on a sample of the ore carefully selected by himself,[1] and from one by Gilchrist and Riley (page 833), that at least some of the ore is of high grade as regards manganese percentage, whilst the silica is low, and the iron comparatively so. The iron is, however, probably too high for the ore to be able to command a special price for the glass industry :—

Mn_3O_4	75·86
Oxygen	9·96
F_2O_3 (with a trace of Al_2O_3)	4·53
BaO	3·55
P_2O_5	0·28
Insoluble in HCl	2·74
H_2O (combined)	2·41
Moisture	0·28
	99·61

This is equivalent to :—

Manganese	54·66
Iron	3·17
Silica	2·74
Phosphorus	0·12

and the amount of MnO_2 is 83·00%.

[1] *Rec. G. S. I.*, XII, p. 100.

The following is an analysis of Gosalpur pyrolusite by Messrs. Gilchrist and Riley [1] :—

Manganese	53·22
Iron	1·87
Siliceous matter	1·93
Phosphorus	0·19
Sulphur	trace
Moisture	0·56

An analysis of Gosalpur ore has also been published by C. R. von Schwarz. [2]

The outcrops of the Gosalpur rocks in which are found the pyrolusite referred to above are surrounded by laterite, in which, also, manganese-ore sometimes occurs.

To the north-west of the area of Gosalpur rocks and laterite the Sihora rocks crop out. Both Mallet [3] and Bose record sections across the Sihora rocks at a little less than ¼ mile to the N. W. and N. N. W. of the Gosalpur dák bungalow. There seems to be a considerable thickness of manganiferous hematite with psilomelane at the surface. Mallet says :—

'A sample of the more manganiferous part of the schist afforded 18·02 per cent. of manganese (with a little cobalt), while the psilomelane gave 83·20 per cent. of available peroxide.'

31. Dharampura.

See Bose, pages 73, 74, 85, 86, 224.

At intervals along the ridge of Sihora rocks, principally banded hematite-jaspers, running S. W. from Gosalpur through Dharampura, Hirdenagar, and Deonagar, to Marhásan, the hematite is very manganiferous. Mr. Bose records three sections seen in trenches across this ridge. I cleaned up the one he mentions on the middle of page 74 of his first paper as lying about ¾ mile east of the village of Dharampura. In addition to the portion of the trench recorded by Mr. Bose there is another 104 feet of interrupted trench to the N. W. In this portion the manganiferous hematite seemed to be of better quality than in the portion of the trench recorded by Mr. Bose. Hence I took a sample

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1 *Iron*, XXVIII, p. 476, (1886) ; *Jour. Iron Steel Inst.*, No. II of 1886, p. 618.
2 *Stahl. u. Eisen*, XXI, p. 341 ; *J. I S. I.*, No. II of 1901, p. 350.
3 *Rec. G. S. I.*, XVI, pp. 102, 103.

(No. A. 17) from this part; the analysis is given on page 809. I took another sample from the psilomelane found in the former of the two pits near this trench recorded by Mr. Bose. The result of the analysis of this by Messrs. J. & H. S. Pattinson is given below :—

Sample No. A. 18.

MnO_2	66·20
MnO	4·51
Fe_2O_3	14·71
BaO	1·76
SiO_2 (combined)	1·20
SiO_2 (free)	0·20
P_2O_5	1·044
As_2O_5	0·012
H_2O (combined)	5·80
Moisture at 100°C.	0·90

This is equivalent to :—

Manganese	45·36
Iron	10·30
Silica (total)	1·40
Phosphorus	0·456

Mr. Bose also mentions the occurrence of pyrolusite in Gosalpur quartzites, at the foot of a hill known as Changeli, situated about a mile W. N. W. of Dharampura village. He estimates that there may be 13,000 tons of dressed ore available

32. Hirdenagar.

See Bose, pages 73, 74, 87.

33. Marhásan.

See Bose, pages 76, 83.

34. Keolári.

See Bose, page 83.

35. Nargaon.

See Bose, page 86.

36. Pararia (Pandaria).

See Bose, pages 86, 225.

37. Nonsar.

See Bose, pages 72, 75.

This is interesting as being some distance from the main manganiferous area of this district. It is about 12 miles W. N. W. of Jabalpur and 14 miles W. S. W. of Panagarh. Mr. Bose records both psilomelane and manganiferous hematite in the Lora rocks at this place.

38. Gangai.

See Bose, pages 72, 87.

Gangai is 4 miles south of the Marble Rocks or Bhera Ghát. Mr. Bose thinks that since the Lora group occurs here it may be found to yield some manganese-ores when it is examined.

CHAPTER XXXVI.

DESCRIPTION OF DEPOSITS—*continued.*

The Central Provinces—Nágpur District; with the Nimár, Seoni, and Wun Districts.

Nágpur district—History—Output and labour—Geology—Physical characters of the country—Classification and list of deposits—Nature and quality of the ores—Communications and transport.

Class I—Group I—Kodegáon—Gungáon—Rámdongri.

Group II—Risárá—Nándgondi—Sitagondi.

Group III—Kándri—Mansar—Mansar Extension—Parsoda—Borda.

Group IV—Pársioni and Bansinghi—Dumri Kalán—Sátak—Beldongri—Nagardhan—Nandapuri—Lohdongri—Kácharwáhi—Waregáon—Khandálá.

Group V—Mándri—Panchála—Mánegáon—Guguldoho—Bhandárbori.

Class II.—Group VI—Mohugáon—Páli—Ghoguna (Pench River)—Mándvi Bir—Junawáni—Junapáni—Rájkota.

Nimár District—Chándgarh—Jámdihi Nálá—Bankuta.

Seoni District—Kurai.

Wun (Yeotmál) District—Málágarh Hill.

The Nágpur District.

This is the district in the Central Provinces in which manganese-ore was first worked on a commercial scale and also that in which the occurrence of manganese-ore has been longest known. It also contains the largest number of deposits being actively worked and will need a large amount of space for its description.

History.

The earliest record of the occurrence of manganese-ore in India refers to the Nágpur district. Captain F. Jenkins in 1829 describes an exposure in the Pench[1] river near Pársioni of black manganese-ore in crystalline limestone, and gives quite a long account of a similar deposit of manganese-ore in crystalline limestone at a place 3 or 4 miles north of the village of Kumári[2], which is almost certainly the deposit I have described under the heading of Mándvi Bir and Junawáni[3].

H. W. Voysey [4] in 1830 mentions the same occurrence of 'foliated black manganese-ore' in the Pench.

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[1] *Glean. Sci.*, I, pp. 226, 227, (1829); *Asiatic Researches*, XVIII, p. 210, (1833).

[2] *Loc. cit.*, p. 208.

[3] Page 966.

[4] *Gleanings Sci.* II, p. 28, (1830); *As. Researches*, p. 127, (1833).

The first discovery of the class of deposit at present being worked was by Lieutenant R. E. Oakes[1] in 1859 of the fine deposit described below under the heading of Mansar. It was afterwards noticed by Mr. Wilson, Executive Engineer of the Kanhán Division, and then a sample of it, sent by W. Ness, analysed by F. R. Mallet, (1879)[2], and shown to be braunite with a little rhodonite[3] and to contain 55% of manganese. Dr. W. T. Blanford, in 1872, discovered ore at Kodegáon[4]; but which of the two deposits that occur there is not known.

Nothing more seems to have been heard of the Nágpur manganese until Messrs. W. H. Clark in 1899 and Harvey Dodd in 1900, of the Vizianagram Mining Co., Ltd., came to this district to prospect for manganese. Following up the references in Ball's Economic Geology they visited Mansar and Kodegáon, and continuing to prospect in the neighbourhood discovered the Gumgáon and Rámdongri deposits near Kodegáon, and the Kándri, Beldongri, Sátak, and Lohdongri, deposits in the Mansar neighbourhood.

A syndicate known as the Central Provinces Prospecting Syndicate, and consisting of Messrs. J. H. Glass, P. Macfadyen, and H. G. Turner, was then formed to work these deposits, Mr. Clark being appointed manager, a position which he has retained ever since. Work was commenced late in 1899 on the Mansar deposit and the first shipment took place in the spring of 1900; the operations of this syndicate have constantly increased until in 1906 it extracted from the three districts of Bálághát, Bhandára, and Nágpur, 223,822 tons of ore or nearly $\frac{1}{6}$ of the world's output. The success of this syndicate led to the discovery of fresh deposits in the same district by Mr. H. D. Coggan, and in the beginning of 1902 Messieurs Charles Jambon and Cie. of Calcutta started work on the deposits discovered through Mr. Coggan's agency. The actual times of commencement were as follows :—

Sátak, Parseda	January, 1902.
Mándri, Mánegáon	February, 1902.
Waregáon	March, 1902.
Kácharwáhi	April, 1902.
Mansar Extension	October, 1902.
Páli	February, 1903.

These deposits were actively worked, and. after they had been opened up and considerable quantities of ore exported, a company

1 Manual of Geology of India, Pt. III, Economic Geology, p. 329.
2 *Rec. G. S. I.*, XII, p. 73, (1879).
3 Really spessartite; see page 140.
4 Manual, Pt. III, Economic Geology, p. 330.

styled the Central India Mining Company, Ltd., was formed in January 1904 to continue the work of Messieurs Jambon and Cie. The Agents of this company are Messrs. Killick Nixon & Co. of Bombay.

In 1902 the late Mr. A. M. Gow Smith came to this neighbourhood to prospect for coal in the Chhindwára district, and the active export of manganese-ore from Nágpur and Kámthi attracting his attention, he was led to prospect for this mineral as well. From Ball's Geology he was led to the Kodegáon deposit which, on account of its insignificant outcrop, had been rejected by the Central Provinces Prospecting Syndicate, and when up in the Chhindwára district he discovered eight of the deposits noticed under the heading of that district. The two deposits at Kodegáon were opened up at the end of 1902 and during the first half of 1903 and about 8,000 tons shipped to England. In November 1903 Mr. H. Kilburn Scott reported on Gow Smith's deposits, and the report being a favourable one, the Indian Manganese Co., Ltd., with Messrs. Shrager Brothers of Calcutta as agents[1], was formed in 1904 to work them.

Several other firms have interested themselves in the Nágpur manganese. Messrs. Gillanders, Arbuthnot & Co. of Calcutta, in 1902, secured deposits at Risára, Nándgondi, and Khandála, but these deposits were all found to be valueless, consisting, as they do, mainly of quartz and the manganese-silicates, spessartite and rhodonite. Messrs. Jessop & Co. of Calcutta discovered deposits at Bhandárbori and Guguldoho and actively worked the latter, accumulating a large amount of ore. But, owing to lack of facilities for transport, work had been stopped at the time of my visit; it was continued in 1906 with the resultant export of some ore. Mention must also be made of Mr. Cooverji Bhoja, also of Calcutta, who secured deposits at Mándvi Bir, Junawáni, Borda, and Pársioni, and has since transferred them to the Madhu Lall Doogar Mining Syndicate; and also of Mr. D. Laxminarayan of Kámthi.

I have visited the district thrice. The chief visit was in the field season of 1903–04 when nearly all the material included in this chapter was gathered. In December 1906, I revisited Kandrí, Mansar, Sátak II, Beldongri, Lohdongri, Kácharwáhi, Mándri, and Mánegáon, and also saw the newly discovered deposit of Panchála. In December 1907, I revisited Kodegáon, Gumgáon, Lohdongri, Kácharwáhi and Mándri. The descriptions following are mainly based on my first visit; the other two were very hurried; but I have made such alterations or additions as seemed necessary.

[1] The Agents are now Messrs. Martin & Co. of Calcutta.

Output and labour.

The following table shows the annual output of this district from 1900 to 1907, and the average daily number of coolies employed throughout this period :—

Year.	Output of manganese-ore in long tons.	Average daily number of workers.
1900	47,257	(*a*)
1901	76,925	1,460
1902	68,819	1,676
1903	95,051	3,543
1904	66,142	1,651
1905	100,063	1,904
1906	146,117	2,345
1907	199,311	3,924

Geology.

The manganese-ore deposits of this district occur in the large area of Archæan rocks stretching from the Chhindwára and Nágpur districts on the west, through Seoni and Bhandára, to Bálághát on the east. In the last-named district it is in part possible to separate from the Archæan complex, under the name of the Chilpi Ghát Series, a series of metamorphosed sediments in which are situated the manganese-ore deposits. In the Nágpur district, where the metamorphism has been much more intense than in the parts of the Bálághát district above referred to, no such separation could be made without very detailed field work accompanied by a minute microscopic study of the rocks. Consequently, on the map (Plate 43) of the Nágpur-Bálághát area, the whole of the crystalline complex in the Nágpur district has been coloured pink, the manganese-ore deposits alone being indicated by a different colour—blue.

This crystalline complex consists of acid gneisses, pyroxenic gneisses, hornblende-schists, mica-schists, quartzites, crystalline limestones, and calciphyres, with intrusive granite and pegmatite. A perusal of the account given elsewhere[1] of the Archæan rocks of the manganese area of the Chhindwára district will convey a very good idea of the characters of the Archæan rocks of the Nágpur district, which are essentially the same. In the Nágpur district these rocks are arranged in parallel bands having a general east to east-south-east strike, often varying

[1] *Rec. G. S. I.*, XXXIII, pp. 159-220, (1906).

locally. These bands are not usually continuous for more than a few miles and often only for a fraction of a mile. As is usual in an Archæan complex the rocks are much folded and as a rule steeply dipping, sometimes to the north side of the strike and sometimes to the south side.

There are two chief modes of occurrence of manganese-ores in this district. They occur principally as bands, often of considerable length, and usually thinning out in lenticular fashion, intercalated between the gneisses, schists, and quartzites, of the crystalline complex, so as to conform to the strike and dip of these rocks. This type of deposit is supposed, as already explained, to have been derived, at least in part, by the chemical alteration of rocks composed of spessartite (manganese-garnet), rhodonite, and quartz, such rocks, in all stages of alteration to manganese-ore, being frequently found in association with the ores. Consequently, any bands of fresh or only partially altered manganese-silicate-rock are also shown in blue on the map and are also regarded as manganese deposits. The other mode of occurrence is as much smaller lenticles and bands of nodules of manganese-ore in crystalline limestone, usually in association with piedmontite. In one case, Junapáni, the manganese-ore occurs in a bed-like band similar to those of the first type.

A reference to the map (Plate 43) will show that the manganese-ore deposits are often arranged in lines conforming to the general strike of the rocks.

The manganese zone in this district is 31 miles long from Kodegáon on the extreme west to Bhandárbori on the extreme east. The maximum breadth of the zone as at present known is about 11 miles, measured from Junawáni on the north to Sátak on the south; but this will probably be considerably extended when the country to the north of Chorbáoli is carefully examined. On the west this zone is bounded by the large N. W.—running boundary fault, first noticed by Blanford[1], that separates the metamorphics from the rocks of the Kámthi division of the Gondwána system; it is connected—to the north of Kelod—to the manganese-bearing zone of the Chhindwára district. On the east the zone continues into the Bhandára district, while to the south it is bordered by alluvial plains.

Physical characters of the country.

As regards the physical characteristics of the country, it is sufficient to say that the southern portion of the zone is occupied by an alluvial plain, at an average elevation of about 1,000 feet above sea-level, from which project low ridges and hills; many of the manganese deposits reveal themselves only by the

[1] *Mem. G. S. I.*, IX, p. 310, (1872).

projection at the surface of the summits of hills now practically submerged in alluvium. The deposits of groups I and IV of the classification given below occur in this manner. But in the northern part of the zone, though bands and patches of alluvium are found, hilly and densely jungle-clad country predominates; the deposits of groups II, III, V, and VI are characterized by this type of country. According to reports there must be—in the wild region starting from Chorbáoli and extending to the west, north, and north-east—a considerable quantity of manganese-ore; but unfortunately I had no time to do more than pay a flying visit to Mándvi Bir and Junawáni to the west-north-west of Chorbáoli, the remainder of the jungles being untouched.

The district is drained by the Kanhán, the Pench and the Súr, the Kanhán and Súr flowing direct into the Wainganga, whilst the Pench is a tributary of the Kanhán.

Classification of the deposits.

In describing these deposits in more or less detail according to their interest and importance, it will be convenient to divide them into two classes according to the mode of occurrence of the ore, and to divide the classes into groups according to the geographical distribution of the deposits. The classes are as follows:—

Class I.—Deposits characterized by the association of spessartite and rhodonite—one or both—with the ore, the 'country' being gneiss, schist, or quartzite.

Class II.—Deposits characterized by the association of piedmontite with the ore, the 'country' being crystalline limestone.

These classes can be divided into groups as follows:—

		Name of Deposit.	Concessionaire.
Class I.	Group I.	1. Kodegáon . . .	Indian Manganese Co. (I. M. C.).
		2. Gumgáon . . .	Central Provinces Prospecting Syndicate (C. P. P. S.)
		3. Rámdongri . . .	Do.
	Group II.	4. Risára (Reechara) . .	
		5. Nándgondi . .	
		6. Sitagondi . . .	
	Group III.	7. Kándri . . .	C. P. P. S.
		8. Mansar . . .	Do.
		9. Mansar Extension . .	Central India Mining Co. (C. I.M.C.)
		10. Parsoda . . .	Do.
		11. Borda . . .	Madhu Lall Doogar Mining Syndicate (M. L. D. M. S.)

Class	Group	Name of Deposit.	Concessionaire.
Class I.	Group IV.	12. Pársioni and Bansinghi	D. Laxminarayan.
		13. Dumri Kalán . .	M. L. D. M. S.
		14. Sátak . . .	C. I. M. C. & C. P. P. S.
		15. Beldongri . . .	C. P. P. S.
		16. Nagardhan . . .	C. I. M. C.
		17. Nandapuri . . .	Do.
		18. Lohdongri . . .	C. P. P. S.
		19. Kácharwáhi . .	C. I. M. C.
		20. Waregáon . . .	Do.
		21. Khandála . . .	
	Group V.	22. Mándri . . .	C. I. M. C.
		22*a*. Panchála . . .	Do.
		23. Mánegáon . . .	Do.
		24. Guguldoho . . .	Jessop & Co.
		25. Bhandárbori .	Do.
Class II.	Group VI.	26. Mohugáon . . .	I. M. C.
		27. Páli	C. I. M. C.
		28. Ghogara (Pench River)	
		29. Mándvi Bir . . .	M. L. D. M. S.
		30. Junáwani . . .	Do.
		31. Junapáni . . .	Do.
		32. Rájkota . . .	

All these deposits, except 22*a* and 32, will be found indicated by their numbers on the map (Plate 43), of the Nágpur-Bálághát area. In addition, manganese-ore was found at Warpáni during 1907.

The nature and quality of the ores.

The ores found in this district consist typically of mixtures of braunite and psilomelane. Such ores may be either very fine-grained, when it is very difficult to make out what is the mineral composition, or they may be more coarsely crystalline owing to the braunite's being present in larger crystals. In some cases the ores are very coarsely crystalline as at Lohdongri, and consist almost entirely of braunite, usually with a certain amount of interstitial psilomelane. More rarely the ores consist entirely of psilomelane. The best locality for such ore is Guguldoho. Amongst the composite ores there is also the one I have referred to as *speckled ore*, composed of a crystalline mineral such as braunite or mangan-magnetite (?), set in a matrix of psilomelane and soft black powders (see page 696). Other rarer ores are the crystalline manganate, hollandite, found chiefly at the deposits of Group VI, especially at Junawáni; and pyrolusite, the best locality for which, not only in this district, but also in the whole of India, is Páli, where it occurs in crystalline limestone. Other minerals are vredenburgite and beldongrite both found at Beldongri; and possibly mangan-magnetite, as for example, at Guguldoho.

I took samples from nearly all the deposits visited. A few of them, in cases where the deposit had not been much opened up, were taken by breaking pieces off the outcrops, but the majority were taken from stacked ores. The samples so collected were analysed at the Imperial Institute and are dispersed throughout the text under the headings of the respective deposits. The limits and mean of the 26 samples analysed are shown below :—

	Limits.	Mean.
Manganese	42·28—55·15	51·36
Iron	2·09—16·34	6·45
Silica	2·90—18·48	7·07
Phosphorus	0·04— 0·65	0·115
Moisture	0·11— 1·32	0·49

No samples were taken at Kándri and Mansar. The foregoing average is therefore somewhat low because the ores of these two deposits are some of the best in the district. Of course, the above does not give a true average. The only way to get such figures would be to get the average analysis of the total amount of ores exported from each deposit and then to average all these analyses by giving to each a value proportionate to the total output of the deposit it represented. Such figures are unfortunately not available.

Communications and transport.

The deposits in this district are all situated at varying distances to the north of the Bengal-Nágpur Railway. When the mining of manganese was first started all transport of ore to the railway was effected by carting over distances varying from 5½ to 20 miles and over. Messieurs Jambon & Cie. then laid down (1903) a 2 foot-gauge tramway from Thársa station to Waregáon (5½ miles) and this has since been extended westwards by the Central India Mining Co., Ltd., to Kácharwáhi (7 miles) and Lohdongri (8½ miles), and northwards to Mándri (11½ miles), and Mánegáon (13½ miles), the distances in brackets being measured from Thársa station, Bengal-Nágpur Railway. This tramway also serves to carry ores from Guguldoho (Jessop & Co.) and Panchála, after they have been carted as far as the tramway. Hand-traction was at first used, but the whole line has now been converted for steam-traction, by means of which it is possible to run trains of 20 to 40 trucks carrying 1 to 2 tons of ore each. A broad-gauge line has been constructed from Kámthi to Rámtek, by the Bengal-Nágpur Railway, with a siding passing Mansar and terminating at Kándri, 16 to 17 miles from Kámthi. It was opened, I believe, in 1907, and will serve to transport not only the Kándri and Mansar ores, but also those of Mándvi Bir, Junawáni, and Junapáni, situated some 6 miles north of Kándri, up to which place the ore will have to be carted. Up till 1907 the ores of all these deposits have been carted at great expense in bullock-carts holding about ½ a ton each, over the main road from Jabalpur to Kámthi, first to Kámthi itself, and later to the Kanhán siding situated on the east side of the Kanhán river about a mile outside Kámthi.

The ores of Beldongri and Sátak are still carted to Salwa station, but it may pay later on to carry them to a point on the Rámtek Railway.

The ores from the deposits of Groups I and II are carted to Nágpur, over distances of 20 miles and upwards along the main road from Chhindwára to Nágpur. Those of Rámdongri cannot be carted in the rains as the Kanhán river is then too high; at other times of the year a temporary bridge is constructed. There will, however, be a great reduction in the cost of transport of the ores of this part of the district when the proposed railway from Nágpur to Chhindwára is constructed, as it will then be possible to run out sidings to the various deposits.

When the majority of the deposits have been connected to the main line from Bombay to Calcutta it will be a happy day for the roads of this district. At present they are kept in a very bad condition by the passage over them of a constant stream of bullock-carts staggering along with heavy loads of manganese-ore.

GROUP I.

1. Kodegáon.
2. Gumgáon.
3. Rámdongri.

This being the area where I first became acquainted with the Archæan manganese-ore deposits, a considerable time was spent in the examination of these three localities, with the idea that after carefully working them out they would form a key to the interpretation of the many other deposits of like origin occurring in the four districts of Chhindwára, Nágpur, Bhandára, and Bálághát. As the largest scale map of the Nágpur district [1] is the ½-inch sheet, on which the hills are often very imperfectly shown, the three accompanying maps were constructed (from a rough prismatic compass survey).

From the map (Plate 24) it will be seen that there is a range of hills stretching for about 5 miles in an east-north-east direction from Kodegáon on the west to Kuthulna on the east. For convenience of description I have given local names to the separate portions of the ranges and numbered the hills and hillocks composing each group.

On the west the ranges are mere hillocks or very small hills about 50 to 100 feet high, but towards the east they become much higher, reaching a maximum, at the Rámdongri H. S. on the east shore of the Kanhán river, of about 280 feet, as measured by the aneroid, above the

[1] Except for excellent maps, by the Forest Department, on the scale of 4″ = 1 mile, of the reserved forests.

surrounding alluvial plains. Further, at the west end the hills are almost bare of wood, but at the east end often very thickly jungle-clad.

The commonest rock is a purplish, pinkish or greyish, coarse, vitreous quartzite, usually with abundant parallel included flakes of white mica, and, as the rock is often schistose, it might in some places be called a mica-quartz-schist. Under the microscope it is also seen to contain fairly abundant crystals of tourmaline, of indigo, lavender or purple-brown colour, which in the hand-specimen appear as tiny black specks. This rock constitutes the main portion of the Kodegáon hills, the north part of Gumgáon hill, the Haladgáon hills, and the ridge of the Rámdongri range.

In the section exposed on the left bank of the Kanhán it is seen that on both sides of the quartzite band occur decomposed mica-schists, often reddish or mottled. The southern band of schists is also seen on the southern side of the Haladgáon hills in a murram quarry and as a band separating the quartzite and manganese-ore of Gumgáon hill.

The Kodegáon hills are probably terminated at their western end by the boundary fault shown by Blanford as separating the crystallines from the Gondwánas [1]. This probably runs north-west from the west of mine 1, past Durbadi hill, the most westerly of the Khápa hills. At the east end the Rámdongri hills are separated from the Kuthulna hills by a valley, probably corresponding to a fault with a north-north-west strike.

It should be noticed that all these hills rise out of the alluvium.

The transport of the ore from these deposits is at present effected by carting to Nágpur in country-carts taking ½ to nearly 1 ton of ore. Both from Kodegáon and Gumgáon it is about 22 miles to Nágpur, whilst in going from Rámdongri the Kanhán has first to be crossed by a temporary bridge, which gets washed away in the rains; the total distance is about a couple of miles further.

1. Kodegáon.

(INDIAN MANGANESE CO.)

(See Plates 23 and 24.)

Within the limits of this village there are apparently two separate deposits of manganese-ore held on mining lease by the Indian Manganese Company. One of them (mine 1) is situated in the alluvium about ¼ mile south-west of the west end of the Kodegáon hills, whilst the other (mine 2), as shown on the map (Plate 24), just cuts into the north slope of the same hills. They are apparently two distinct bodies of ore separated by the micaceous quartzites in between; but see below.

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[1] *Mem. G. S. I.*, IX, map, (1872).

The deposit designated here as mine 1 was originally visible only as a small outcrop 3 or 4 feet across, projecting from the alluvial soil of a field; but on opening up the deposit it was found to widen out rapidly in all directions, as if this outcrop were the peak of a hill that had been covered up by alluvium. The plan (fig. 49) shows the shape of the excavation at the time of my visit

Mine 1.

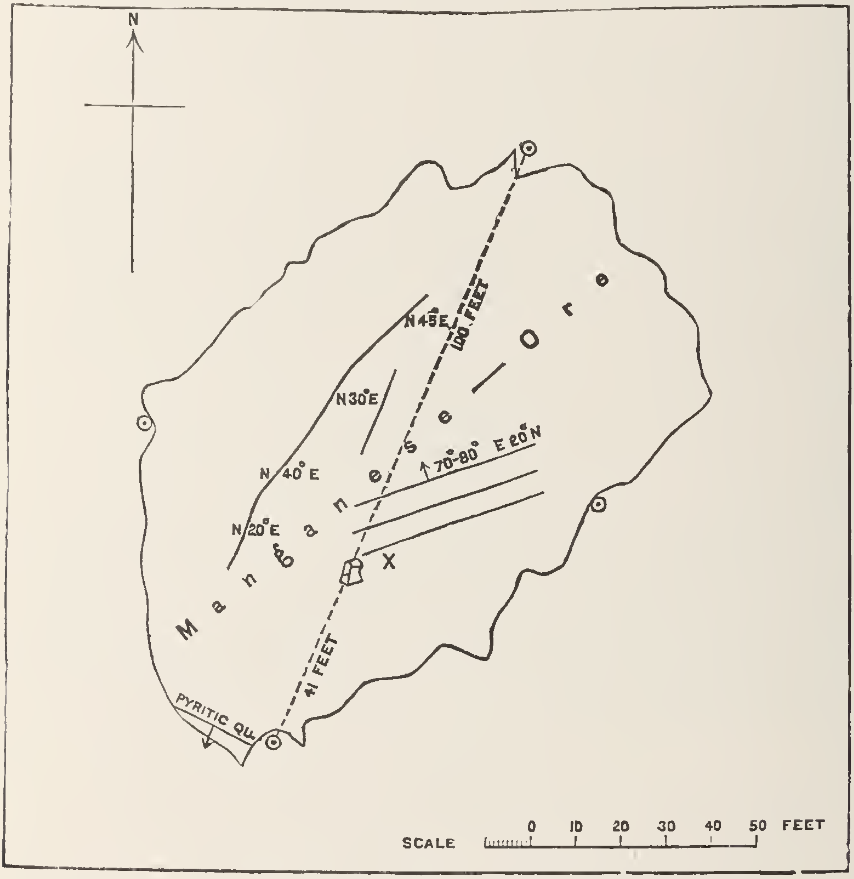

Fig. 49.—Sketch-plan of Kodegáon mine 1.

in November 1903, and X shows the position of the original outcrop, which had been left standing. It is also visible in Plate 23. The quarry was then 141 feet long by 90 feet broad with a greatest depth of 19 feet. As seen round the sides of the quarry the ore was covered by 2 or 3 feet of brownish clay under which there was often, immediately above the ore *in situ*, 2 or 3 feet of a rubble of fragments of the same. As then exposed the whole deposit consisted of a practically solid mass of most beautiful looking ore with very little foreign matter. The ore

Photographed by L. L. Fermor. *Bemrose, Collo., Derby.*

MANGANESE-QUARRY AT KODEGÁON, NÁGPUR DISTRICT, C. P.

is a bluish grey, very compact mixture of braunite and psilomelane, the braunite appearing as finely crystalline granules in a compact and apparently non-crystalline matrix of psilomelane. An analysis of this ore by me showed it to be a mixture of two parts of braunite and one part of psilomelane (see page 850). The specific gravity is about 4·55 to 4·59. The small joints in this ore sometimes contain a film of brownish-black material that soils the fingers. The ore, of course, shows divisional planes, which are stained red by ferruginous matter; but they are rather far apart, so that huge blocks of ore of a cubic yard or more in volume can sometimes be obtained. There is also a small amount of an inferior sort of ore showing rather abundant jointing, while soft thin powdery black partings sometimes occur in the very best ore. As shown on the plan, the various vertical or nearly vertical divisional planes—usually one to two feet apart—have different strikes in different parts of the deposit, thus cutting into one another. This may perhaps be due to the proximity, to the west, of Blanford's boundary fault between the metamorphic and crystalline rocks on the one hand and the Gondwánas on the other. There is also a set of joint planes dipping at 10° to 40° to the south-west.

As regards other material: this though small in amount is of great interest. In the first place it is necessary to mention the complete absence of manganese-garnet, so characteristic of the deposits of this area. In one place in the middle of the quarry was an 8-inch band of the dark-grey, almost black, quartzite mentioned on page 343. It is only 20 feet long, being terminated abruptly at both ends by ore. This may be taken as another sign of the proximity of the above-mentioned fault.

Opal.

In places there occur in the ore irregular veins and layers of a pinkish white, very compact substance, which is really a variety of opal-silica having G.=2·52. It is, of course, of secondary origin, for it fills in fissures in the ore.

Pyrite.

Lastly at the south-west end of the quarry there is band of cavernous hornstone-like quartzite, containing a large amount of pyrite in small grains and crystals; some of the pyrite has changed to limonite. The cavities are frequently lined with minute quartz crystals, often iridescent from a coating of some compound of iron. In 1907 it was seen that this rock is a vein in the ore-body and therefore subsequent in time of formation to the ore itself.

Data obtained in 1907.

By the time of my second visit (in 1907) the quarry had been considerably enlarged. The true strike had been shown to be E. 30° to 40° N. varying to north-north-east, the dip varying from very steep to the north-west side of the strike to vertical. This strike indicates that mines 1 and 2 are probably on the same band of ore. The ground between the two should therefore be opened up.

The horizontal width across the strike of the ore-beds here was 115 feet, but it was not certain that the full width was exposed. Owing to the dirty state of the floor of the quarry I was not able to ascertain if the whole of this width consisted of ore, or whether there were any interlaminations of barren rock. On the south-east edge of the pit some light grey and dark grey quartzites were exposed, whilst in the ore at this point there were some patches of coarse felspar-rock with a little quartz. The length of the ore-body in a N. 35° E. direction was 205 feet as far as exposed.

The working of the deposit.

In 1903 the working of this deposit was extremely simple. It consisted in inserting crowbars between the divisional planes of the ore, and prizing it out; but when very large masses were encountered without any cracks it was then necessary to resort to blasting.

By 1907 the pit had reached a depth of 33 feet, a steam-winch was employed for hauling the waste and ore in trucks up a single pair of rails from the bottom of the pit, and a pump for keeping the water under. As at many other deposits in this district the old waste-dumps are in positions where they will hinder the future opencast working of the deposit.

Mine 2.

This has been excavated at the north foot of the mica-quartz-schist hills, and has been carried to the junction of the ore with the mica quartz-schists to the south of the deposit (see fig. 50). The original outcrop was a yard or two across, and the excavation, at the end of 1903, was 170 feet long, and of very irregular shape, varying from 20 to 80 feet in width. [By Decembe

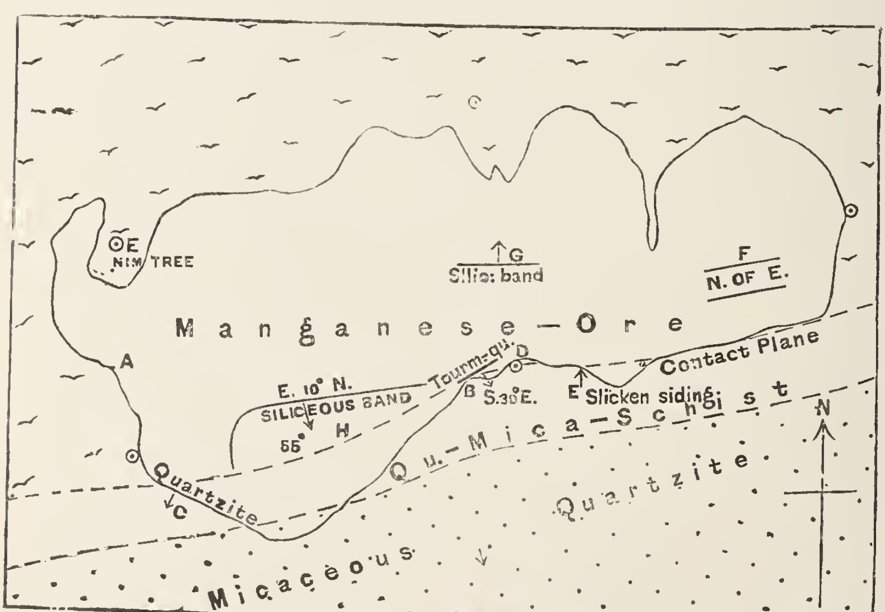

Fig. 50.—Sketch plan of Kodegáon mine 2. Scale—Same as fig. 49.

1907 it had been lengthened to 300 feet, and had reached a maximum depth of 25 to 30 feet.] The bottom of the quarry was very uneven because the best ore had been extracted leaving the inferior portions standing up in irregular masses. This deposit is much inferior to that of mine 1, as it contains many patches and bands of quartz, dark grey quartzite, spessartite-quartz-rock and some magnetite-spessartite-quartz-rock. The ore is the same mixture of braunite and psilomelane with exactly the same physical characters as in the other quarry. But it is sometimes more coarsely crystalline; a fine crystal of braunite from this quarry was presented to the Geological Museum by the late Mr. A. M. Gow Smith (see page 60). In addition to this ore there is also a very jointed variety which is found in the lower parts of the pit, suggesting that the quality is deteriorating in depth: for it will be seen from analysis 5 below that this type of ore is distinctly inferior to that represented by analysis 4. In December 1907 a large mass of decomposed, and presumably intrusive, granitic rock was exposed about the middle of the ore-body.

Nature and quality of the ores.

By November 1903, 6,500 tons had been quarried from mine 1 and 8,500 from mine 2, and of this 3,000 and 4,000 tons respectively were still lying at the mine in stacks. The material in the stacks was very well cleaned, though there was often a little adherent clay, especially on the ore found as loose débris on top of the ore *in situ*. A sample taken by me from all the stacks of both quarries gave the following result on analysis at the Imperial Institute, London :—

Sample No. 1.

Manganese peroxide (MnO_2)	57·05
Manganese protoxide (MnO)	21·35
Ferric oxide (Fe_2O_3)	10·86
Alumina (Al_2O_3)	2·34
Baryta (BaO)	0·00
Lime (CaO)	1·33
Magnesia (MgO)	0·28
Silica (combined) } SiO_2	3·91
Silica (free) } SiO_2	0·17
Phosphoric oxide (P_2O_5)	0·23
Arsenic oxide (As_2O_5)	0·011
Water (combined)	1·65
Moisture at 100°C.	0·28
Carbon dioxide	0·22
	99·681

This is equivalent to :—

Manganese	52·54
Iron	7·60
Silica	4·08
Phosphorus	0·10
Moisture	0·28

and indicates an average composition for the Kodegáon ores of 39% braunite and 61% psilomelane.[1]

A picked specimen of Kodegáon ore, consisting of the hard fine-grained mixture of braunite and psilomelane, was analysed by myself with the following result[2]:—

Manganese peroxide	56·72
Manganese protoxide	30·83
Ferric oxide and alumina	3·94
Cobalt and nickel oxides (CoO + NiO)	0·48
Baryta	1·10
Magnesia	trace
Silica	6·80
Phosphoric oxide	0·22
Water (combined)	0·49
Moisture at 100°C.	0·05
	100·63

This is equivalent to:—

Manganese	59·73
Phosphorus	0·10

The silica was not separated into combined and free, but as it was left as a gelatinous residue on dissolving the ore in HCl, it may be supposed that it was largely present in combination as braunite. On this assumption the ore must have been composed of 68% braunite and 32% psilomelane, or roughly 2 of braunite to 1 of psilomelane.

For the analyses given below I am indebted to the Indian Manganese Company:—

Analyses of Kodegáon ores.

	Mine 1.			Mine 2.		
	1	2	3	4	5	Taken from a report made by Mr. H. Kilburn Scott for the promoters of the Indian Manganese Company. All dried at 212°F.
Manganese	52·83	51·62	42·60	52·68	49·40	
Iron	6·19	8·52	14·84	6·18	9·22	
Silica	4·53	4·90	7·57	9·58	11·13	
Phosphorus	0·151	0·083	0·080	0·092	0·132	

[1] This sample was subsequently found to contain the following additional constituents:—

NiO, Co_3O_4, CuO	0·04
K_2O	0·82
Na_2O	0·29

[2] *Rec. G. S. I.*, XXXI, p. 47, (1904).

	Mine 1.			Mine 2.		
	6	7	8	9	10	
Manganese	49·04	53·90	53·02	50·02	48·82	Taken from a report made by Mr. W. Selkirk for the Indian Manganese Company. All dried at 212°F.
Iron	6·90	4·55	6·00	8·70	9·87	
Silica	6·62	4·61	5·83	7·42	6·27	
Phosphorus	0·130	0·078	0·033	0·135	0·083	
Arsenic		traces	traces			
Moisture as received..		0·20	0·22			

No. 1. General sample of the ore-body exposed.
No. 2. Piece of second quality ore showing some cleavage.
No. 3. Piece of second quality ore showing cleavage and appearing to be siliceous.
No. 4. General sample of best ore from stacks and quarry.
No. 5. General sample of class of ore showing cleavage, taken principally from the lower part of the quarry.
No. 6. Sample taken from whole of 3,200 tons ore stacked at mine 1.
Nos. 7 and 8. Similar samples previously taken.
No. 9. Sample taken from 4 points at bottom of mine No. 2.
No. 10. Sample of the pebble-ore at mine No. 2.

A cargo of 300 tons *ex* 'City of Venice' gave on analysis by Messrs. Pattinson and Stead:—

Manganese peroxide	56·39
Manganese protoxide	21·09
Ferric oxide	9·86
Alumina	1·40
Baryta	0·33
Lime	0·85
Magnesia	0·40
Lead oxide	*Nil.*
Copper oxide	trace
Cobalt oxide	*Nil.*
Nickel oxide	*Nil.*
Zinc oxide	trace
Potash	0·87
Soda	0·37
Silica	5·95
Phosphoric oxide	0·27
Arsenic	0·012
Sulphur trioxide	0·075
Combined water	1·50
Moisture	0·29
Carbon dioxide	0·60
	100·257

The equivalent of this in manganese, etc., is shown below, together with partial analyses of two other cargoes :—

	500 tons *ex* 'City of Venice.'		600 tons *ex* 'Syria.'		600 tons *ex* 'Malacca.'	
	As received.	Dried at 212°F.	As received.	Dried at 212°F.	As received.	Dried at 212°F.
Manganese	51·84	51·99	51·65	52·19	50·95	51·31
Iron	6·87	6·89	6·43	6·50	7·62	7·67
Silica	5·93	5·95	4·75	4·80	4·47	4·50
Phosphorus	0·116	0·116	0·120	0·121	0·122	0·123
Moisture	0·29	..	1·03	..	0·71	..

Output. The figures of production for this deposit are shown below :—

Year.	Long tons.
1903	11,436
1904	9,000
1905	11,094
1906	9,657
1907	7,527

It will be seen that the figure given for 1903 does not agree with the statement on page 849, according to which 15,000 tons were extracted in 1903. I have had the greatest difficulty in getting even the above figures ; for all records of the output for 1903 and 1904 seem to have been lost ; but the discrepancy is probably due to that portion of the ore extracted during 1903, but not carted away, having been included in the 1904 figures.

2. Gumgáon.

(CENTRAL PROVINCES PROSPECTING SYNDICATE.)

(*See Plates 24 and 25.*)

This deposit is held on a mining lease by the Central Provinces Prospecting Syndicate and forms a hill, the west end of which is about 100 feet to the east of the new road from Pátansáongi to Khápa. This hill forms the boundary between Khápa and Gumgáon village areas. A plan of it is shown in Plate 25. Geologically it may be said to consist of three parallel bands of rock having an average dip of about 60° to the S.10°E. : —

(1) A southern band having the general strike of the rocks of this hill, namely E.10°N. This band is the ore deposit and is exposed for 1,200 feet along the strike and is 300 feet wide for a great portion of its length. Along the northern boundary the predominant rock is spessartite-quartz-rock. Of this 300 feet only about 50 feet represents ore *in situ*, the remainder being loose ore fragments covering the 'country' to south of the ore-band.

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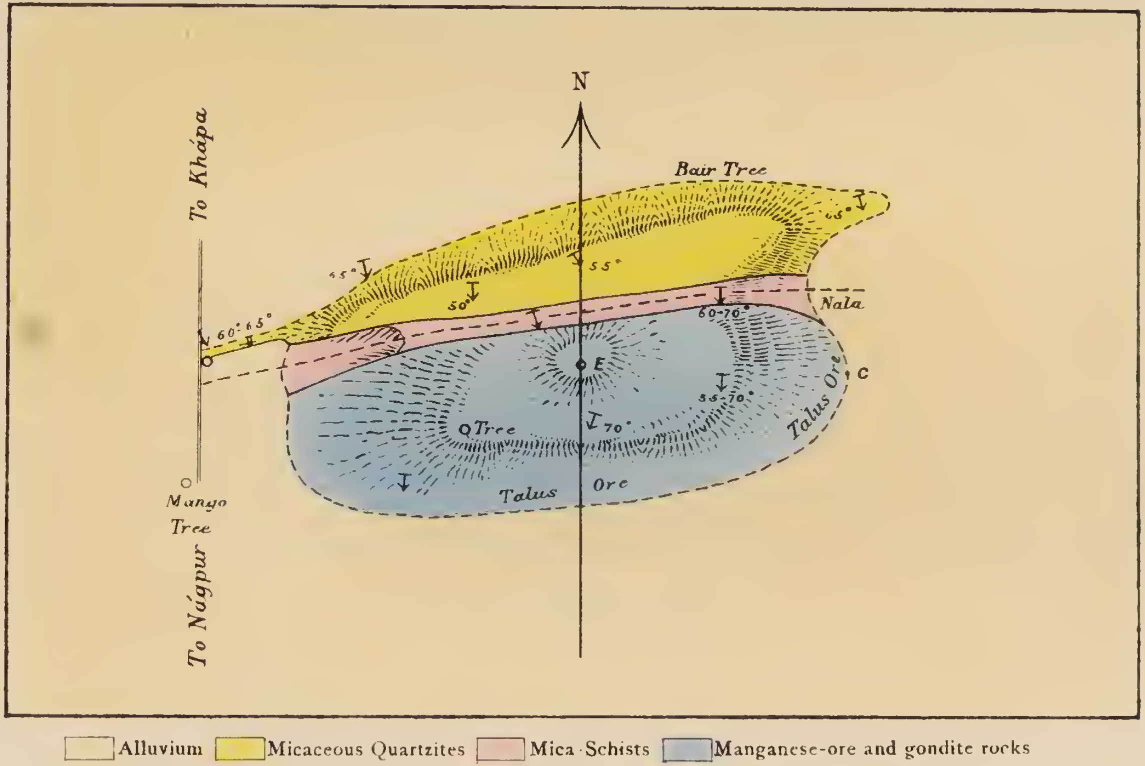


SKETCH MAP OF GUMGÁON MANGANESE-ORE DEPOSIT.
NÁGPUR DISTRICT.

Scale, 12" Inches = 1 mile.

(2) A middle band of decomposed felspathic mica-schist, 50 to 100 feet wide. These schists being softer than the rocks to the north and south form a depression along the middle of the hill.

(3) A northern band of micaceous schistose quartzites with an outcrop 200 feet broad at the widest part.

The ore-body.

Along its northern boundary this ore-body consists mainly of spessartite-quartz-rock, in places with secondary chalcedonic silica. It shows a lateral transition along the strike into ore, which, however, still contains some unaltered yellow garnet.

The ore improves in quality with distance from the north edge of the deposit and is worked chiefly along the south face of the hill. The excavation situated in the middle of the southern slope of the hill was the only one being worked while I was there in 1903. It showed that the ore is divided by large divisional planes dipping at 70° to vertical to the S. 10° W.; these divisional planes evidently show the strike and dip of the rock. There are various other quarries along the hillside, all much longer than broad, and 10-20 feet deep, and showing ore of rather variable quality. At the west end of the hill the manganese-ore runs up the hill with a distinctly bedded appearance, even as seen from $\frac{1}{2}$ mile away. Here the ore is often much veined and streaked with quartz, the streaks being usually at right angles to the strike.

Nature and quality of the ore.

The quality of the ore is very varied. The psilomelane-braunite mixture of Kodegáon is again the principal ore, with a specific gravity of 4·54 (small piece); but frequently the ore is a light steel grey, wholly crystalline variety, with a fine grey-black crystalline powder in the parting planes. A third variety is porous, soft, black, with lighter grey streaks, and is rejected by the quarry men, probably correctly, for its specific gravity is only 3·39, good merchantable ore usually having a density of 4·5 or more. Finally there is a fourth, extremely interesting, variety. It is a spotted variety of the crystalline ore, designated *chita-wálá patthar* by the coolies. The spots are flattened parallel to the banding of the ore, from $\frac{1}{4}$ to $\frac{1}{2}$ inch or more in diameter, and perhaps $\frac{1}{16}$ to $\frac{1}{8}$ inch thick. They may be either pinkish in colour or a dull sooty black. The microscope shows the pink spots to be really mosaic quartz, with undulatory extinction and containing some black prismatic inclusions. The black spots also consist of quartz, but contain a greater abundance of dark material. This ore is probably some that has not been completely transformed from the original gondite or allied rock to the final stage, the spots being perhaps secondary segregations of the remaining free silica. As one piece showed a specific gravity of only 3·71, this ore is probably very siliceous.

I took a sample from all the ore stacked here (November 1903). It consisted mainly of the psilomelane-braunite mixture, but included a certain proportion of the spotted ore. The analysis carried out at the Imperial Institute showed :—

Sample No. 2.

Manganese peroxide	60·17
Manganese protoxide	19·31
Ferric oxide	7·95
Silica (combined)	3·02
Silica (free)	1·45
Phosphoric oxide	0·28
Moisture at 100°C.	0·33

This is equivalent to :—

Manganese	53·05
Iron	5·565
Silica	4·47
Phosphorus	0·12
Moisture	0·33

The amount of combined silica points to an average composition for these ores of 30% of braunite and 70% of psilomelane.

Mr. W. H. Clark, Manager of the Central Provinces Prospecting Syndicate, has kindly supplied the following analyses, dated September 1905, by Mr. R. D. Connell :—

Tonnage represented.	316	419
Manganese	53·24	52·01
Iron	4·62	5·16
Silica	5·00	6·40
Phosphorus	0·09	0·09

Talus-ore deposits.

The lower slopes of the southern side of this hill are covered with loose ore resulting from the mechanical disintegration of the ore deposit. Such material is commonly called either 'boulder-ore' or 'float-ore', but had better, as explained on page 876, be referred to either as 'talus-ore' or 'detrital ore'.

At the base of the hill some pits, 5 feet deep, showed talus-ore right to the bottom. The whole of the southern part of the hill is coloured on the map to represent manganese-ore, but the ore band itself is probably not wider than about 50 to 100 feet across the outcrop, the southern fringe representing talus-ore.

The work here was of the usual description, the ore being extracted by crow-bars, broken up and cleaned with hammers, and stacked in the usual rectangular ore heaps 2-3 feet high. In 1907 the waste was being removed by means of trucks on a pair of rails carried on waste dumps, across the strike of the deposit at the west end and round to north side of the hill.

4. Rámdongri.

(CENTRAL PROVINCES PROSPECTING SYNDICATE.)

(*See Plate 24.*)

The geology of the hills to the east of the Kanhán river, stretching from Rámdongri H. S. to the big mass of quartzite I have called the Kuthulna hills, is very intricate and difficult to unravel, owing to thick jungle.

The map of this area shown in Plate 24 was constructed after a very careful examination of the ground during which practically every exposure was visited. In many places the ground is obscured by débris or jungle so that it is very difficult to join up the various outcrops. The result shown on the map is such as to suggest an intrusive relation of the manganese-silicate-rocks with regard to the quartzites, schists, and gneisses. It should be noted, however, that the long thin band of manganiferous rock shown as running in a east-north-east direction from the river-bank was not actually seen to connect with the mass of manganese-silicate-rock forming hill 5. Instead of so connecting it may have thinned out in lenticular fashion a little before. The apparent bifurcation at its eastern end of the mass of manganese-silicate-rock forming hill 5 certainly suggests, most strongly, intrusive relations to the other rocks. This bifurcation may, however, be the effect of faulting.

It was largely on the evidence of this occurrence, however, that the theory was put forward, doubtfully it is true,[1] that the manganese-silicate-rocks of the Central Provinces are, like those of Vizagapatam, to be regarded as igneous intrusives; and if this were the only occurrence of such rocks it would be difficult to confute this theory. A careful study of the many other occurrences of these rocks has, however, as described earlier (page 315), pointed irresistably to the conclusion that the manganese-silicate-rocks of the Central Provinces are metamorphosed sediments. When the Rámdongri deposits have been opened up much more than at present, it may become possible to explain how the manganese-silicate-rocks of Rámdongri simulate igneous rocks in their relations to the quartzites, gneisses, and schists, and yet are, as they must be, considering their similarity to the other manganese-silicate-rocks of the Central Provinces, really chemically-altered metamorphosed sediments.

The Rámdongri mass of hills rises at Rámdongri H. S. to about 280 feet above the surrounding alluvial country. All the hills and hillocks owe their elevation either to quartzites, more or less micaceous, or to manganese-ore bodies, while the lower lying ground is occupied by mica-schists, biotite-gneisses, and tourmaline-granites. The various bands of

[1] *Rec. G. S. I.*, XXXIII, p. 97, (1906); *Trans. Min. Geol. Inst. Ind.*, I, p. 91, (1906)

quartzites shown on the map have been marked only where seen; but some of them possibly connect up as shown. The quartzites forming the Kuthulna hills are separated from the Rámdongri hills to the west by a well-marked valley running north-north-west, and probably due to a fault having the same direction.

Another feature, in addition to those mentioned on page 855, that seems to point to the manganese-silicate-rocks being igneous intrusives, is the fact that the backbone of hills 1 and 2 apparently runs into the ore-body of hill 5; for there is no evidence to be seen in the nálá dividing hills 2 and 5 that could be taken as indicating the presence there of a fault. Also, where this deposit, at its west end, crosses the nálá shewn, it is interbanded with schists, quartzite, and gneiss, suggesting that the presumed intrusion terminates by breaking up into parallel bands intercalated between the pre-existing metamorphics. Even including these bands of gneiss, etc., the width of outcrop, in this nálá, of the ore-body—which here mostly takes the form of spessartite-quartz-rock (gondite)—is only about 150 feet, and at the southern end of the exposure the spessartite-bearing rock is seen to dip to the west under the grey gneiss, again hinting at the termination of the ore-body; this would also be best explained by an igneous origin.

By referring to the map it will be seen that—neglecting the thin band that runs west to the bank of the Kanhán river and consists of rhodonite-spessartite-quartz-rock partly altered to manganese-ore—there are three distinct ore-bodies, forming hills 4, 13, and 5, respectively. They are all of lenticular shape, though ore-body 5 is divided at its eastern end.

Hill 5.

Hill 5 is practically the only one on which work had been done in 1903. The ore-body giving rise to this hill is of enormous size, in fact it is the largest I have yet examined. The total length is about 2,500 feet and the total width about 1,500 feet, whilst the hill rises to a height of about 140 feet above the neighbouring low ground. A very large proportion of the ore is, however, quite unworkable, especially in the northern parts of the deposit, where the rock is chiefly gondite in various stages of change into manganese-ore. Here also is some intercalated mica-schist and pegmatite. There is, however, a band of good ore about 80 yards long on the south edge of the top of the hill and here a little work had been done in November 1903; but even this ore is of variable quality. The east, south-east and south slopes of the hill are covered by talus-ore, and it is here that the principal work had been done. These talus-pits were at the most only 10 to 12 feet deep on the side nearer the centre of the hill and of course less on the side farther away. The pebbles and fragments in these pits decrease, of course, in size with the distance from the top of the hill. In the main quarries on the south-east and east sides of the hill, where the slope becomes less, the average size of the pebbles is from 1 to 6 inches diameter. These pebbles are set in a ferruginous clay, which largely falls off in the process of extraction and cleaning. Every pebble has to be broken, and the clerk in charge of the work said that 40% of them on being broken are found to be good ore; the remainder, composed of poor ore, spessartiferous rock, quartz, etc., are of course thrown on the waste heaps.

Hillock 12.

At its west end the main mass of the hill is joined to a small hillock, 12, by a neck composed mainly of slightly altered, interbanded, quartz and gondite. Among the rocks composing this neck is one of quartz and martite. On this hillock 12 there is some good ore like that of Kodegáon, and also some partially altered rhodonite, and some rock consisting of resin-coloured garnets set in the ordinary black ore.

Blanfordite.

Attention may be here drawn to the extremely beautiful new manganese-pyroxene, blanfordite, an account of which will be found on page 127. It is found sparingly in a pyroxene-felspar-rock, occurring as patches in the ore-body on the top of hill 5. This rock is probably an intrusive into the main mass of manganese-silicate-rock and manganese-ore.

Hill 4.

Hill 4 is formed by another of these lenticular masses of manganiferous rock. The dimensions of the lenticle as marked on the map are roughly 1,500 feet long by 700 feet broad, but it is to be understood that the actual boundaries of this—as of most other deposits—are partly conjectural due to the boulders and pebbles found on the lower slopes of the hill. The hill is constituted partly of good ore, and partly of gondite, more or less altered. The ore seems to occupy the central portion of the deposit, the northern and southern portions consisting mainly of the spessartiferous rock, whilst even the good ore passes into spessartiferous rock along the strike. Intercalated with the ore, on the south side of the summit, are light and dark grey quartzites and a little gneissose rock; the dark grey quartzite is the usual manganiferous rock so often found with the ore deposits. A moderate quantity of fairly good compact ore can be obtained from the very top of the hill, but as a large proportion of it is rendered unmarketable by soft black spots and patches and by spessartite, the amount of good ore cannot be large, and it seems doubtful if it could pay to work this deposit except when prices rule high. Even of talus-ore there does not appear to be a large quantity.

Hillock 13.

Hill No. 4 deposit does not reach quite as far as the Rámdongri nálá, the rock seen in the stream bed and banks, directly on the line of strike of the lenticle, being various schists. But, on the other side of the nálá there occurs almost at once another, though very small, lenticle of ore forming hillock No. 13. The lenticle, which runs E. 10° S., is exposed for a length of about 150 yards and may be 30 yards across; at its west end it runs almost to the very bank of the nálá in which the schists are seen. The 'country' on the north side is grey gneiss, which, together with schists and quartzites, separates this lenticle from the deposit of hill 5. The ore itself is mostly not of much value.

Hill 9.

This is the hillock to the north of hill 5. The manganiferous rocks here consist of manganese-ore, and partly altered spessartite-rock and spessartite-rhodonite-rock with quartz. There is a certain amount of merchantable ore, but probably not enough to repay the cost of extraction. The associated rocks are pinkish quartzites, micaceous schists, and tourmaline-gneiss and granite.

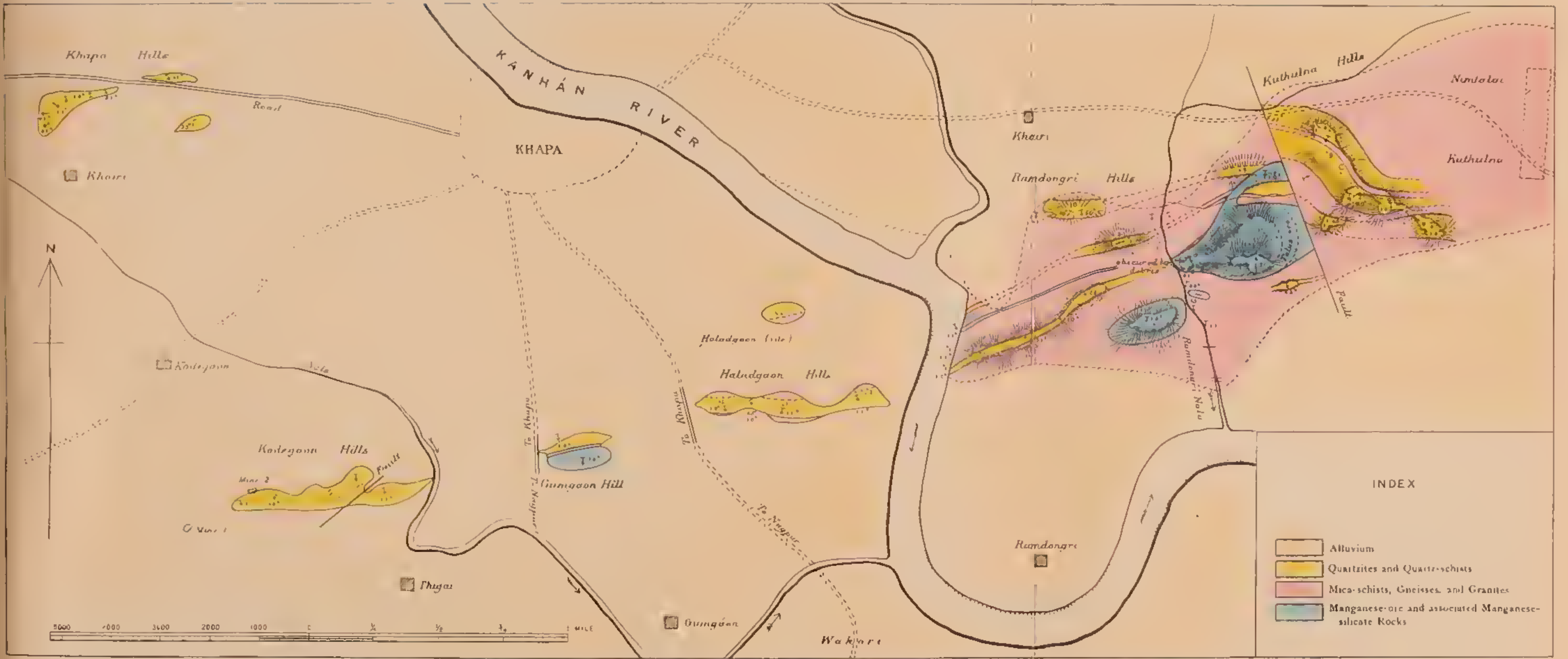
Nature and quality of the ores.

The ore of these deposits is largely the usual fine-grained hard grey compact mixture of braunite and psilomelane; but there is a fair proportion, mainly in hill 5, of coarsely crystalline ore, showing facets up to $\frac{1}{4}$ or $\frac{1}{2}$ inch across, nearly all the ore then being braunite. It seems possible that the fine-grained compact ore has been formed from spessartite-rock and the facetted ore from rhodonite-rock.

I took four samples, the analyses of which carried out at the Imperial Institute are shown in the following table:—

Analyses of Rámdongri ores.

Sample number	3	4	5	6
Manganese peroxide	48·25	51·75	51·33	46·48
Manganese protoxide	28·10	27·48	26·79	28·25
Ferric oxide	11·81	8·46	8·58	10·00
Silica (combined)	5·19	5·69	6·15	6·50
Silica (free)	0·28	0·39	0·38	1·14
Phosphoric oxide	0·19	0·22	0·13	0·35
Moisture at 100° C.	0·37	0·38	0·36	0·63
Manganese	53·34	54·07	53·17	51·31
Iron	8·27	5·92	6·01	7·00
Silica	5·47	6·08	6·53	7·64
Phosphorus	0·12	0·08	0·10	0·06



GEOLOGICAL SKETCH MAP OF GROUP I OF THE MANGANESE DEPOSITS OF THE NÁGPUR DISTRICT.

The details of these samples are as follows :—

Sample 3.—Taken from the stacked talus-ore derived from hill 5 (November 1903). Composed principally of the fine-gained braunite-psilomelane mixture.

Sample 4.—Taken from the ore quarried *in situ* and from the débris near the top of hill 5, where the blocks are very large (November 1903). Composed principally of the fine-grained braunite-psilomelane mixture, with a certain proportion of the facetted braunite-ore. Several pieces rather cindery in appearance. Also a little siliceous impurity in one or two pieces.

Sample 5.—Taken from the outcrop on hill 9 (November 1903), composed mostly of rather cavernous hard grey fine-grained ore (braunite-psilomelane mixture), containing a considerable quantity of soft black powder and sometimes little strings of white quartz.

Sample 6.—Taken from the outcrop and loose blocks of the top of hill 4, down its eastern slope, and a little way down its north-north-western slope (November 1903). Composed of hard grey fine-grained braunite-psilomelane mixture, some pieces containing a little spessartite and traces of quartz.

The above analyses indicate that these ores contain from 50 to 65 per cent. of braunite, the balance being psilomelane.

The following analyses were kindly supplied by Mr. W. H. Clark :—

	Talus-ore (small) from pits S. E. of hill 5.	Talus-ore (large) from pits S. E. of hill 5.	Stacked ore from outcrop on south edge of hill 5.	Stacked ore from outcrop on south and west sides of hill 5.
Tonnage represented.	100	75	200	300
Manganese	54·27	54·63	52·47	51·97
Iron	5·47	5·39	6·44	6·70
Silica	5·47	4·96	6·74	7·14
Phosphorus	0·07	0·065	0·08	0·085

GROUP II.

4. Risára.
5. Nándgondi.
6. Sitagondi.

This area includes the cultivated tracts of Risára, and the wild, very hilly, and uninhabited, jungle-clad tracts of Sitagondi and Nándgondi.

At the time of my visit prospecting licenses over the village of Risára, Sugundra, Nándgondi, Mahárkund and Chárgaon had been taken out by Messrs. Ogilvy, Gillanders and Company of Calcutta. I was unable, however, to obtain any news of the existence of manganese-ore in any of these village areas except Risára. Quite by accident I found outcrops of spessartite-bearing rocks in the dense jungles of Sitagondi and Nándgondi, and it is probable that a careful search through these Government forests would lead to the discovery of further localities for these rocks, with the prospect of some of them containing merchantable manganese-ore.

4. Risára (Reechhara).

There are three occurrences of manganese-silicate-rocks and manganese-ores near this village. The first spot is a little over ½ a mile north by east from Risára, about 50 yards west of a water-course and 150 yards south of the boundary of the Government Forest to the north. Here had been collected a pile of fragments of mixed spessartite and manganese-ore, while two or three blocks of similar rock seemed to be *in situ* in the ground. The rocks seen in the nálá to the east of this deposit are acid gneisses. The second outcrop is a little over ½ mile north-east from the village. This outcrop strikes west-south-west and at its south-west end crosses a nálá. It is 50 yards long and 17 wide and consists of fine-and medium-grained spessartite-rock of yellow and grey colours, which is altered in patches to manganese-ore, and shows quartz both in patches and bands. There is also in places rose-pink rhodonite superficially blackened to a depth of ¾ to 1 inch. A small amount of manganese-ore of second-grade quality occurs in places. The 'country' of this deposit is not visible, but a little to the west there is an outcrop of yellowish pink crystalline limestone striking E. 5° N., vertical.

The third outcrop is some ¼ mile S. 30° E. from the second, and on the other side of a nálá. It is about ⅝ mile east-north-east of the village. This outcrop is found on a hillock perhaps 30 to 40 feet high and some 350 yards long, and strikes W. 20° N. The portion carrying manganese-silicates and ores is about 100 yards wide at the broadest part. The manganiferous rock consists of the usual spessartite-quartz-rock, in which the garnet varies in colour from yellow to grey and brown. When there is plenty of quartz present the rock is hard; but when mostly of spessartite it is friable. The garnets are not usually more than $\frac{1}{64}$ to $\frac{1}{32}$ inch in diameter. In places the rock has been converted into manganese-ore, but nowhere did I see a single piece of marketable quality. At the west end of the hillock, the 'country' on the north side is biotite-felspar-schist, but towards the east end white quartzites crop out on both sides of the spessartite-bearing rocks.

None of the three outcrops noticed above can be considered to be of any economic value, if one can judge from outcrops.

A sample taken from this locality by Messrs. Ogilvy, Gillanders and Company was analysed by Mr. E. Riley of London with the following result:[1]—

	Per cent.
Manganese	34·68
Iron	2·26
Silica	23·46
Phosphorus	0·43
Moisture	1·02

[1] Published with the kind permission of Messrs. Ogilvy, Gillanders and Company.

5. Nándgondi.

Somewhere in the Nándgondi jungles I found an outcrop of spessartite-bearing rock—often quite blackened—occurring as patches and streaks in quartz. At its two ends this rock seemed to pass into quartzite. The strike was west-north-west and the rock on the north side of the band was a bronze-coloured biotite-schist. The ½-inch map of this area represents the hills so incorrectly that it is almost impossible to correlate the real topography with that shown on the map. As far as I could make out, however, this outcrop was at the foot of the southern end of the long S. S. W. running ridge on which the deserted village of 'Nandgondee' is marked on the map.

6. Sitagondi.

In the reserved forest, in the valley just to the north of western end of the large mass of quartzite hills marked on the ½-inch map as the site of the village of 'Seethagondee', there are two obscure occurrences of manganiferous rocks to be found only with difficulty, or rather by accident, on account of the jungle and long grass. One of these localities is about ½ mile due north of the 'ee' of 'Seethagondee' and here fragments of spessartite-bearing rock, probably derived from a neighbouring or underlying band of similar rock are found scattered on the ground for 100 to 200 yards along an east to west line. The rock is composed of a friable dark-brown to black aggregate in which the garnets average perhaps $\frac{1}{64}$ to $\frac{1}{32}$ inch in diameter. A little to the north of these fragments there is an outcrop, in one place, of biotite-gneiss dipping to S. 20° W. at 30° to 40°, and in another, more to the west, of bronze-coloured mica-schist dipping at 45° in the same direction.

Some 500 to 600 yards west of this spot and apparently on the same line of strike there are to be found—associated with very schistose biotite-gneiss and biotite-felspar-quartz-schists, which dip to S. 20° W. at 50°—several blocks of spessartite-bearing rock, consisting largely of the yellow fine-grained variety, streaked and patched with black due to conversion to manganese-ore; but partly of the red-brown granular variety, much blackened. There is also a fair quantity of greenish-grey rhodonite associated with a little of the pink variety.

At neither of the above localities was any merchantable manganese-ore seen.

GROUP III.

7. Kándri.
8. Mansar.
9. Mansar Extension.
10. Parsoda.
11. Borda.

Leaving out of account the Borda deposit, which is an isolated one, the deposits of this group lie in the mass of hills situated to the west of Rámtek and to the north and east of Mansar. The associated rocks are mica-schists, quartzites, fine-grained gneisses containing a magnetic mineral, perhaps mangan-magnetite, and occasional crystalline limestones. Although the Kándri deposit is now apparently isolated from that of Mansar, and is probably a lenticular mass, yet at one time it may have been joined to what is now the Mansar deposit and have been separated from it by squeezing during the earth movements by which the original manganiferous sediments were metamorphosed. Mansar Extension is only a portion of the Mansar deposit lying at its western end. The Parsoda deposit lying about $\frac{5}{8}$ mile to the south-south-east of the south-east end of the Mansar band is in all probability an extension of the latter, the intervening portions of the manganiferous band being obscured by alluvial soil. The ore from this group of deposits was, up till 1907, carried by bullock carts along the road to Kámthi, a distance of some 16 to 17 miles; but this has been changed now the Rámtek Railway, with its siding to Mansar and Kándri, has been completed.

If the deposits of this group represent what was once a continuous layer of manganiferous sediments, then we might expect to find the continuation of this layer somewhere to the east. If the line of deposits forming group IV is to be regarded as this continuation, then it is obvious from the map (Plate 43) that there is probably a large cross fault running in a north-east direction from the west of Dumri towards Rámtek, passing to the west of this town.

7. Kándri.

(CENTRAL PROVINCES PROSPECTING SYNDICATE.)

(See Plates 26 to 31.)

This is probably the finest body of manganese-ore yet found in India, and certainly one of the finest in the world.

Geology of the deposit.

The ore-body (see Plate 32) takes the form of a lenticular band about $\frac{1}{2}$ mile long and curved into a horse-shoe shape, forming three hills. Two of these, the south and north hills, rise to about 260 and 210 feet, respectively, above the low ground to the east (see Plate 26, fig. 1). They are joined by a saddle, the elevation of which is not many feet below that of the north hill. The ore-band in both these hills consists of merchantable ore, but in the saddle it consists mostly of spessartite-rock and spessartite-bearing quartzites. The east hill is about 120 feet high and here the ore-band is composed of gondite and spessartite-bearing quartzites, often largely changed to manganese-ore, but not sufficiently so to be workable. The portion of the band which we must suppose joins the east hill to the north hill is obscured by talus-ore. As regards the terminations of the ore-

FIG. 1.—KÁNDRI HILL FROM THE EAST.

Photographed by L. L. Fermor. *Bemrose, Collo., Derby.*

FIG. 2.—LEVEL 3 OF KÁNDRI MANGANESE-QUARRY.

band, the excavations, at the south-east end of the southern arm of the horse-shoe, show unequivocally that this end of the band dips below the surface as indicated in figure 51. Moreover, a bore-hole, No. 3 on the plan, which was put down at 65 feet from the end of the lens, struck the manganese-ore body at a depth of 65 feet, thus showing that the back of the lens here dips below the surface at 45°. It is not known what happens to the eastern end of the northern branch of the horse-shoe, as it is obscured by detrital ore. But since it does not crop out again further to the east, we must suppose that it either dies out here or dips below the surface. The projection from the ore-body shown opposite level 2 (South Hill) in the plan is due to what is probably an overturn of the southern edge of the lens along the part of it stretching from levels 2 to 4. It is most noticeable at level 2 and has practically disappeared opposite level 4. This is illustrated very roughly in figure 52, which makes no pretence to dimensional accuracy. The actual anticline was visible at the upper end of a trench running about W. 17° N. along the southern side of ore-body between levels 2 and 3, and is illustrated in figure 53.

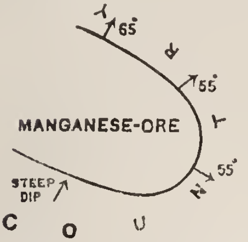


Fig. 51.—Diagram of the south-east end of the Kándri manganese-ore body.

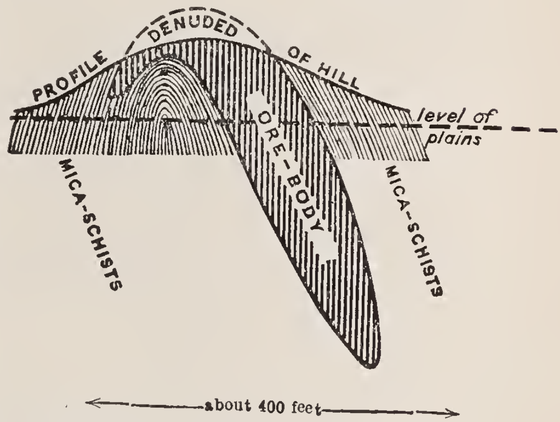


Fig. 52.—Diagrammatic section across South Hill at level 2

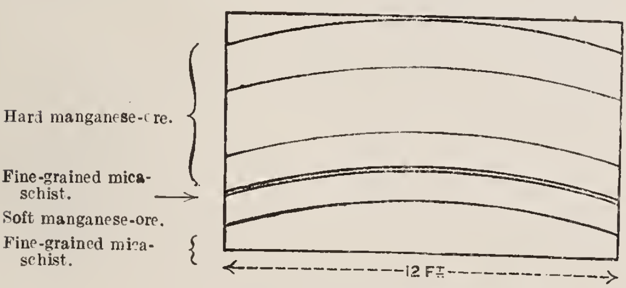


Fig 53.—Anticlinal overturn of back of manganese-ore body near level 3, Kándri.

On South Hill, where a considerable amount of work has been carried out, several good sections were to be seen in levels 1 to 4. These indicate that the thicknes of the ore-body is 70 to 100 feet measured horizontally

Or, taking an average dip of 60°, the actual thickness in the South Hill varies from about 60 feet at level 1 to about 87 feet at level 4. Plate 29 shows the ore-body in South Hill. [On the saddle, North Hill and East Hill, the boundaries of the ore-band are obscured by débris, so that it will not be possible to give the actual thickness until cross-cuts have been made across these parts of the deposit.] The various levels indicate that on the north-north-east side of the ore-band there is a thickness of about 100 feet of a fine-grained (often granulitic) gneiss, composed of quartz and microcline, with subsidiary oligoclase, a fair amount of magnetite (?mangan-magnetite), and often muscovite in abundance. This rock may vary from whitish to pinkish in colour, be either very hard or quite crumbly, and if much mica be present it may be very schistose. It is separated from the main ore-body by a small thickness of interbanded ore-layers, spessartite-bearing and other quartzites. On the side of the gneiss remote from the ore-body, *i.e.*, towards the middle of the horse-shoe, is typical mica (muscovite)-schist occupying all the ground between the south and north hills. The clearest section of the country on the north or hanging-wall side of the ore-body was seen in level 1 and was as follows (measurements horizontal):—

49 feet . .	fine-grained magnetite-muscovite-microcline-gneiss,
1 foot . .	interbanded gondite, quartzite, and manganese-ore,
4 feet . .	soft manganese-ore,
1 foot . .	very fine-grained, soft, dove-coloured, sandy rock, with bands of gondite altered in places to manganese-ore,
1 foot, 5 inches .	soft manganese-ore with two 2-inch partings of the soft sandy rock,
70 feet . .	the main ore-body of solid braunite-ore.

The only clear section of the rocks on the footwall or south side of the deposit was also in level 1 and was as follows (measuring away from the deposit in continuation of the above):—

1 foot 8 inches	dark grey quartzite, partly replaced by manganese-ore,
6 inches	soft manganese-ore,
9 feet 6 inches	soft dove-coloured sandy rock (of lenticular shape) and fine-grained mica-schist, with a thin band of manganese-ore,
29 feet . .	interbanded manganese-ore and dark grey quartzites, often containing spessartite,
29 feet . .	fine-grained mica-quartz-schist and decomposed spessartite-bearing quartzites,
10 feet . .	rather soft manganese-ore (this is the overturned part of the ore-body),
11 feet . .	interbanded soft dove-coloured sandy rock, spessartite-quartzite, and mica-schists,
20 feet . .	mica-schist with little quartz lenticles,
35 feet . .	soft micaceous pink and grey schistose gneisses containing a band of dark grey quartzites.

Here start the talus-ore quarries.

It will be noticed (see Plate 32) that the dips of the ore-body are everywhere directed towards the inside of the horse-shoe. As far as can be discovered (the ground being much obscured by débris) mica-schists occupy all the ground in the horse-shoe and round its outside as far as dotted boundary shown on the plan. The strikes and dips of the mica-schists probably curl round parallel to those of the ore-body and associated rocks they enclose. All the ground outside the mica-schist boundary is occupied by medium-grained gneisses composed of quartz, microcline, and magnetite, with subsidiary plagioclastic felspar. They have a general strike of about east-south-east, which would carry them right into the ore-body. It is, of course, extremely difficult to unravel the structure of such disturbed Archæan rocks, but there are two fairly obvious ways of explaining the relations of the gneisses to the mica-schists. We can either suppose that the mica-schists and included ore-band form a large 'eye,' with the gneisses curling round it to the north and south; or we can, perhaps with less probability, suppose that the mica-schists and included ore-band form a faulted block in the gneisses.

From the evidence of the rocks cropping out on the east hill it is necessary to assume the existence of a strike fault QY (in Plate 32). This fault, with a cross-fault QZ, explains how the ore-band has become doubled in width in the eastern half of the hill. The downthrow is to the north as explained in figure 54. The amount of the throw is probably about 200 feet or a little less.

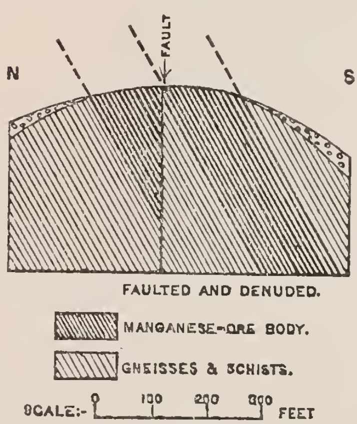


Fig 54.—Diagram illustrating the faulting of East Hill, Kándr.

The ore-body is in plan apparently a lenticular band doubled on itself and its south-east end dives below the surface as if the ore-body were increasing in length with depth from the surface.

It seems probable that this deposit is really a synclinal trough the axis of which dips in an east to east-south-east direction. There is little doubt that at the west end of this supposed trough the two limbs of the deposit join below the surface, as shown in figure 1, Plate 27. But it is probable that further to the east these two limbs do not join below the surface, as indicated in figure 2, Plate 27. My idea of the structure can be best grasped by means of a paper model. If a copy of the diagram in figure 55 be drawn upon a piece of paper and cut out

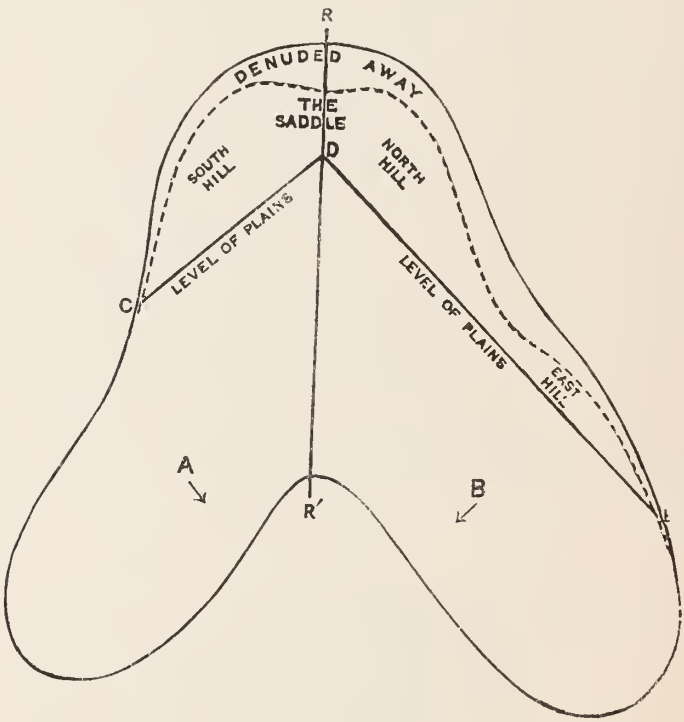


Fig. 55.—Diagram to illustrate shape of Kándri manganese-ore body

along the outer boundary, and then the line RR′ be placed pointing east-south-east so as to dip at an angle of 45° in that direction, and the two limbs A and B be bent up about this line so that they each dip at about 60° in the direction of the arrows; then the lines C D, DE, representing the level of the plains surrounding Kándri hill, will be found to be roughly horizontal, and the model will give a very rough idea of the probable shape of the deposit.

On the theory that this ore-body has been derived by the chemical alteration of metamorphosed sediments, we must suppose either that

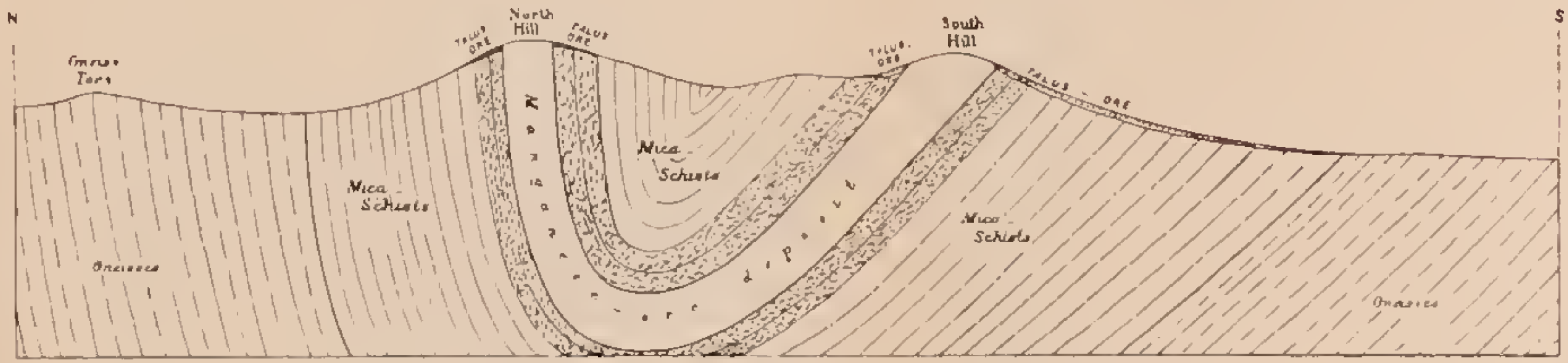


FIG. 1.—SECTION ACROSS THE KÁNDRI MANGANESE-ORE DEPOSIT ALONG THE LINE PP′ (PLATE 32).

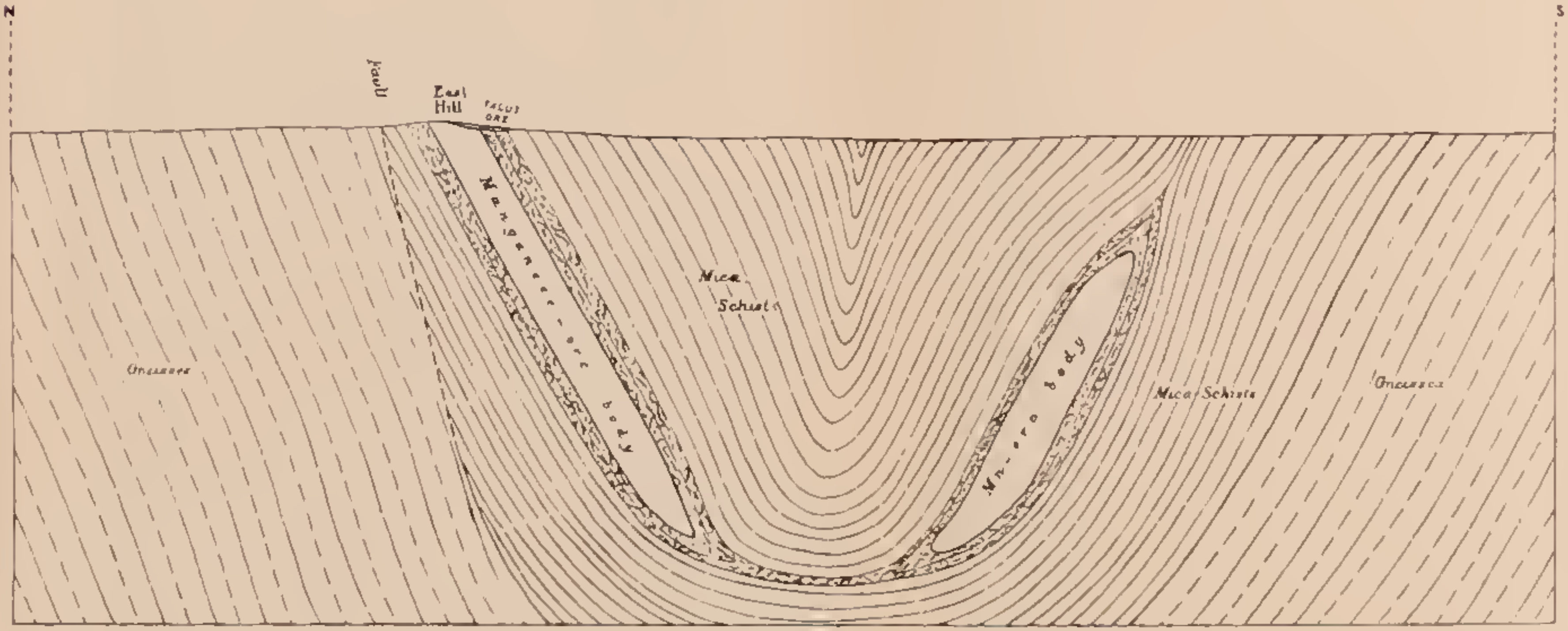


FIG. 2 - SECTION ACROSS THE KÁNDRI MANGANESE-ORE DEPOSIT ALONG THE LINE RR′ (PLATE 32).

the shape of this sheet shown in figure 55 is roughly the original shape of the basin in which the sediments were deposited, or that this supposed shape has been produced by earth movements pinching this piece off from the remainder of the ore-layer. This sheet has been spoken of above as an ore-body, but it is of course not known how much of the sheet is manganese-silicate-rock and how much is merchantable manganese-ore.

Slickensides-grooving.

A very interesting feature of this deposit is the fact that almost everywhere both the manganese-ores and the accompanying granulitic gneiss show a well marked parallel grooving. This is no doubt of the nature of slickensides, but real polished slickensides are rare and have been found only on loose pieces of manganese-ore in the talus-deposits. The grooves are sometimes as much as 4 inches deep, the sides of these grooves being then often scored by smaller grooves. The average direction of this grooving is about E. 30° S. at 30°, but it varies somewhat in different parts of the deposit. Thus in the North and East Hills it tends to point more to the south-east at a somewhat steeper angle, whilst in South Hill it is almost constantly to E. 25° S. at 25° to 30°, usually 28°. In South Hill, the slickensides-grooving points right down the ore-deposit, giving the manganese-ore body a columnar structure, and this, together with the cross-jointing, greatly facilitates the extraction of the ore. Plate 30 shows well the slickensiding in level 2. If we regard the mica-schists and included ore-body as an 'eye' in the gneisses, then we can suppose that these groovings, which roughly conform to the length of the eye, were formed by the same earth movements as formed the eye.

An interesting rock.

One piece of manganese-ore was found with attached white material, which under the microscope was found to be a rock composed of practically colourless garnet in a matrix of untwinned (probably orthoclase) felspar. The garnet is probably a pale variety of spessartite and has been largely replaced by manganese-ore. The rock is of interest as being probably an orthoclase-spessartite-rock and thus a felspathic member of the gondite series.

Nature and quality of the ores.

In the portion of South Hill lying between the south-east end and the summit A, the manganese-ore is, as far as exposed, of uniformly good quality for the whole width of the band. It is a fine-grained crystalline ore varying from very hard to soft and composed apparently of braunite with a certain proportion of admixed psilomelane. The following three analyses of picked hand-specimens were carried out at the Imperial Institute, London:[1]—

	Soft ore. 982	Soft ore with sericitic films. 994.	Hard ore. 995.
Manganese dioxide (MnO_2) . . .	42·86	33·78	49·42
Manganese protoxide (MnO) . .	39·09	36·40	35·20
Ferric oxide (Fe_2O_3)	4·13	17·12	4·82
Alumina (Al_2O_3)	1·60	0·13	0·16
Baryta (BaO)	0·89	0·21	0·00
Lime (CaO)	0·72	1·35	0·63
Magnesia (MgO)	0·25	0·25	0·34
Combined silica (SiO_2) . . .	6·98	8·06	6·17
Free silica (SiO_2)	2·07	1·20	1·64
Phosphoric oxide (P_2O_5) . . .	0·37	0·49	0·15
Arsenic oxide (As_2O_5) . . .	0·008	0·012	0·019
Combined water (H_2O) . . .	0·40	1·00	1·27
Moisture at 100°C. (H_2O) . . .	0·10	0·10	0·15
Carbon dioxide (CO_2) . . .	0·35	0·07	0·06
	99·818	100·172	100·029
Manganese	57·41	49·60	58·55
Iron	2·89	11·98	3·37
Silica	9·05	9·26	7·81
Phosphorus	0·16	0·21	0·06
Moisture	0·10	0·10	0·15
Specific gravity	4·54	4·502	4·272

Spec. 982—collected in level 1
Spec. 994— do. do. 2
Spec. 995— do. do. 3

[1] The following additional constituents were later found in these specimens —

	982	994	995
NiO, Co_3O_4, CuO	0·015	0·014*	0·028
K_2O	0·18	0·05	0·14
Na_2O	0·50	0·49	0·42

* Mainly NiO.

[2] These values were determined at the Imperial Institute. As one would expect No. 994 to have a lower G. than 995, I took the specific gravities of the duplicate specimens of these retained in the Geological Survey of India Office and found the value for No. 994 = 4·04 and for No. 995 = 4·52.

The analysis of 995 can be restated in terms of its mineral composition as follows :—

Hard ore—No. 995.

Apatite		0·35
Calcite		0·14
Braunite (including 4·82 Fe_2O_3)		61·91
Psilomelane, composed of :—		
$Al_4(MnO_5)_3$ . .	0·40	
Ca_2MnO_5 . .	0·67	
Mg_2MnO_5 . .	0·77	
H_4MnO_5 . .	4·90	
Mn_2MnO_5 . .	29·71	
	36·45 . . .	36·45
Quartz		1·64
As_2O_5		0·019
Moisture		0·15
		100·659
Subtract oxygen assumed		0·63
		100·029

That of 982 can be restated as follows :—

Soft ore—No. 982.

Apatite	0·86
Dolomite	0·74
Braunite (containing 4·13 Fe_2O_3)	70·01
Mn_2MnO_5	23·37
Quartz	2·07
Impurities:—	
Al_2O_3	1·60
BaO	0·89
MgO	0·09
H_2O (combined)	0·40
As_2O_5	0·008
Moisture	0·10
	100·138
Subtract oxygen assumed	0·32
	99·818

It is necessary to suppose that the psilomelane consists entirely of Mn_2MnO_5, because if the Al_2O_3, BaO, etc., be converted into manganates, as was done in the case of No. 995, there is a deficit of 1·14% of oxygen. A still less probable arrangement of the above analysis shows the ore to contain 18·90% hausmannite and 6·95% manganates of Al, Ba, Mg, and H, in place of the psilomelane; this arrangement, however, has the advantage of leaving only 0·18% oxygen unused.

The analysis of the third ore No. 994 can be re-arranged in the two following ways:—

Soft ore with sericitic films—No. 994.

A.			B.		
Apatite		1·13	Apatite		1·13
Calcite		0·16	Calcite		0·16
Braunite:—			Braunite:—		
SiO_2	8·06		SiO_2	8·06	
MnO	9·47		MnO	9·47	
Mn_2O_3	60·71		Mn_2O_3	46·32	
Fe_2O_3	2·55		Fe_2O_3	17·12	
	80·79	80·79		80·97	80·97
Hematite		14·57	Mn_2O_3		14·39
Quartz		1·20	Quartz		1·20
Water hydrating part of hematite		1·00	Water hydrating part of Mn_2O_3		1·00
Impurities:—			Impurities:—		
Al_2O_3	0·13		Al_2O_3	0·13	
BaO	0·21		BaO	0·21	
CaO	0·62		CaO	0·62	
MgO	0·25		MgO	0·25	
As_2O_5	0·012		As_2O_5	0·012	
	1·222	1·222		1·222	1·222
Moisture (at 100°C.)		0·10	Moisture (at 100°C.)		0·10
Total		100·172	Total		100·172

Of these A is perhaps the preferable interpretation; for Mn_2O_3 has not been yet obtained as a definite mineral, except doubtfully.

Photographed by L. L. Fermor.

Bemrose, Collo., Derby.

GENERAL VIEW OF THE MANGANESE-QUARRY AT KÁNDRI, NÁGPUR DISTRICT, C. P

I am indebted to Mr. W. H. Clark for the following complete analyses of large quantities of Kándri ore :—

Date of analysis.	18th August 1900.	16th May 1901.
Details of sample.	Mixture of 4 samples.	Mixture of 18 samples.
Tonnage represented.	Over 2,000.	Unknown.
Analyst.	H. H. Dains.	G. M. Prichard.
Manganese peroxide	49·07	46·295[1]
Manganese protoxide	32·91	33·17[1]
Ferric oxide	5·31	6·84
Alumina	0·96	1·31
Baryta	0·45	0·84
Lime	*Nil*	0·42
Magnesia	0·04	trace
Alkalies	..	*Nil*
Silica	8·77	8·15
Phosphoric oxide (P_2O_5) . . .	0·20	0·16
Arsenic oxide (As_2O_5)	*Nil*	*Nil*
Sulphuric oxide (SO_3)	0·045	0·035
Nickel oxide (NiO)	0·32	trace
Cobalt oxide (CoO)	...	
Copper oxide (CuO)	*Nil*	0·74
Combined water	1·35	1·43
Moisture at 100°C.	0·41	0·61
Carbon dioxide	...	*Nil*
Total .	99·835	100·00
Manganese	56·52	54·96
Iron	3·72	4·79
Silica	8·77	8·15
Phosphorus	0·09	0·07

[1] The manganese divided into MnO_2 and MnO on assumption that analysis adds up to 100·00

and for the following partial analyses :—

Date of analysis.	18th August 1900.	11th July 1905.
Details of sample.	Range of 4 samples referred to above.	Average of ore at mine.
Tonnage represented.	—	601
Analyst.	H. H. Dains.	R. D. Connell.
Manganese	52·80—59·00	55·25
Iron	3·21— 4·41	..
Silica	5·98—10·32	9·81
Phosphorus	0·07— 0·12	0·12

The following may be taken as the ordinary range of the Kándri ores despatched :—

Manganese	54 to 57
Iron	3 to 5
Silica	8 to 10
Phosphorus	0·08 to 0·12

The characteristic ore of this deposit as mined in South Hill is the finely crystalline, nearly always containing a high percentage of braunite. When there is a fair amount of psilomelane present the ore is compact and hard, the psilomelane acting as a cement to the braunite. With smaller amounts of psilomelane the ore becomes more friable. This is well illustrated by the three analyses of specimens 982, 994 and 995 given on page 868. The hard variety 995 contained 36½% psilomelane and the two soft varieties 23% and *nil*, respectively. At a second visit to this mine in December 1906, it was found that the proportion of the soft, or rather, friable ores is increasing rapidly as the deposit is worked deeper. This points to the proportion of psilomelane decreasing with depth. An unfortunate result of this change in physical character of the ore is that the percentage of ore wasted is increasing very rapidly with depth; for a considerable proportion of the ore breaks down into a fine powder when it is handled. As this powdery ore is usually of very high grade it is a pity that a market cannot be found for bagged ore.[1]

In South Hill these soft and hard ores seem to be arranged in layers one on top of the other, parallel to the surface of the deposit, and often to pass one into the other. They frequently contain dark brown sooty films along cracks. At the very top of South Hill near A, the ore often

[1] See *Trans. Min. Geol. Inst. India*, I, p. 224, (1907).

Photographed by L. L. Fermor.

Bemrose. Collo., Derby.

KÁNDRI MANGANESE-QUARRY, GENERAL VIEW.

contains opal and chalcedony in cracks. Between A and C, the deposit is mostly not worth working ; for the manganese-ore to a large extent gives way to spessartite-quartz-rock and quartzite, often interbanded. The spessartite is often partly altered to manganese-ore.

Between B and C there is a little rhodonite associated with these rocks. There is a continuous outcrop of manganese-ore all the way down the ridge of the north hill from nearly C to F. It is to a large extent merchantable ore of both the hard and soft varieties : but, as it often contains a little quartz or spessartite, it would require some cleaning to fit it for the market. On the east hill there is an outcrop of huge blocks of rock composed of yellow spessartite-rock, largely changed to soft ore, but still showing plenty of the fresh rock in broad and narrow bands.

The working of the deposit.

The plan of this deposit (Plate 32) was constructed at the time of my first visit to Kándri in February, 1904, and represents the state of affairs at that time. Since then the old ropeway No. 1 has been removed and a gravity incline put in its place, whilst another incline is under construction in the position shown, on the south-western slope of South Hill. The pits in the talus-ore are, of course, now different to those shown on the plan. The levels Nos. 1 to 4 have been increased in length and three other levels Nos. 5 to 7 (not shown on the plan) have been constructed on the same side of South Hill between level 4 and the summit. The fact that the plan is not quite up to date is, however, a matter of small consequence, since any plan would represent the workings only at one particular time ; the object of the plan is not so much to show the workings as to indicate the geological structure of the deposit.

This ore-body has been developed in a very skilful manner by Mr. H. C. McNeill (see Plates 28 and 29). Although North Hill has been to a certain extent opened up, yet the principal workings are on South Hill, to win the ore of which a series of levels or benches has been constructed on the northern side of the ore-body. Each of these levels has, at its south-west end, a working face in the ore-body, and runs horizontally to the north-east towards the interior of the horse-shoe. These levels or benches are embankments built out of the waste material extracted in carrying out the dead-work of removing the country from the sides of the ore-body. Each embankment carries rails along which the waste can be run in trucks and dumped over the end of the level, which is thus constantly increasing in length. A couple of aërial ropeways were put up to bring down the manganese-ore from the higher levels. Ropeway No. 1, which was removed during 1906, had its loading station between levels 3 and 4 and was in the main a wooden structure. It used to bring down about 150 buckets of ore a day. This was equivalent to a daily capacity of 75 tons, as each bucket load was about ½ a ton. Plate 28 shows the four levels, the old ropeway (No. 1), and one trestle of the new ropeway.

The new ropeway (No. 2), finished during 1904, consists essentially of two supporting steel ropes and one hauling steel rope with a bucket attached to each end. The supporting ropes stretch from a point near the top of South Hill to the low ground on the east base of the hill. The total span is about 885 feet, the average gradient being 1 in 40. There are two intermediate girder-work standards or trestles, situated on levels 1 and 4, respectively, to support these wires. These trestles, which are 48 and 39 feet high, respectively, are fine mild-steel erections constructed on the spot by local blacksmiths trained at the mine. The buckets are, of course, supported on these ropes by means of grooved pulleys. The descending loaded bucket hauls up the ascending empty one, the hauling rope passing round a brake-wheel at the top. The hauling rope is prevented from sagging too much by means of a tail-gear. Each bucket, with a false bottom, has a carrying capacity of ⅓ ton, and as the number of trips that can be made in a day when working steadily is about 150, the daily capacity of this ropeway is about 50 tons.

A gravity incline (No. 1 on plan) was under construction in the early part of 1904. The embankment for it is seen in Plate 29. It has since been finished and serves to bring down the ore from the south-east talus quarries. The distance from loading to discharging station is 415 feet, whilst the slope is 1 in 4½. The descending loaded truck, attached to one end of a steel wire rope, hauls up the ascending empty one, attached to the other end of the same rope, the whole being controlled by a horizontal brake-wheel, round which the rope passes in 2 or 3 turns, at the top of the incline. The trucks carry about 1¼ tons each. The average number of trips on a full working day is 120, corresponding to a daily carrying capacity of 150 tons.

A second gravity incline (No. 2 on plan) has been put in to replace the old ropeway, No. 1. This incline differs from all others on the Central Provinces manganese mines, in that it is possible to fix trucks on to the rope at any of the levels passed by the incline, the rope being an endless one. The actual length of the incline is 530 feet, whilst the distance from haulage gear to tail-gear is 570 feet; the gradient is 1 in 3·75. The amount of ore carried by each truck is 1¼ tons, and, as the average number of trips made during a full working day is about 200, the daily carrying capacity of this incline is about 250 tons.

Memoirs, Vol. XXXVII, Pl. 30

Photographed by L. L. Fermor.

Bemrose, Collo., Derby.

WORKING-FACE AT LEVEL 2 OF THE KÁNDRI QUARRY.

Owing to the columnar prisms into which the ore is divided by the slickensiding and cross-jointing the work of extracting the ore is easier than it would otherwise be. Still it is usually necessary to resort to blasting. Two men work at each hole and take turns at the hammer, the other one holding the drill (see Plate 30). The hole is drilled 1 to 3 feet deep according to the character of the ore and in the evening, when all work has ceased, the blasting is carried out with the use of gunpowder or dynamite. As the result of this the columns of ore are split and loosened, and the next morning the masses of ore are detached with crow-bars and the bigger blocks broken up with sledge-hammers.[1] On levels 1 and 2 the large pieces of ore are carried by women and children on their heads and stacked on the level ground at the south-east end of the ore-body, while on levels 3, 4, 5 and 6 these large pieces of ore are charged into the trucks of the new incline (No. 2). The ore from level 7, *i.e.* the top of the hill, and part of that from level 6, is despatched by the aërial ropeway. The smaller pieces are removed in baskets and disposed of in the same way. Most of the ore, except that which powders, is fit to be stacked at once, but a little of it requires cleaning. This is done by women and children with cobbing hammers, in some cases at the working-faces and in others at the ore-stacks, which are built on the low ground to the east of the quarry. The ore is stacked into rectangular heaps 2 to 5 feet high.

The work is let out by contract, one contractor taking perhaps one level or one area of talus-ore pits and employing perhaps as many as 100 coolies. He engages his coolies by contract in gangs composed of 4 to 20 men, women, and children, who are paid by the petty gang contractor at the rate of 4 to 6 annas per day for men, and 2 to 3 annas for both women and children. The petty gang contractor, being only a coolie himself, works with his gang and is paid by the contractor so much per 100 cubic feet of ore stacked and sometimes also on the waste extracted. The contractor in his turn is paid by the mining company so much per 1,000 cubic feet of ore stacked and so much per 1,000 cubic feet of the 'deads' measured in trucks.

The stacked ore after sampling and analysis is then railed to Bombay *viâ* Kámthi, Bengal-Nágpur Railway, some 16 miles distant. Before the completion of the Rámtek railway the ore was carted to Kámthi. The carting was then also let out by contract, the usual rate being Rs. 4 to Rs. 4-8 per ton. But it often varied outside these limits owing to greater demands for carts for agricultural purposes at one time of the year than at another. Each cart holds about ½ a ton.

[1] Four Ingersoll-Sergeant rock-drills (two 2½ inch and two 3½ inch) had been installed at this mine by the time of my third visit—Nov. 1908.

Output. The annual output from Kándri is shown below:—

Year.	Long tons.
1900	20,940
1901	26,913
1902	12,507
1903	19,546
1904	15,984
1905	12,897
1906	23,717
1907	30,307

In addition to the above figures, D. Laxminarayan, who has secured some talus-ore ground in Kándri limits, reported the following production:—

Year.	Long tons.
1906	849
1907	12,066

The deposits of detrital or talus-ore.

In the previous paragraphs no account has been given of the quarries in the detrital-ore. The yellow-tinted area on the plan shows the distribution of the loose deposits of manganese-ore composed of fragments derived from the manganese-ore *in situ*. Such ore is usually known in the Nágpur district as 'drift' ore or 'boulder' ore. The former term is inadmissible, as it implies that the ore fragments have been drifted along by water or ice, and the second implies that the fragments are all large enough to be called boulders, which is not the case. As these loose deposits almost always consist of a talus of loose fragments of ore that have tumbled down from the ore-body *in situ*, a good name for them would be *talus-ore*; but to allow for the cases in which they have been somewhat rolled and arranged by water they had best be known as *detrital-ore* deposits. Both these terms will be used in this Memoir. Loose fragments of manganese-ore are, of course, found also outside the limits shown on the plan. I have attempted to represent only the area over which the 'country' is more or less completely obscured by the talus-ore.

The distribution shown is exactly what would be expected after taking into consideration the form of the hills (see small map attached to plan) and the dip of the rocks. The steepest slope down is on the south and south-west sides of South Hill, and as this is also the scarp-side of the ore-body we naturally have here the most extended and thickest deposits of talus-ore. A similar large accumulation of talus-ore might have been expected on the north side of North Hill. There, however, the total descent is much less owing to the ridge of gneiss tors a little to the north. That there is no considerable accumulation of talus manganese-ore down the western slopes from the saddle is due to this part of the deposit consisting largely of spessartite-bearing rock

Photographed by L. L. Fermor.

Bemrose, Collo., Der.

EXCAVATIONS IN THE 'BOULDER'- OR 'TALUS'-ORE DEPOSIT AT KÁNDRI

The chief workings in the talus-ore are on the western and southern slopes of South Hill. Over this area the thickness of the detrital-ore deposit varies from a maximum of 12 feet to almost nothing, while on the north-east side of the ore-band in South Hill the detrital-ore beds vary from 6 to 16 feet in thickness immediately against the ore-body and rapidly tail out in the course of 20 to 30 yards.

The excavations made near F at the east foot of North Hill show a thickness of 1 to 6 feet of detrital ore. These detrital deposits consist usually of pieces of ore of varying size, and fragments of the 'country,' with a more or less abundant interstitial red clay containing small pebbles of ore; where the underlying rock is exposed there is usually seen intervening between the bed-rock and the detrital ore a layer, often about a foot thick, composed of little pisolitic concretions of manganese-ore set in red gritty clay. As will be seen from Plate 31 the size of the boulders and fragments of ore varies greatly; in one place I estimated a single block of ore to weigh some 7 tons. In the south-east quarries on the south side of south-east end of South Hill there is an almost gradual passage, on passing away from the ore-band, from huge blocks of manganese-ore practically *in situ*, to the ordinary detrital accumulations. This detrital ore is, of course, quarried, partly because it is necessary in order to work the ore *in situ* properly, and partly because it is, as a rule, profitable to do so. As the ore fragments, except close to the ore-band, are usually covered with a ferruginous coating, it is necessary to fracture every one before stacking it, in order to make sure that it is of good quality. But all pebbles under 1 to 1½ inches diameter are rejected irrespective of quality. With regard to the amount of merchantable ore obtained from such deposits, I understand that the extreme upper limit is perhaps 60% of the volume of the deposit; but such a high percentage can only be obtained right against the ore-body. The lower limit is about 4% of the volume of the deposit, and the proportion obtained in different parts of the deposit varies between these limits. Such poor deposits as those yielding only 4% of merchantable ore would not be worked except for the facts that (1) it is necessary to work the deposits uniformly, and (2) it is never known when the barren deposits may change to better.

The excavations on the south-west side of the hill have in many places been carried down to the underlying rock, usually mica-schist. They show moreover that in several places there are layers of quartz and quartzite fragments in these deposits. One section seen was :—

7 feet.	Ore rubble.
6 inches to 1 foot.	White saccharoidal quartzite fragments.
1 foot.	Ore and quartzite gravel.
3 inches.	Grey quartzite fragments.
1 foot.	Mica-schist *in situ*.

Figures 56 and 57 show two other sections seen. They indicate

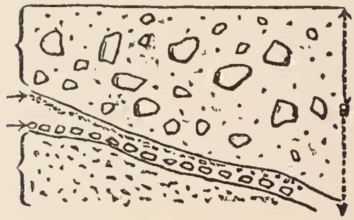


Fig. 56.—Section in the detrital deposits at Kándri.

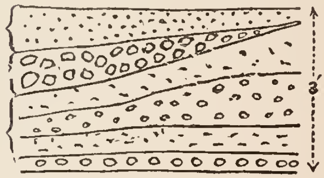


Fig. 57.—Section in the detrital deposits at Kándri.

that parts at least of these deposits have been subjected to the action of moving water. The white quartzite fragments that are so abundant in certain layers were probably transported to their present position in earlier times when the local drainage was somewhat different to the present. It will be seen from figure 57 that a layer of manganese-ore gravel in the quartzite gravel tails out to zero. As many of the manganese-ore pebbles and boulders in many parts of these detrital deposits are rounded so as to suggest that they have been rolled by water, and as, moreover, where not yet quarried, these detrital accumulations are often covered by soil and grass, it will be seen that they cannot to any extent be in process of formation at the present day; and it seems probable that in earlier times the accumulations round the base of the hill were sorted or rolled by water, leaving the fragments higher up the slopes in their original angular condition.

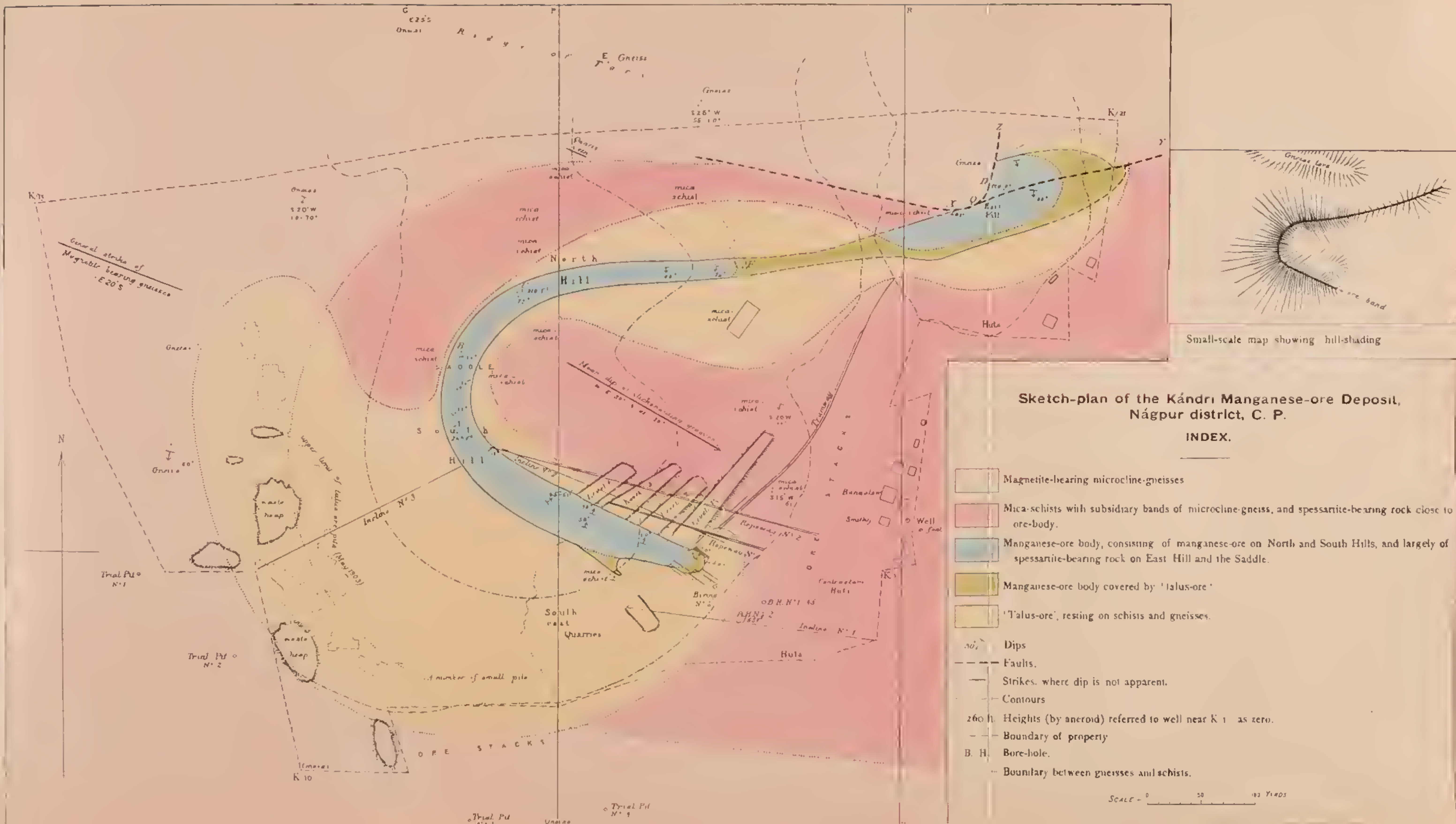
8. Mansar.

(CENTRAL PROVINCES PROSPECTING SYNDICATE.)

(*See Plates 33 to 36.*)

The manganese-ores of Mansar Hill were first brought to notice by Lieutenant R. E. Oakes in 1859,[1] and later the outcrop was described by Mr. Wilson, Executive Engineer of the Kanhán Division, as being

[1] Ball, Economic Geology, page 329, (1881).


Sketch-plan of the Kándri Manganese-ore Deposit, Nágpur district, C. P.
INDEX.
Magnetite-bearing microcline-gneisses
Mica-schists with subsidiary bands of microcline-gneiss, and spessartite-bearing rock close to ore-body.
Manganese-ore body, consisting of manganese-ore on North and South Hills, and largely of spessartite-bearing rock on East Hill and the Saddle.
Manganese-ore body covered by 'talus-ore'
'Talus-ore', resting on schists and gneisses.
Dips
Faults.
Strikes, where dip is not apparent.
Contours
260 ft. Heights (by aneroid) referred to well near K 1 as zero.
Boundary of property
B. H. Bore-hole.
Boundary between gneisses and schists.
Small-scale map showing hill-shading
North Hill
South Hill
East Hill
SADDLE
General strike of Magnetite-bearing gneisses E 20° S
Mean dip of slickensided gneisses
Incline N° 3
Ore stacks
South-east Quarries
A number of small pits
Trial Pit N° 1
Trial Pit N° 2
Trial Pit N° 4
waste heap
mica schist
Gneiss
Tramway
Bungalow
Smithy
Well
Contractors Huts
Huts
K 10
N

visible for about a quarter of a mile with a thickness of about 10 feet.[1] In 1879 a sample sent to the Geological Museum by Mr. W. Ness, Mining Engineer in charge of the Warora Collieries, was analysed by Mr. F. R. Mallet.[2] In 1899 the rights to work this body of ore were secured by the Central Provinces Prospecting Syndicate, which commenced work on it in the same year. In fact this was the first manganese-ore deposit in the Central Provinces to be worked for export. In Plate 35 is given a sketch plan of the deposit reduced from an old plan and with recent additions by Mr. W. Whyte. The outcrop of manganese-ores has been traced practically continuously for about $1\frac{1}{4}$ miles in a general east-south-east direction, curling round to south-east at the south-east extremity of the band. The Parsoda deposit, distant some $\frac{5}{8}$ mile to the south-south-east of this end, is no doubt only a continuation of this band; for although the intervening ground is covered by alluvial soil, yet, according to Mr. W. Whyte of Mansar, fragments of ore can be found scattered on the surface of the ground along the line joining the two deposits. For about $\frac{2}{3}$ of its length the ore crops out along the crest of a ridge which rises to a height of 350 feet above the plains at its highest point, namely the Grand Trigonometrical Station (G. T. S.) shown on the $\frac{1}{2}$ inch map of the Nágpur district.[3] In the other $\frac{1}{3}$, forming the south-east end of the deposit, the ore-band descends nearly to the level of the plains and is exposed in several pits known as the Kámthi Lady Pits, the Satara Pits, and the South East Mound Pits, the last named being immediately to the north of the Mansar-Rámtek road.

The ore-band continues to the south of this road, where it has been traced for 100 yards in a S. 40° E. direction in some pits recently opened up near the Central Provinces Prospecting Syndicate hospital; whilst a trial pit 80 yards further to the S. 40° E. has shown angular talus-ore in alluvial clay.

The area taken out on mining lease includes portions of the village-areas of Mansar, Khairi, Chárgáon, and Parsoda, taken in order from north-west to south-east. The main part of the deposit on the ridge is divided between Mansar and Khairi, while the south-east end of the deposit north of the Mansar-Rámtek road, including the pits named above, and a large part of the talus-ore pits that lie on the north-east side of the ore-band, is within Chárgáon limits. The portion to the south of the above-mentioned road is in Parsoda limits.

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[1] Mallet, *Rec. G. S. I.*, XII, page 73, (1879).

[2] *Ibid.*

[3] This Survey mark has now been quarried away.

Length of band.

This band has been traced below the surface by means of a series of pits for about 400 yards in a westerly direction beyond the western end of the outcrop included within the concession of the Central Provinces Prospecting Syndicate. This extension, which is being worked by the Central India Mining Company, will be described separately as the Mansar Extension; taken together with the concession of the Central Provinces Prospecting Syndicate it gives a total length of 1½ miles for this ore-band, or if the Parsoda deposit (of the Central India Mining Company, page 893) be regarded as a part of it, then the total length is over 2 miles.

'Country.'

On both sides of the ore-band the immediate 'country' is very similar to that of the Kándri deposit, and consists mainly of a fine-grained light-coloured gneiss, usually containing abundant scattered specks of a black slightly magnetic mineral (? mangan-magnetite). This gneiss is interbanded with layers of vitreous grey quartzite, of yellow spessartite-rock partly altered to ore, and of a very fine-grained, friable, white mica-quartz-schist. The best section on the south side was seen in December 1906 alongside the incline No. 1 South, near the west end of the deposit. This section showed, measuring horizontally (the dips being steep):—

1. Manganese-ore forming the southern wall of ore-body;
2. 10 paces of interbanded rocks, as above noticed, passing down into very quartzose mica-schists;
3. 10 paces of mica-schists with quartz lenticles.

To south of this the fine-grained gneisses were again seen.

On both the north and south sides of the ore-band the felspathic gneisses and interbanded rocks give place further from the deposit to mica-schists; whilst quartzites form low hills both to the north and south of the ore-ridge. Hence the generalized section across the ore-ridge, from north to south is, as far as can be at present judged:—

1. Quartzites,
2. Mica-schists,
3. Interbanded fine-grained gneisses and mica-quartz-schists, viterous quartzites, and spessartite-rock,
4. Ore-body,
5. Similar to 3,
6. Mica-schists,
7. Quartzites.

Figure 58 is a north to south section across the hill at its highest point and is based on surface evidence, both along the line of section and in openings to the west of it. It is intended to be diagrammatic only.

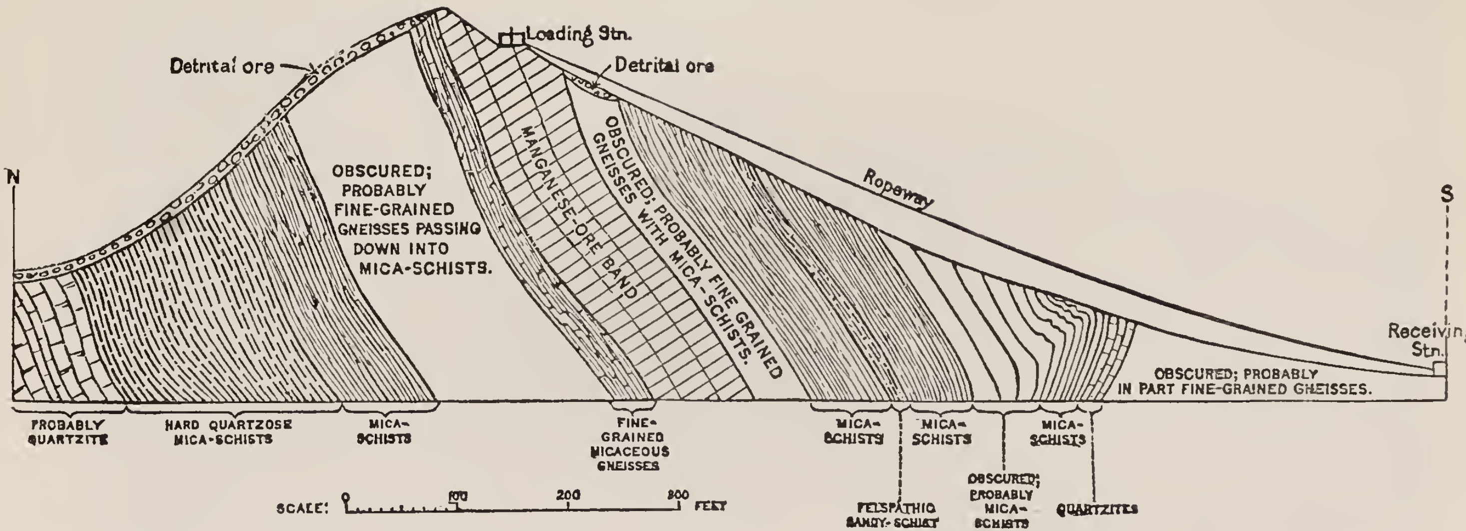


Fig. 58.—Sketch section across the Mansar deposit at its highest point.[1]

[1] My second visit—December 1906—to this deposit has shown that the diagram needs a little modification, because there is a small sharp fold in the ore-band near the outcrop. This does not affect the above diagram much, however, except that the ore-band is shown too thick.

Dips.

The dip of the ore-band in the south-east half is almost constantly towards the north-east side, at angles lying usually between 45° and 60° (except in the Parsoda porti n, where it is 30° to 45°). The band then becomes overturned, so that the dips are at 30° to 60° to the south-west side. This south-south-west dip continues as far as the highest parts of the hill, to the west of which the dip again changes to the north-north-east at 55° to vertical, then to south-south west at 70°, and finally again to north-north-east, which is the dip seen in the quarry at the extreme west end of the Central Provinces Prospecting Syndicate's concession, where the dip is very steep to almost vertical. The varying dips given above for the part of the outcrop lying between the top of Mansar Hill and the west end of the deposit were those seen on the outcrop and in such openings as had been made up to January 1904. The opening up of most of this outcrop and removal of large portions of the upper part of the ore-band by December 1906 have shown that that there is a sharp fold, in one place violent enough to produce a small strike fault, in the ore-band some 50 feet below the highest point of the hill. As the outcrop to the west of this was considerably lower it actually cut into this fold, thus accounting for the variable dip. In several of the workings at the west end of the deposit the actual overturns can be seen in small sections of a few feet vertical, as in figure 59.

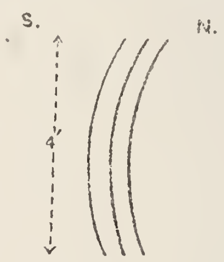


Fig. 59—Overturn in beds of manganese-ore at Mansar.

The ore-band itself varies in character. On Mansar Hill it is to a large extent composed of manganese-ore, often of the best quality. But on the descent down this hill to the south-east and right along the ore-band to its south-eastern end, the manganese-ores give way in most places to various manganese-silicate-rocks.

Constitution of the ore-band.

The commonest variety of these is spessartite-quartz-rock (gondite), occurring interbanded with what was thought in the field to be a quartzite. Microscopic examination, however, shows that the rock is a fine-grained granulitic gneiss containing grains of a black ore, probably braunite, and a few of spessartite, together with an abundance of a pale yellowish pyroxene. In this rock thin bands of spessartite also occur. These rock-bands are often only an inch or two thick. The gneiss-bands weather out a little above the spessartite-bearing ores and often show crumplings on a small scale. Any ore-band can often be traced for some yards, but probably ultimately thins out in a lenticular fashion. There are also bands of dark grey quartzite containing abundant granules of a manganese-ore.

Photographed by L. L. Fermor. *Bemrose Collo., Derby.*

MANGANESE-ORE DEPOSIT.—MANSAR, NÁGPUR DISTRICT, C. P.

In the Kámthi Lady Pit there is a most interesting set of rocks. One layer is composed of beautiful, fresh, deep orange coloured, spessartite trapezohedra set in a matrix of pink rhodonite, white barytes, and a green phosphate, probably allied to dickinsonite. The rhodonite, which is the commonest of these three minerals, often occurs in plates, up to an inch and more across, enclosing several spessartite crystals, which average $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter. In many places this rock has been much altered, and then somewhat altered spessartites are set in a matrix of partly altered rhodonite, or of manganese-ore with a colour and lustre like that of lead — probably a variety of psilomelane allied to the mineral from Beldongri (the analysis of which corresponds to the formula, $6Mn_3O_5.Fe_2O_3.8H_2O$) that I have called beldongrite (see page 116). This manganese-ore has no doubt arisen by the chemical alteration, or replacement, as the case may be, of minerals forming the matrix in which the spessartite is set. In some bands where this altered matrix is soft, it is easy to separate the trapezohedral garnet crystals, and in this way some perfect trapezohedra have been obtained, the largest perfect one being $\frac{3}{4}$ inch in diameter. Others are as large as 1 inch in diameter. As shown in figure 14, page 172, these crystals have their faces striated parallel to the faces of the rhomb-dodecahedron.

The Kámthi Lady Pit.

Some of the bands in this pit are composed entirely of spessartite and in one place the spessartite-rock has a rough columnar structure, like that of a small dyke, due to the spessartite individuals all being drawn out in a direction at right angles to the bedding. Figure 60 gives a rough section of the ore-body as seen here.

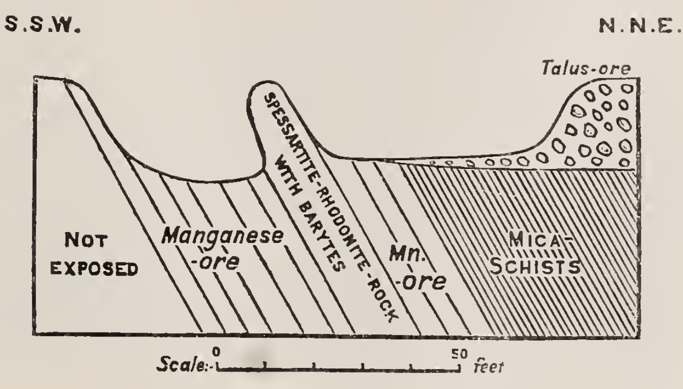


Fig. 60.—Section across the Kámthi Lady Pit, Chárgáon.

The manganese-ore shown on each side of the spessartite-rhodonite-barytes band is often more or less impure owing to remains of these minerals.

In the Satara pit immediately to the south-east of the Kámthi Lady

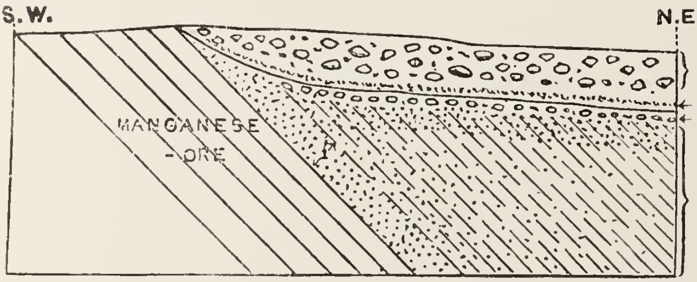


Fig. 61.—Section across one of the Satara Pits, Chárgáon.

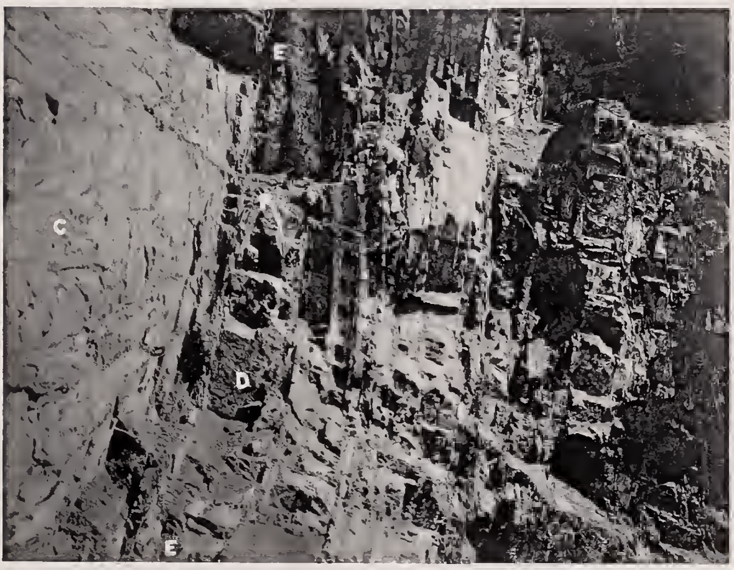
The Satara Pits.

Pit, the section shown very roughly in fig. 61 was visible. The manganese-ore at the junction with the overlying schists is apparently the good quality hard variety, but a few feet away from the junction it becomes interbanded with quartzite and more or less garnetiferous. The overlying 'country' is very decomposed, but once consisted perhaps of bands of mica-schist, spessartite-quartzite, and dark grey quartzite. The interesting feature of this section is that where these decomposed rocks rest on the manganese-ore they are full of very numerous pisolitic concentric-structured concretions of manganese oxide. For a thickness of one foot these concretions are so abundant as to constitute about half the rock; but they become gradually scarcer with distance from the junction. The pisolites are also very abundant for a depth of about one foot below the overlying talus deposits. All these schists were very damp, even in January, when there had been no rain for weeks, so that it seems likely that the junction between the ore-body and the schists is a path along which water circulates, and that in so doing it impregnates the schists and deposits manganese oxides in them. There was water in this pit at a depth of 17 feet below the surface.

Quarry at the north-western end.

At the north-western end of the ore-ridge there is a quarry showing a very interesting section, illustrated in Plate 34, figures 1 and 2. This section shows that the thickness of the ore-band is here 46 feet measured horizontally, the dip of the rocks being very steep (practically vertical) to the north side. The north wall of the deposit consists of very fine-grained greyish white mica-quartz-schist (C in figure 2) containing interlaminated with it one or two bands of ore and dark grey, sometimes spessartite-bearing, quartzites.

FIG. 1.—THE WEST END OF THE MANSAR-DEPOSIT.



Photographed by L. L. Fermor. *Bemrose, Collo., Derby,*

FIG. 2.—VIEW SHOWING STRUCTURE OF A PORTION OF THE MANSAR ORE-DEPOSIT.

On the south wall the last 2 feet 8 inches of what has been measured as part of the ore-band consists of interlaminations of fine-grained mica-schist, micaceous quartzite, dark grey quartzite containing abundant patches of yellow spessartite, and yellow spessartite-quartz-rock (gondite) often in lines of lenticles as in figure 62. The rocks here curve over so as to change in amount of dip in a similar manner to that shown in figure 59, page 882. The 'country' south of this consists of ordinary medium-grained mica-schists, containing a few quartz lenticles. The section exposes 50 feet of these schists. The manganese-ore composing the ore-body is soft and usually of poor quality, and occurs in layers up to 1 foot thick. There are numerous partings of fine-grained mica-quartz-schists, with here and there 1 or 2 inch bands of dark grey quartzite, often showing thin lines of yellow garnet. Near the north wall there are bands of fine-grained light grey quart zite up to inches thick, and in one place there is a lenticle of soft ore (see D, Plate 34, figure 2) in rather powdery, greyish white, fine-grained quartzite containing some bands of vitreous quartzite $\frac{1}{2}$ to $\frac{3}{4}$ inch thick. From the fact that at the three places (E, E, F), where the edge of the lenticle was seen, the ore gave way to soft yellow gondite, it seems as if we have here a good case of a lenticle of gondite since altered inside to manganese-ore.

Fig. 62.—Lenticularly expanding and contracting band of gondite.

Red ochre.

At the time of my second visit to Mansar, in December 1906, the excavations on the north side of the bed at its western end had revealed the presence, in the thin-banded gneisses and spessartite-bearing rocks forming the 'country' here, of a couple of lenticular masses of red hematite. One of these was about 20 feet long, 4 feet high, and 2 feet thick at the thickest part; the other had evidently been of somewhat larger dimensions, but had been partly removed. The mineral is of the soft red ochreous variety.

Thickness of the ore-band.

With regard to the thickness of the ore-band: in the quarry mentioned above, it is 46 feet; on the summit of Mansar Hill the ore-band, though not properly opened up at the time of my visit in January 1904, was estimated as being about 60 to 70 feet thick (measured at right angles to bedding); but my visit of December 1906 shows that this in an over-estimate, due to the fold mentioned on page 882. The true thickness is about 45 feet. At various places between here and the Chárgáon pits the unworked outcrop showed widths varying between 30 and 60 feet measured horizontally;

in the Kámthi Lady Pit the actual thickness of the ore-bed is at least 47 feet. Hence we see that the ore-band is of fairly uniform thickness. namely about 45 feet.

Nature and quality of the ores.

Although some good ore has been, and doubtless still can be, obtained from the various pits at the Chárgáon end of the deposit yet the merchantable ores lie chiefly in the western portions, where practically the whole length of the deposit for the last half mile is worth working. In fact, in some places in the original outcrop workings, such as the parts on the top of Mansar Hill tapped by the aërial ropeway, and the part tapped by No. 1 Incline South, practically the whole thickness of the deposit seemed to consist of merchantable ore. Now that the deposit has been quarried to a considerable depth below the original outcrop it is found that a much larger proportion of the bed has to be rejected than was expected. Thus, in December 1906, I found masses of yellow spessartite-rock, and some of rhodonite-rock, both partly changed to manganese-ore, included in the ore-body at points where the original outcrop had indicated manganese-ore only. The following figures showing the actual proportion of cleaned ore obtained in quarrying the ore-bed, were supplied by Mr. W. Whyte, manager of the Mansar mine:—

	March, 1906.	April, 1906.	May, 1906.
	cu. ft.	cu. ft.	cu. ft.
Cleaned ore	18,600	18,500	19,400
Waste (smalls), consisting of ore, quartzite, etc.	11,800	13,900	11,700
Bad ore (large pieces)	17,500	27,000	24,400
Total .	47,900	59,400	55,500
Proportion of cleaned ore to total excavated .	38·8%	31·2%	34·9%

Since the smalls will pack much closer than the large fragments of ore, both cleaned and rejected, they would really occupy a somewhat larger volume than shown above if they were packed with the same proportion of air space between the fragments. Consequently the proportion of cleaned ore to total excavated must be somewhat smaller than shown above and might fairly be taken as averaging 30 per cent.

This ore is very similar to that of Kándri, being finely crystalline, both hard and soft, and to a large extent composed of braunite. The difference between the hard and soft ores seems to be that in the hard ores the braunite granules are more firmly cemented by the psilomelane matrix than in the soft varieties; moreover, to judge from the analyses of Kándri ores Nos. 994 and 995 (pp. 869-70), the harder ore contains a larger proportion of psilomelane to act as cement to the braunite, One piece of ore often consists of streaks of the two varieties.

The two following analyses have been made on specimens from this deposit. No. 1037 was collected by me from an ore-stack on top of Mansar Hill and was a piece of finely crystalline ore. It was analysed at the Imperial Institute. The other specimen was analysed by Mr. F. R. Mallet [1] and was apparently, also, hard grey, finely crystalline, ore, containing some small cavities, which were many of them 'partially, or almost entirely, filled by a translucent, light brownish-red and yellowish, indistinctly crystalline mineral, which proved on examination to be rhodonite.' This supposed rhodonite is really spessartite, as is shown by a specimen of this ore still in the Geological Museum, and as is indicated by the description of the colour given above. The analysis given below is that recalculated by Mallet so as to exclude the 'disseminated rhodonite' and moisture. The Mn_2O_3 and surplus oxygen shown in Mallet's analysis have been, for the purposes of comparison, rearranged as MnO_2 and MnO.

Analyses of Mansar ores.

	Imperial Institute [2] (Spec. No. 1037).	Mallet.
Manganese dioxide	55·72	52·81
Manganese protoxide	28·55	28·25
Ferric oxide	4·39	9·87
Alumina	0·64	
Baryta	1·49	
Lime	1·24	1·21
Magnesia	0·13	trace
Silica (combined)	5·59	6·06
Silica (free)	0·36	
Phosphoric oxide	0·21	0·21
Arsenic oxide	0·017	
Water (combined)	2·26	2·63
Moisture at 100°C.	0·10	
Carbon dioxide	0·06	
Total	100·757	101·04
Manganese	57·39	55·27
Iron	3·07	6·91
Silica	5·95	6·06
Phosphorus	0·09	0·09
Specific gravity, G.	4·68	(3)

Except for the fact that Mr. Mallet's analysis does not show alumina or baryta, it will be seen that there is a wonderful agreement between these two analyses, considering that they were made on two hand-speci-

[1] *Rec. G. S. I.*, XII, p. 73, (1879).

[2] The following additional constituents were determined later :—

NiO, Co_3O_4, CuO (chiefly Co_3O_4)	0·020
K_2O	0·10
Na_2O	0·16

[3] Three different samples were found by Mallet to have specific gravities of 4·22, 4·36, and 4·46.

mens collected at times almost thirty years apart from a deposit $1\frac{1}{4}$ miles long. This agreement probably indicates a great uniformity in the mineral character of the merchantable ore. What this character is, is shown below, where the analyses have been recalculated to mineral constitution :—

	Imperial Institute.		Mallet.	
Apatite	..	0·49	..	0·49
Calcite	..	0·14	..	..
Braunite		..	..	..
(containing 4·39 and 9·87 Fe_2O_3 respectively)	..	56·08	..	60·85
Psilomelane :—				
$Al_4(MnO_5)_3$	1·61	..	..	..
Ba_2MnO_5	1·99	..	..	..
Ca_2MnO_5	1·69	..	1·79	..
Mg_2MnO_5	0·30	..	..	..
H_4MnO_5	8·72	..	10·15	..
Mn_2MnO_5	29·64	..	28·15	..
	43·95	43·95	40·09	40·09
Quartz	..	0·36	..	..
As_2O_5	..	0·017	..	..
Moisture	..	0·10	..	..
Total		101·137		101·43
Subtract oxygen assumed		0·38		0·39
Total		100·757		101·04

Hence we can say that, roughly speaking, the manganese-ores of Mansar consist of about 60% braunite and 40% psilomelane.

Mr. W. H. Clark has kindly furnished the following complete analysis made in January 1900 by Mr. H. H. Dains on a sample of 100 tons of 'boulder-ore' from the north side of the deposit. Although it was made on a comparatively small quantity of ore as long ago as 1900, Mr. Clark tells me that it can be regarded as typical of the ore exported at the present day.

Manganese peroxide	54·08	Manganese = 54·93
Manganese protoxide	26·77	
Ferric oxide	6·88	Iron = 4·82
Alumina	1·34	
Baryta	0·80	
Lime	*Nil*	
Magnesia	0·15	
Silica	6·94	
Phosphoric oxide	0·12	Phosphorus = 0·05
Arsenic oxide	*Nil*	
Sulphuric oxide	*Nil*	
Nickel oxide	*Nil*	
Copper oxide	*Nil*	
Zinc oxide	0·18	
Combined water	1·92	
Moisture	0·35	
	99·53	

Another sample, representing 381 tons of ore stacked at Mansar, was analysed in July 1905 by Mr. R. D. Connell, chemist to the Central Provinces Prospecting Syndicate, with the following result :—

Manganese	54·00
Silica	9·79
Phosphorus	0·09

Methods of working.

This deposit is one of the, if not the, largest deposits in the Nágpur district and provides yearly for the market about the same quantity of ore as Kándri. As the best part of the ore-body lies on the highest parts of the ore-ridge, *i.e.* at elevations of 250 to 350 feet above the plains on the south side, it has been found necessary to construct an aërial ropeway and various gravity inclines to bring down the ore. The ropeway consists essentially of four $1\frac{1}{4}''$ plough steel ropes, two for each bucket, thus differing from the Kándri ropeways, where each bucket is supported by a single wire-rope. The ropes are each about 1,000 feet long and make a descent of about 300 feet from near the top of the hill on its south side to the low ground on the south side of the ore-ridge. As they have no intermediate supports there is a great sag in the ropes, which are seen in Plate 33. The buckets each carry about one ton of ore at a time and are attached to the two ends of a hauling rope passing round a horizontal brake-wheel at the top of the ropeway. They are also fitted with a balance-rope passing round a tail-wheel at the unloading station. The ore is quarried, cleaned, and stacked, much as at Kándri and despatched to Kámthi station, some 16 miles distant by rail (formerly in bullock carts).

Two gravity inclines, marked as No. 1 (N) and No. 2 (S) respectively on the plan (Plate 35) have also been constructed, whilst a third, No. 1 (S), is under construction. The ropeway is now (December 1906) also to be taken down, as nearly all the ore above the level of its brake-gear has been quarried. In its place an incline, No. 3 (S), is to be erected with its brake-gear at a somewhat lower level.

The vertical heights between the brake-gear and unloading station of each incline and of the old ropeway, and the average gradients, are shown in the following table :—

	Vertical distance in feet.	Average gradient.
Ropeway	300	1 in 3·3
No. 1 incline S.	120	1 in 3·8
No. 2 incline S.	180	1 in 4·4
No. 3 incline S.	180	1 in 4·4
No. 1 incline N.	105	1 in 4·3

The gauge of the rails used on the inclines is 2 feet 6 inches, and the distance between centres of rails 6 feet, the diameter of the horizontal brake-wheel at the top of each incline being 5 feet 11 inches. Various types of trucks, carrying from ½ to 1 ton of ore each, are used on the inclines.

Output

The annual output from this deposit for the years 1900 to 1907 is shown below:—

Year.	Long tons.
1900	22,913
1901	27,931
1902	15,924
1903	13,523
1904	13,293
1905	16,497
1906	18,731
1907	24,974

The talus-ore pits.

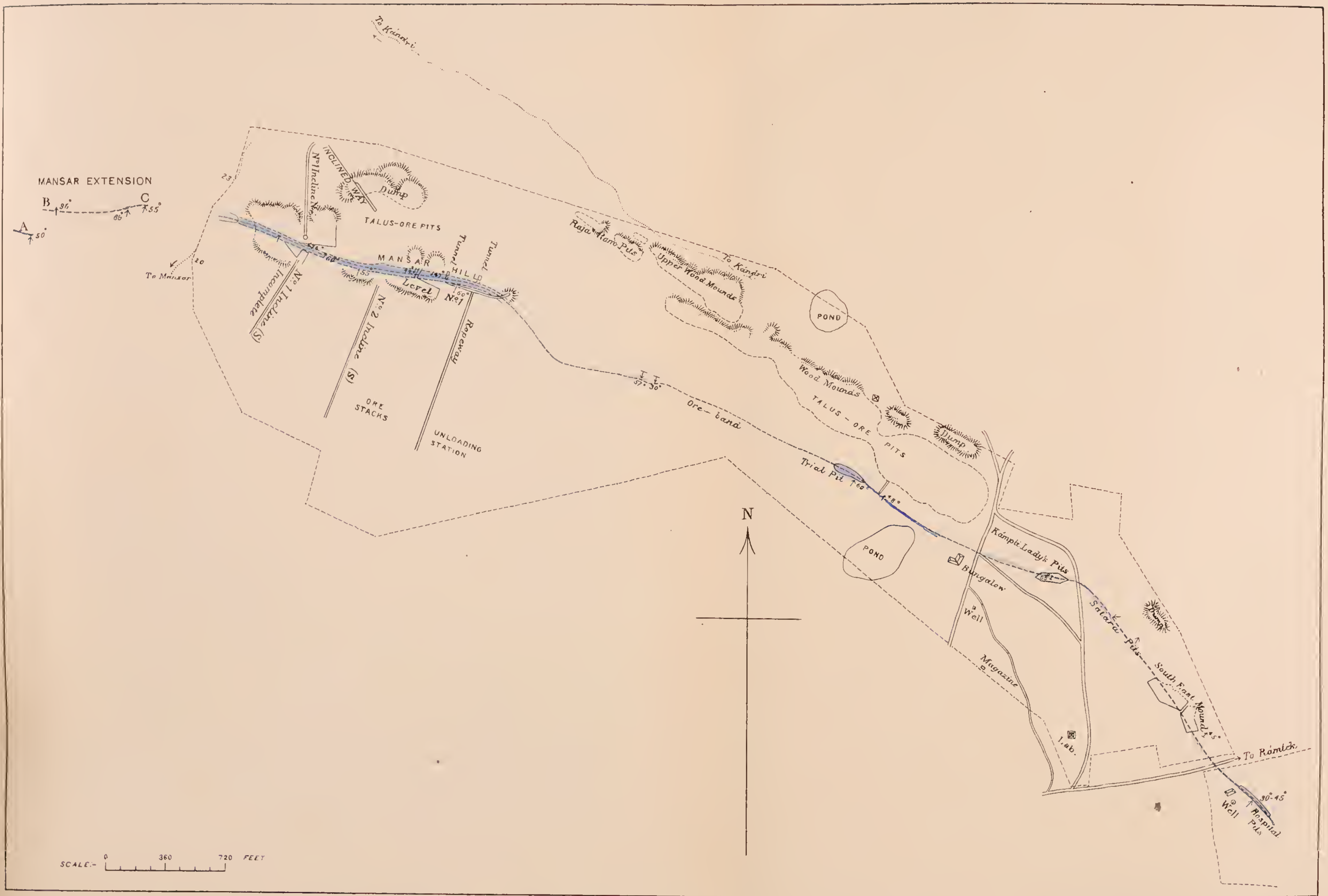
Along the north slopes of the ore-ridge near its base was originally a big accumulation of detrital ore similar to that of Kándri. The pits in this ore, which have supplied a large quantity of merchantable ore, had been largely worked out at the Chárgáon end, at the time of my visit in January 1904; they then showed on their south side quartzite fragments with a little ore, and on their north side small fragments of ore with some bits of mica-schist.

More recently, a large area of the talus-ore at the west end of the north side of the hill has been worked out incidentally to the opening up of the ore-body, and work is still proceeding on the remaining talus-ore deposits on the south side towards the west end of the ore-band. Mr. W. Whyte tells me that in one place on the north side the talus-ore deposit was as much as 35 feet deep.

The following figures, supplied by Mr. W. Whyte, relate to the talus-ore deposits at Mansar:—

	March, 1906.	April, 1906.	Best pit, No. 1 incline N. April, 1906.
	c. ft.	c. ft.	c. ft.
Good 'boulder-ore'	14,200	13,700	11,200
Bad 'boulder-ore'	8,500	3,800	1,500
Volume of excavation	73,200	53,600	34,800

The ore was of course measured in the stacks. Now a ton of ore of specific gravity 4·5 occupies 7·96 cubic feet, whilst a ton of manganese-ore stacked measures 16 to 17 cubic feet and therefore consists of about equal



SKETCH-PLAN OF THE MANSAR-CHÁRGÁON ORE-BAND.

amounts of manganese-ore and air space. Consequently if the figures in the first two lines above be halved they will give the actual volume of the manganese-ore, as follows :—

c. ft.	c. ft.	c. ft.
7,100	6,850	5,600
4,250	1,900	750

and these correspond to the following percentages of ore in the material quarried :—

Good 'boulder-ore'	9·7	12·8	16·1%
Bad 'boulder-ore'	5·8	3·5	2·1%
Total	15·5	16·3	18·2%

9. Mansar Extension.

(Central India Mining Company.)

(*See Plate 35.*)

This property—held by the Central India Mining Company—is a westward extension of the Mansar deposit (B, C, and A, in the sketch-plan, Plate 35). The ore was originally exposed for only a little way along the south slope of the low ridge of mica-schists that forms the westward continuation of the main Mansar ore-ridge. A series of excavations made along this line have exposed, for about 200 yards, the back of the ore-body, which, it seems, was in places just exposed at the surface, but more usually just below it. The ore-body, which here strikes roughly east and west, dips to the north side at 55° to 60° and is overlain by mica-schists. It often contains interlaminations of various rocks, such as mica-schist, soft white quartzite, and spessartite-bearing quartzites. The maximum width of the ore-band seen in any pit was 12 feet 9 inches measured horizontally, but it was not certain that this was the full thickness. Immediately underlying the ore-band there is usually a thickness of 1 to 6 feet of interbanded hard quartzite, soft manganese-ore, and yellow spessartite-bearing rock, doubtless to be regarded as part of the ore-body. Under this come the ordinary mica-schists. In one of the middle pits, however, a brown dolomitic limestone immediately underlay the ore-band.

About 200 feet south of the west end of these pits is another (A), exposing what is probably a parallel band, perhaps taking up the main band *en échelon* ; or it may be the same band brought to the surface again by a fold. The ore is here overlain by vitreous grey quartzite with interlaminations of mica-schist and underlain by fine-grained micaceous quartzites followed by mica-schist. In one place the quartzites on the south side of the ore-band are very hematitic to a thickness of 1 foot. The hematite, which has probably been introduced by the metasomatic replacement of the quartzite, sometimes forms half the rock, and has often crystallized in scales up to ½ inch thick. In two places between the main ore-band (BC) and the footwall-rock, hematite was also seen, in one case as a 1-inch vein and in the other as a 6-inch layer of hematite-clay. This occurrence of hematite is very interesting, because iron-ores are very rarely associated with the manganese-ore deposits occurring in the Archæan schists and gneisses of India.

Hematite.

Nature and quality of the ores.

The manganese-ore in these pits is very soft and wet; moreover, on account of the large amount of foreign matter, it requires a lot of cleaning. From two stacks containing some 35 tons of ore, sample 19 was taken. It was analysed at the Imperial Institute, with the following result:—

Sample No. 19.

Manganese peroxide	34·31
Manganese protoxide	39·40
Ferric oxide	7·24
Silica (combined)	7·91
Silica (free)	8·86
Phosphoric oxide	0·40
Moisture at 100° C.	0·60

This is equivalent to:—

Manganese	52·27
Iron	5·07
Silica	16·77
Phosphorus	0·17
Moisture	0·60

Since the above analysis totals up to 98·72 it can be regarded as practically complete. It corresponds roughly to the following:—

Braunite		79·27
Hematite		7 24
Quartz		8 86
MnO_2	0·14	
MnO	2·21	
P_2O_5	0·40	
Moisture	0·60	
Undetermined	1·28	
	4 63	4·63
	Total	100·00

The ore in the stacks from which the above was taken could have been improved in quality by cleaning out the visible siliceous matter, though probably only by rejecting a rather large proportion of the ore. The ore itself is a finely crystalline aggregate consisting largely, as shown above of braunite with admixed siliceous matter.

FIG. 1.—SAMPLING MANGANESE-ORE AT MANSAR.

Photographed by L. L. Fermor. *Bemrose, Collo., Derby.*

FIG. 2.—OUTCROP OF MANGANESE-ORE.—SÁTAK, NÁGPUR DISTRICT, C. P.

Mr. H. D. Coggan has given me the following as showing the average analysis of the ores raised in 1905 :—

Manganese	48·86
Silica	10·10
Phosphorus	0·204

Output. The output figures from 1904 to 1907 are :—

Year.	Long tons.
1904	835
1905	637
1906	*Nil*
1907	*Nil*

10. Parsoda.

(CENTRAL INDIA MINING COMPANY.)

This deposit is situated about ⅝ mile south-south-east of the south-east end of the Mansar-Chárgáon ore-band, of which it is probably a continuation.

The manganese-ore has been obtained from a pit dug in the alluvial soil of the fields in which the deposit occurs. This, at the time of my visit, was half full of water, and the only rock *in situ* that could be seen had a dip of 50° to 60° to N. 35° E. This consisted of a massive band of spessartite-rock and greyish quartzite with some soft manganese-ore, and rested upon a rock composed of interbanded quartzite and spessartite-bearing quartzite partly altered to manganese-ore. Everywhere else the pit showed brown clay containing in places loose fragments and pisolitic concretions of manganese-ore. A second pit showed similar alluvial accumulations. By the side of the first pit there was stacked a heap of good hard grey ore, obtained, no doubt, *in situ* from below the present water-level. A large proportion of the ore was like the hard variety found at Kándri and the remainder was a light bluish grey psilomelane containing scattered bright shining facets. A piece of this, which is, of course, not typical of the deposit, was analysed at the Imperial Institute with the following result :—

Specimen No. 1017.

Manganese dioxide	53·45
Manganese protoxide	7·24
Ferric oxide	29·37
Alumina	0·36
Baryta	0·45
Lime	1·69
Magnesia	0·29
Combined silica	2·50
Free silica	0·59
Phosphoric oxide	0·15
Arsenic oxide	0·007
Combined water	3·96
Moisture at 100°C.	0·15
Carbon dioxide	0·07
	100·277

Manganese	39·43
Iron	20·56
Silica	3·09
Phosphorus	0·06
Moisture	0·15
Specific gravity	4·18

This analysis corresponds to one of the two following mineral compositions:—

		I	II
Apatite		0·35	0·35
Calcite		0·16	0·16
Braunite		25·05	...
Hematite		29·37	29·37
Psilomelane:—			
$Al_4(MnO_5)_3$	0·90		
Ba_2MnO_5	0·60		
Ca_2MnO_5	2·69		
Mg_2MnO_5	0·66		
H_4MnO_5	15·28		
	20·13		20·13
Mn_2MnO_5	24·01		46·78
	44·14	44·14	
Quartz		0·59	0·59
Combined silica			2·50
As_2O_5		0·007	0·007
Moisture		0·15	0·15
		99·817	100·037
Add oxygen unused		0·46	0·24
		100·277	100·277

If I express the correct composition, then we must suppose that the bright facets represent the braunite and that the homogeneous fine-grained ground-mass consists of an intimate mixture of psilomelane and hematite. If II be correct then the bright facets must be due to hematite grains in a ground-mass of psilomelane. As II does not account for the 2·50% of combined silica we must suppose that I is probably the correct interpretation.

The following analyses of manganese-ores from this deposit were kindly supplied by Messieurs Jambon and Cie.:—

	1	2	3	
Manganese	52·91	48·83	51·75	All dried at 21° F.
Iron	5·36	9·28	8·27	
Silica	6·17	5·73	8·80	
Phosphorus	0·06	0·08	0·03	
Moisture	0·40	0·92	...	

Nos. 1 and 2 were hand-specimens described respectively as 'bright ore' and 'soft black.' Analysis by Messrs. J. and H. S. Pattinson of Newcastle.

No. 3.—Probably a hand-specimen. Analysis by Dr. Pearson of London.

These analyses are probably more typical of the whole deposit than the complete analysis given above of a specimen picked on account of its mineralogical peculiarities.

Mr. Coggan has given me the following as representing the analysis of ore extracted during 1906:—

Manganese . . .	50·31
Silica	6·60
Phosphorus . . .	0·072

Output. The output figures for 1904 and 1905 are:—

Year.	Long tons.
1904	160
1905 . .	494
1906 . . .	*Nil*
1907 . . .	*Nil*

11. Borda.

(MADHU LALL DOOGAR MINING SYNDICATE.)

This deposit is situated a little over ½ mile north of Borda village. At the base of a low hill of white vitreous quartzite, on its south and east sides, a number of shallow excavations had been made on behalf of Messrs. Cooverjee Bhoja of Calcutta. They showed loose fragments of manganese-ore for a depth of 1 to 2 feet, resting on a reddish sandy clay. As the pieces of ore were angular and some of them a foot in length (some were said to have been 2 feet across before breaking them) it is evident that the ore-body must be close by. In order to find the ore-body it will be necessary to dig some cross-cuts right down through the clay to the underlying rock. The quartzites on the hill show what is probably a dip of 25° to N. 20° E., so that the ore-body will probably have a strike about east-south-east. Hence the cross-cuts should be made in a north-north-east to south-south-west direction. As the alluvium was seen to a depth of 5 feet in one pit, these cross-cuts should be started as near as possible to the quartzites, so as to start where the layer of alluvium is thinnest. There were also a few fragments of quartz-pyroxene-gneiss lying on the ground, possibly indicating a band of this rock associated with the ore-band.

The larger portion of the ore occurs in columnar fragments showing slickensides-striations. It might need a little cleaning, as a fair number of the pieces show occasional small white streaks or spots. One or two pieces contained some yellow spessartite streaks. The ore, which in physical aspect is exactly like that of Kándri, is finely crystalline, some being of the hard and some of the soft variety. A sample was taken representing some 18 tons of ore and the analysis of it at the Imperial Institute showed :—

Sample No. 30.

Manganese dioxide	51·62
Manganese protoxide	28·98
Ferric oxide	5·39
Silica (combined)	6·00
Silica (free)	2·93
Phosphoric oxide	1·49
Moisture at 100°C.	0·11

This partial analysis indicates that the ores are a mixture of about 60% braunite and 34% psilomelane, with the balance of quartz and apatite. They are in fact very similar to the Mansar ores, the analyses of which are given on page 887. The above analysis corresponds to :—

Manganese	55·15
Iron	3·77
Silica	8·93
Phosphorus	0·65
Moisture	0·11

Hence, except for the high phosphorus contents, this ore is of very good quality. It could doubtless, if obtainable in quantity (which it is not, unless the ore-body *in situ* be found) be sold as a phosphoric ore for the same purposes as the Kájlidongri and Vizagapatam ores.

GROUP IV.

12 Pársioni and Bansinghi.

13. Dumri Kalán.

14. Sátak I and II.

15. Beldongri.

16. Nagardhan.

17. Nandapuri.

18. Lohdongri.

19. Kácharwáhi.

20. Waregaon.

21. Khandála.

The Pársioni-Bansinghi deposit lies some 5 miles west-north-west of the Dumri deposit, and it is doubtful if it forms a part of the same band of deposits as the remainder, lying as it does some distance to the north of their line of strike. The remaining deposits form a line about 12 miles long stretching almost due east from Dumri Kalán to Khandála. They lie in alluvial country about 4 miles south of the Rámtek range of quartzite hills. Each deposit is only a few hundred yards in length, and either forms a small hillock, or is being worked by a quarry in the alluvium, the deposit having been originally discovered from the projection at the surface of a very small mass of manganese-ore. Most of these deposits seem in fact to be the summits or small hills buried in the alluvium, and, owing to the fact that they all lie on the same line of strike, it does not seem improbable that they really form one continuous band of rock, the intermediate portions of which are buried beneath the alluvium, so that they correspond to one original layer of manganiferous sediments. Before this portion of the country was covered up by alluvium this supposed continuous band probably cropped out continuously over the whole length of 12 miles and was eroded by the usual agencies into a line of small hills or hillocks. I have often noticed that in a manganese-ore deposit where there is also manganese-silicate-rock, the manganese-ore stands up relatively to the silicate-rock as if it withstood weathering better than the latter. Assuming this to be the case and that the manganiferous band was irregularly altered into manganese-ore, it seems probable that in the line of hillocks postulated above, the highest peaks correspond usually to the portions that were most largely composed of manganese-ore.

If this be the case, then on extending the present excavations along the strike it should be found that the ore-band sinks to a greater and greater depth below the alluvium, at the same time changing to the manganese-silicate-rocks that formed the necks between the upstanding hills or hillocks of manganese-ore in the times when the rocks were subjected to erosion and not covered by alluvium.

The deposits of this group, excluding Pársioni, are situated at distances of 5 to 8 miles to the north of the Bengal-Nágpur Railway, to which the ore quarried was formerly all carted, the stations used being Salwa and Thársa. A system of light tramways of 2-foot gauge constructed by the Central India Mining Company now taps all the deposits from Lohdongri eastwards, the ore being carried to Thársa station. This system of tramways also taps the deposits of Group V further to the north. The ore from the deposits to the west of Lohdongri is still carted to Salwa station, unless any use be made of the newly opened line to Rámtek.

12. Pársioni and Bansinghi.

(MADHU LALL DOOGAR MINING SYNDICATE.)

The band of manganese-silicate-rock situated in these two village areas is exposed at intervals for 2 miles. It starts on the east just inside the eastern Pársioni boundary about ½ a mile from the Pench River and, after passing through the town of Pársioni, finishes at the western end in the Bansinghi village area. At the eastern end the strike is a little north of east, and at the western end slightly north of west. The maximum outcrop width of the manganiferous band is at the eastern end, where it is 136 paces across; but this consists of two outcrops, 74 and 42 paces across, respectively, separated by 20 paces of soil, which may correspond either to a part of the manganiferous rocks not exposed, or to a band of some softer rock such as mica-schist dividing the manganiferous rock into two parallel bands. At various points to the west much smaller outcrop widths were measured, namely, 12, 22, 15 and 30 paces. As the manganiferous rocks only just protrude from the ground their dip is usually not apparent; but they are situated on the south slope of a low range of hills of quartzites. These quartzites are often greyish white and vitreous and weather into large blocks with some jointing; at other times they are schistose, containing a variable quantity of muscovite. The strike of the quartzites is the same as that of the ore-band and the dip is everywhere to the south side at angles of 45° to 50°, except at the east end of these hills, where the dip is to N. 10° W. at 55°.

The manganese-silicate-rock is composed chiefly of rhodonite and spessartite, with some quartz and a little orthoclase and apatite. Sometimes it is almost entirely composed of the manganese-garnet, the colour varying from brownish-orange, when fine-grained and compact, to orange-red, when separate spessartite crystals are included in quartz. This rock is sometimes very crumbly. Quartz occurs, not only mixed with the spessartite and rhodonite, but also as thin white bands weathering out, and as black vitreous quartzite and dark grey fine-grained quartzite, interlaminated with the manganese-silicate-rock. In one place the spessartite-rhodonite-rock contains rosettes of a greyish-green to brownish amphibole, which occurs as asbestiform to prismatic radiations sometimes with a nucleus of spessartite. This rock also contains a small amount of a rhombohedral carbonate—? rhodochrosite. Both garnet and rhodonite are often quite black, tending to form hard grey braunite ore. But I did not see a single piece of ore that was merchantable.

Output. Mr. D. Laxminarayan reports the following output from this deposit:—

Year.	Long tons.
1906	742
1907	495

13. Dumri Kalán.

(MADHU LALL DOOGAR MINING SYNDICATE.)

This deposit, although of no economic importance, is of interest because it forms the western termination of the series of deposits Nos. 13 to 21 (see page 896) that stretch in an west-east direction over a length of 12 miles from Dumri to Khandála. I did not visit the locality myself, but have extracted the following from a report by Mr. J. H. Goodchild made on behalf of Messrs. Shaw, Wallace and Company of Calcutta:—

'The ground is covered with rice and cornfields. Along the line of a wide ditch between the two fields some loose ore seems to have been discovered and an excavation started out of which some 130 tons or so of manganese ore were taken out. The excavation had been completely filled up with mud by the recent rains so that it was impossible for me to form any idea as to the nature of the deposit, or even to tell where the pile of ore lying close by, had been taken from. A sample from this pile gave:—

Manganese	39·65
Iron	9·33
Silica	8·40
Phosphorus	0·177

14. Sátak.

Within the limits of this village manganese-ores have been traced at intervals for about $\frac{3}{4}$ mile. The ores to the west of, and in, the village only just cropped out at the surface and have been exposed by pits dug, in some places, into the alluvial soil of the fields. This part of the ore-band has a general strike of east-south-east and is worked by the Central India Mining Company, and will be described below as Sátak I. What is probably a continuation of this band reappears to the east of the village in a mound striking E. 10° N. This part of the band is leased by the Central Provinces Prospecting Syndicate and will be described below as Sátak II.

Sátak I.

(CENTRAL INDIA MINING COMPANY.)

The most westerly and also the largest of the excavations of the Central India Mining Company is situated 132 paces east of the road from Chárgáon to Kerdi and just to the south of the road leading from Dumri Kalán to Sátak. It had been excavated in the alluvial clay soil, and contained a depth of some feet of water, which concealed the ore, except round the edge. The ore has a strike of about south-west and a dip to the south-east in one place at about 40°.

This is probably only a local deviation from the roughly east-west strike of all the deposits on the Dumri-Khandála line of strike. In one place the ore was bedded in layers 2 inches to 1 foot thick and was a hard grey-black braunite varying from finely to coarsely crystalline, and usually containing various impurities (often original spessartite). In addition to a soft variety of ore composed of a network of soft and hard ores, there is also, in this quarry, a large amount of manganese-ore rendered quite valueless by the presence of abundance of unaltered or but partly altered garnets. Quartz-spessartite-rhodonite-rock (rhodonite-gondite), some very similar to that of Chárgáon, is also abundant. It contains red, orange, and yellow, trapezohedra of the manganese-garnet, yellow being the predominant colour at this locality. These trapezohedra are sometimes as large as $1\frac{1}{4}$ inches in diameter, have their faces striated parallel to the faces of the rhomb-dodecahedron, and show a concentric shelly structure on fractures. The large spessartites are often set in matrix of rather glassy quartz. Some of these spessartite-rocks contains a soft chocolate-brown fibrous mineral, possibly an altered amphibole.

Quality of the ores.

The quality of the ore did not seem good, and except in the driest weather it would be necessary to put in a pump to remove the water. Mr. H. D. Coggan, however, has given me the following figures representing the average analysis of the ores raised from this deposit during 1905 and 1906 :—

	1905.	1906.
Manganese	51·74	52·00
Silica	6·80	6·30
Phosphorus	0·112	0·068

Output.

The quantity of ore extracted in the years 1904 to 1907 is, according to Mr. Coggan :—

Year.	Long tons.
1904	377
1905	1,248
1906	3,193
1907	1,598

Separate figures were not kept before 1904.

Other occurrences.

Between this pit and the village a series of pits had been dug over a length of some 150 yards in an east-south-east direction, and since partly filled up, because they spoilt the village cattle-ground, and because the ore found was not of sufficiently good quality to make it worth while compensating the málguzár or village landlord for this piece of land. The dips seen at various points were 50° to 60° to S. 10° W. and very steep to S. 22° W. In one place the ore-band was at least 24 feet wide, but this width included some interlaminated fine-grained mica-schist and a large amount of garnetiferous ore. A very interesting rock obtained from this pit is a white felspar-rock composed of orthoclase (?), microcline, and plagioclase. It contains a few crystals of idiomorphic spessartite and is undergoing replacement by manganese oxides in a manner very similar to the replacement seen in the Garbhám and other mines in the Vizagapatam district. In other places there are bands of quartzite in the ore. The ores are of both the soft and hard facetted varieties noticed above.

Other outcrops of banded gondite partially altered to ore are seen right into the village on this same line of strike, coarse muscovite-quartz-schist being apparently the associated rock. In the village there are a few pits showing loose pebble-ore deposits resting on mica-schist.

Sátak II.

(Central Provinces Prospecting Syndicate.)

(See Plate 36.)

This deposit is situated on the east side of Sátak village, from which it is separated by a pond. It takes the form of a low flat bare mound about ¼ mile long, striking E. 10° N. The west end of it, situated on the south-west side of the pond, is shown in Plate 36, figure 2, and has an outcrop of many large dark-coloured blocks of rock, composed of manganese-ore, large reddish and small yellow spessartite crystals, rhodonite, quartz, and dark grey quartzite. The width of this outcrop is 25 yards and a small pit on top showed a dip of 50° to S. 10° E. Further along the outcrop a dip of 40° to S. 30° E. was shown in another pit. A third pit showed the section illustrated in figure 63. The broken manganese-ore 'beds' shown resting unconformably on the upturned edges of the mica-schist are separated from the latter by a thin layer of broken quartz and mica fragments, which also separates these broken ore-beds from the layer of altered spessartite-quartz-rock and quartzite that forms the top of the manganese-ore 'beds' (A). The probable explanation of this phenomenon is that the mica-schists, being softer than the manganese-ore, were cut down by weathering so as to leave an upstanding ridge of the manganese-ore beds (A). Then the manganese-ore, B, which was probably once a continuation of A above the present surface, was let down along a miniature strike-fault-plane or slip-plane to its present position, forming an interposing friction breccia of mica and quartz from the mica-schist and uppermost layer of the manganese-rock. If this small slip-plane continue for any distance along the ore-ridge it must give rise to a greater width of outcrop

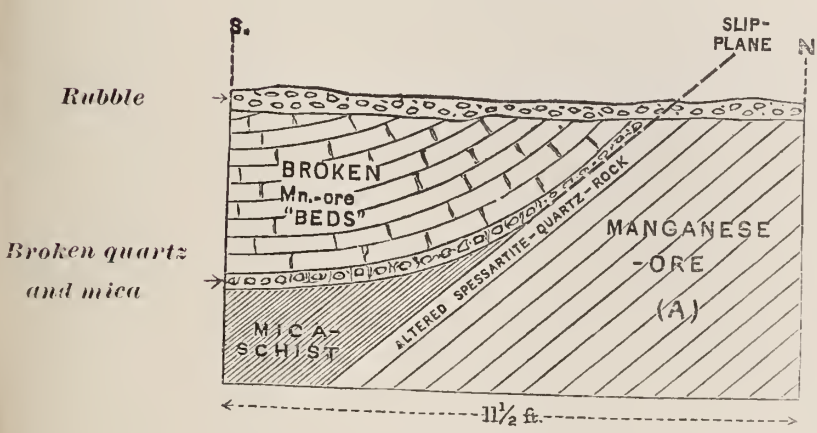


Fig. 63.—Section seen in a pit on the Sátak ore mound.

than corresponds to the true width of the ore-band. Since the above was written, a cross-cut 269 feet long has been made right across the ore-ridge, which I was able to examine in December 1906. This shows a succession of laminated and schistose rocks dipping at angles varying from 15° to 50° to the south side. The most abundant rocks are mica-schists, of both fine and moderately coarse grain, and schistose micaceous gneisses. Interbedded with these, especially with the schists, are subordinate layers of spessartite-quartzites, sandy schists, black vitreous quartzite, and finally the most important of these subordinate rocks, a whitish, very fine-grained rock, sometimes very soft and friable and sometimes hard and jaspery in appearance. This rock is very similar in appearance to the Dhárwár jaspers of Jabalpur and the Panch Mahàls, but was found on microscopic examination to be a very fine-grained spessartite-quartz-rock or gondite. There are also, about the middle of the cutting, and thus corresponding to the highest part of the ridge, two bands of manganese-ore each 7 feet thick, separated by about 12 feet of mica-schists and other rocks.

Section seen in a cross-cut.

There are also other smaller bands of ore evidently formed by the more or less complete replacement or alteration of the light coloured rocks. In this replacement or alteration the rocks most affected seem to have been the gondite layers, corresponding to each of which there is consequently a dark streak in the walls of the cutting. The mica-schists have also been to a small extent affected, frequently showing thin veins and small spots of manganese oxides. When the main ore-bands are examined they also are found to be partly due to the alteration of gondite, but I could not determine if any of the ore was original. This alteration or replacement was distinctly more complete at the surface than lower down.

Intrusive in the rocks seen in this cutting are some masses and veins of felspar-rock sometimes containing yellow crystals of garnet, presumably spessartite. In one place there was a veinlet lying parallel to the bedding of the ore-band, only a yard long, 3″ thick at the middle, and dying out lenticularly at either end. This veinlet contained a vug in which were developed idiomorphic crystals of felspar up to ½ inch in diameter and showing the following forms :—(110), (001), (010), (101), and a negative hemi-orthodome. Since the felspar-rock is often partly replaced by manganese-ore it must have been intruded into the other rocks before the secondary ores were formed, but after the foliation of the rocks and consolidation and metamorphism of any original manganese-ores. For the source of the manganese that brought about the replacement we must look to the spessartite-bearing rocks. Another interesting structural feature is well seen in this cutting. Each band of ore, instead of

Felspathic intrusives.

being abruptly cut off at the surface by overlying talus or soil, bends over on to the underlying rocks and rests unconformably on their upturned edges, so that the bands, all taken together, tend to form a horizontal layer stretching along the whole length of the cutting near the surface, thus accounting for the great width of outcrop. It follows from what has been written above that, if the section seen in this cutting is representative of the whole ridge, no great quantity of ore is to be obtained from the rock *in situ*. It has been mentioned above that the ore-bands are best at the surface, the ore deteriorating in depth both in quantity and quality. The quality of the ore being extracted from the talus-ore deposits is much better than that of the ore *in situ*; one must suppose from this that the portions of the ore band that were removed in the formation of the talus-ore deposits were of better quality than that now left in the ore-mound and that consequently the ore-bands must have improved towards the surface still more than they do now.

The manganese-ore seen *in situ* along the ridge is the hard crystalline mixture of braunite and psilomelane, but it is difficult to find a piece free from at least a little impurity (usually white felspar or quartz).

The talus-ore pits.

A pit on the north side of the east end of the ridge showed 6 feet of pebbles of manganese-ore separated from underlying biotite, muscovite, and felspathic schists, by a 1-foot layer of gravel of mica and quartz; whilst other pits along the base of the ridge on the north side showed up to 6½ feet of detrital ore resting on decomposed schists and pegmatite. In places these deposits are as much as 10 feet thick. The detrital ore, as mentioned above, is of better quality than that found *in situ*; and, during 1906, owing to the high price of manganese, was extensively worked.

Tram-lines have been put down in the cutting above mentioned and bifurcate on the north side of the deposit so as to run through these talus-ore pits. The ore extracted is carted to Salwa station.

Nature and quality of the ore.

A sample was taken, partly from the ore seen *in situ* in the pits on the ridge, and partly from the detrital ore. The ore was evidently a mixture of braunite and psilomelane, several pieces containing whitish quartzose, jaspery, or felspathic, patches. The analysis made at the Imperial Institute is as follows:—

Sample No. 24.

Manganese peroxide	46·01
Manganese protoxide	30·38
Ferric oxide	6·26
Silica (combined)	5·52
Silica (free)	0·17
Phosphoric oxide	0·15
Moisture at 100°C.	9·16

This shows that the ore consists of about 55% braunite and 45% psilomelane, and is equivalent to :—

Manganese . . .	52·37
Iron	4·38
Silica	5·69
Phosphorus . . .	0·065

Output. The output of ore from this deposit for the years 1905 to 1907 is shown below :—

Year.	Long tons.
1905	115
1906	3,581
1907	7,789

15. Beldongri.

(CENTRAL PROVINCES PROSPECTING SYNDICATE.)

(*See Plate 37.*)

This ore-deposit is situated about ½ mile west by south of Beldongri village, and is being worked by the Central Provinces Prospecting Syndicate, who hold it on mining lease. The original outcrop projected only a foot or two above the surface of the fields in which the quarry is situated ; but by removing the covering of alluvial soil the ore-body had been exposed to a length of 270 feet at the time of my visit in February 1904, and for a small distance further at the north-east end by the end of 1906. The strike of the ore-band is E. 5° N. at the west end of the quarry and gradually curls round to E. 40° N. at the east end, and in the latest workings (not shown in the plan, Plate 37, which was constructed in 1904) at the east end, to N. 30° E. The dip averages about 50° to 55° to the south side ; the width of the ore-band as exposed was 70 feet measured horizontally, corresponding to a true thickness of 57 feet (taking dip as 55°). Even by December 1906 the 'country' on the north side of the ore-band had not been properly exposed, so that it is not certain that this is the full thickness. The 'country' on the south side consists of very schistose micaceous gneisses, the mica being usually biotite. Some decomposed mica-schist was also seen, underlying the talus-ore in the south-east corner of the quarry, the section being given on page 910.

The nearest outcrop of rock is Beldongri Hill, about 350 yards S. 10° E. from the quarry. This hill is composed of muscovite-bearing quartzites striking E. 5°—10° N., with a rather doubtful dip, probably about 30°, to the south side. The hill is the seat of a deity known as Gorakhnáth.

Nature of the ore band.

The ore-band itself is of very variable character. Possibly about half its thickness consists of merchantable ore. The other half consists partly of manganese-ore rendered worthless by patches of spessartite not completely converted to manganese-ore; partly of spessartite-rhodonite-rock, similar to that in the Kámthi Lady Pit at Chárgáon; and partly of thin bands of biotite-quartz-schist and dark grey quartzites acting as partings to the ore-layers. The original outcrop, G, consists of spessartite-rhodonite-rock, and has for many years been worshipped by the villagers as symbolical of some deity and consequently been preserved from quarrying; but although it consists largely of unmerchantable material, yet to leave it interferes with the correct working of the deposit. One specimen from this point shows orange-yellow garnet in a soft, dull black matrix of manganese-ore, which shows signs of platey structure and may correspond to rhodonite that has suffered alteration prior to the spessartite. Another specimen from G shows a layer of botryoidal psilomelane on the surface of altered spessartite-rock. Along the south side there is a large number of partings, between the ore-layers, of altered spessartite-bearing rocks and grey quartzites. One of these partings is composed of greyish and white clay containing brown streaks of iron oxide and numerous pisolites and ramifying veinlets of manganese oxides, which are soft, yield a dark brown streak, and often pass centrally into compact psilomelane. Near the east end of the south side of the quarry were seen at least two feet of dark grey quartzites with partings of the above pisolitic clay. An 8-inch band of these quartzites was rose pink in the middle, and a microscope section showed this rock to be composed of coarse-grained, much strained, and often granulitized, quartz, with abundance of rhodonite and a yellow-brown pyroxene; the rock is hence practically identical with the pyroxenic quartzite found at Junawáni (see page 971).

Felspathic intrusions.

At the east end of the quarry, on the south-east side of the deity mentioned above, there was exposed in 1904 a mass of very coarse-grained felspar (microcline)-rock, the felspar crystals often being one to two inches in diameter. It contained a little quartz and rather scarce scattered yellow manganese-garnets up to $\frac{1}{2}$ and 1 inch in diameter and was often dark brownish in colour, owing to impregnation and replacement by manganese oxides. The exposure was not clear enough to show whether this rock was a part of the ore-body or, as seemed more probable, a subsequent intrusion. But in December 1906 a very clear section was visible showing without doubt that the felspar-rock is intrusive. This is illustrated in figure 64. In one place this intrusion was 6 feet across. In another it contained a patch 1 foot in diameter of yellow manganese-garnet, whilst ramifying strings of this garnet occurred in it in other places. Some patches of the rock, however, were free from garnet. The manganese required for the formation of the garnet was presumably absorbed from the ore-body at the time of the intrusion of the felspar-rock.

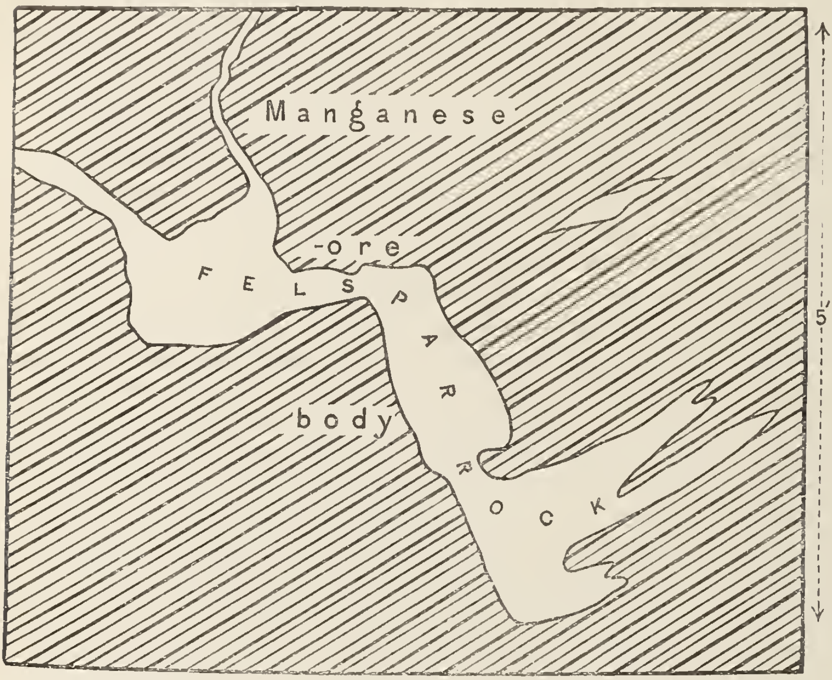


Fig. 64.—Intrusion of felspar-rock into the ore-body at Beldongri.

Nature and quality of the ores.

The manganese-ores found in this quarry are rather varied in character. The large bulk of the ore is composed of the four following varieties, which pass into each other:—

(1) Grey, fine-grained, crystalline, rather friable, consisting of predominating braunite grains in a subordinate psilomelane matrix.

(2) Similar to 1, but less friable, probably on account of a larger proportion of psilomelane.

(3) Similar to 2 but coarser-grained and not friable, and evidently containing a higher proportion of psilomelane.

(4) Hard, fine-grained, and with a still larger proportion of psilomelane. 1 to 3 all contain little cavities, often arranged in layers, lined with soft black manganese oxide. This variety is practically free from them.

The following analysis is of a piece of variety No. 2 and was carried out at the Imperial Institute :[1]—

Specimen No. 1071.

Manganese peroxide	60·58
Manganese protoxide	26·60
Ferric oxide	2·84
Alumina	0·26
Baryta	0·38
Lime	1·01
Magnesia	0·33
Silica (combined)	5·32
Silica (free)	0·00
Phosphoric oxide	0·08
Arsenic oxide	0·007
Combined water	2·55
Moisture at 100°C.	0·20
Carbon dioxide	0·05
	100·207
Specific gravity	4·26

This is equivalent to :—

Manganese	58·95
Iron	1·99
Silica	5·32
Phosphorus	0·035
Moisture	0·20

Stated in terms of its mineralogical composition the analysis is as follows :—

Apatite		0·18
Calcite		0·11
Braunite		53·31
Psilomelane :—		
$Fe_4(MnO_5)_3$	5·58	
$Al_4(MnO_5)_3$	0·65	
Ba_2MnO_5	0·51	
Ca_2MnO_5	1·63	
Mg_2MnO_5	0·75	
H_4MnO_5	9·82	
Mn_2MnO_5	27·82	
	46·76	46·76
Arsenic oxide		0·007
Moisture		0·20
		100·567
Subtract oxygen assumed		0·36
		100·207

[1] The following additional constituents in this ore have since been determined —

NiO, Co_3O_4, CuO	0·020
K_2O	0·12
Na_2O	0·25

This, as well as the two samples of which the analyses are given on page 909, indicates that the manganese-ores of this mine average about half braunite and half psilomelane.

Another variety that is not uncommon, especially in the north-west side of the pit, is a smooth ore, looking very like metallic lead, and having a hardness of 4. It usually contains remains of spessartite-garnet. The following analysis of a piece of this ore was carried out at the Imperial Institute.[1]

Specimen No. 1079.

Manganese peroxide	36·96
Manganese protoxide	22·00
Ferric oxide	7·49
Alumina	0·40
Baryta	0·78
Lime	2·31
Magnesia	0·15
Silica (combined)	1·41
Silica (free)	17·72
Phosphoric oxide	0·05
Arsenic oxide	0·005
Combined water	6·16
Moisture at 100°C.	4·21
Carbon dioxide	0·11
	99·755
Specific gravity	3·22

This is equivalent to:—

Manganese	40·43
Iron	5·24
Silica	19·13
Phosphorus	0·02
Moisture	4·21

and shows that such ore should be rejected on account of its low manganese and high silica.

On page 116 it is shown that the analysis corresponds to a mixture of a mineral of the formula $6Mn_3O_5.Fe_2O_3.8H_2O$, with quartz and spessartite. To this mineral, related to psilomelane, the name *beldongrite* has been temporarily given.

There is still another variety of ore; this is rather coarsely crystalline, compact, and steel grey in colour, with a somewhat yellowish or bronzy lustre in the sun. It is quite different to any other variety I have seen

[1] The following additional constituents have since been determined:—

NiO, Co_3O_4, CuO*	0·018
K_2O	0·01
Na_2O	0·33

* Chiefly cobalt.

in any of the Indian deposits and occurs at Beldongri as a band * one inch thick, in the fine-grained hard braunite-psilomelane mixture at the point D, on the south-east side of the quarry. Hardness = 6 to 6·5, and streak brownish black. Strongly magnetic, exhibiting polarity. A piece of this ore was analysed at the Imperial Institute with the result given on page 44. The analysis there given is equivalent to:—

Manganese	44·62
Iron	20·19
Silica	1·77
Phosphorus	0·47
Moisture	0·18

Such ore, on account of its high phosphorus and low manganese, should be rejected when a high grade manganese-ore is required, although if such ore were found in quantity near the coast, it would be exported as a phosphoric manganiferous iron-ore.

The mineralogical composition of this ore is discussed on page 46, and it is shown to correspond to the formula $3Mn_3O_4.2Fe_2O_3$. I have named it *vredenburgite.*

To show the character of the Beldongri ores as exported the samples Nos. 25 and 26 were taken. They were analysed at the Imperial Institute with the following result:—

	Sample No. 25.	Sample No. 26.
Manganese peroxide . . .	49·77	51·63
Manganese protoxide	27·90	29·35
Ferric oxide	8·05	7·77
Silica (combined)	4·54	4·80
Silica (free)	0·54	0·00
Phosphoric oxide	0·14	0·14
Moisture	1·17	0·88

These are equivalent to:—

	No. 25.	No. 26.
Manganese	53·11	54·28
Iron	5·635	5·44
Silica	5·08	4·80
Phosphorus	0·06	0·06
Moisture	1·17	0·88

Sample 25 represents 314 tons of stacked ore, badly cleaned, many of the pieces of ore containing remains of spessartite; a fair proportion of the ore was soft.

Sample 26 represents 533 tons of stacked ore, much better cleaned. This ore was mostly rather soft and finally granular and occasional pieces showed a little spessartite.

* I have since found that what is probably the same mineral occurs in small quantity in specimens I have collected at several other localities in the Central Provinces. A specimen from Garividi, Vizagapatam district, seems to be the same mineral (see page 44).

The analyses do not show as much difference as might have been expected and indicate that a considerable proportion of spessartite can be present without very seriously affecting the quality of the ore. These analyses indicate an average composition of 45 to 48% braunite, most of the remainder being psilomelane (see page 908).

Talus-ore.

As will be seen from the sketch-plan of this deposit, the 'country' on either side of the ore-body is covered by detrital or talus-ore, of which a fair quantity should be obtained in opening up the ore-body. In the south-east corner of the pit the following section was seen :—

4 feet talus-ore with very abundant tiny pisolitic granules of manganese-ore ; this passed down into :—

3 feet pisolitic gravel of manganese-ore,

1 foot pisolites of manganese-ore in a matrix of ferruginous clay,

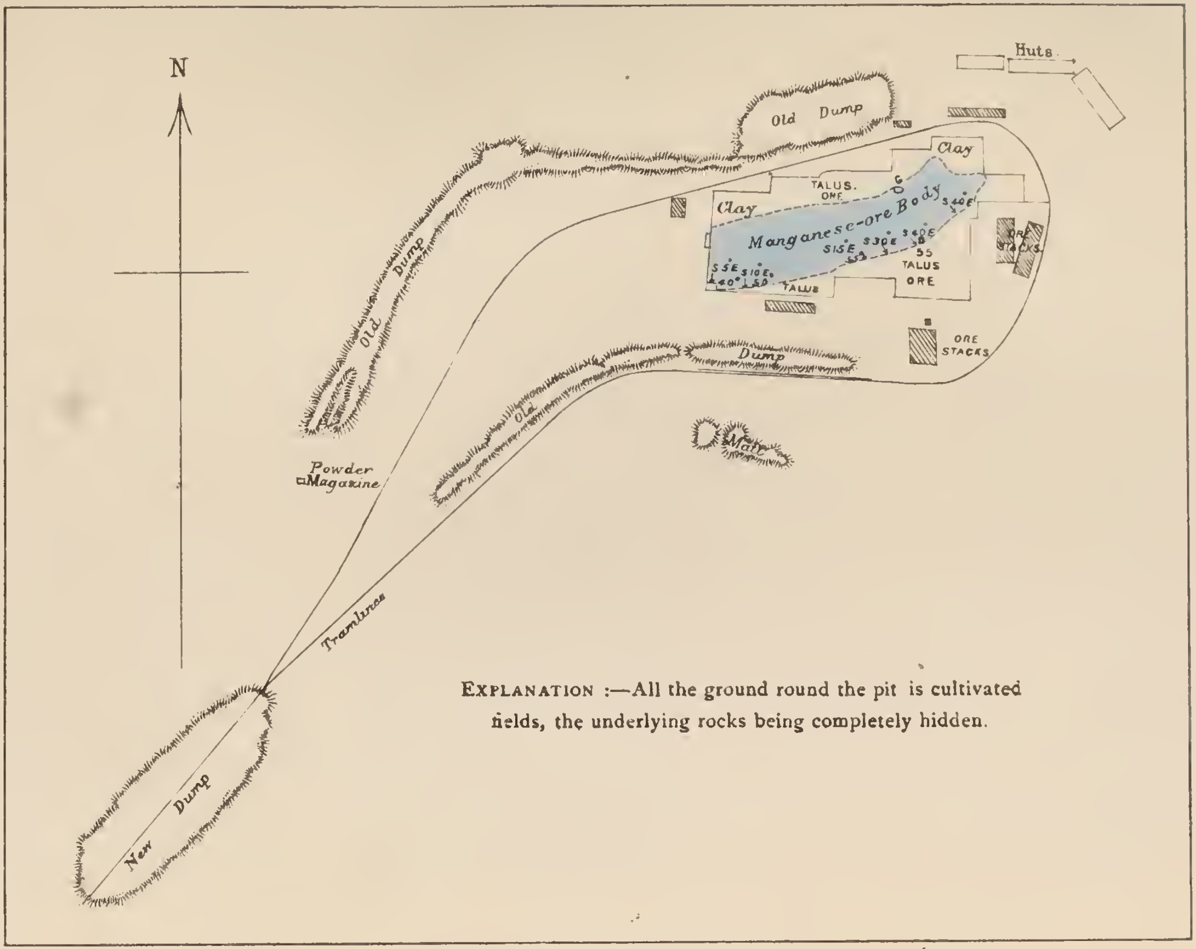
2 feet decomposed mica-schist containing pisolitic concretions of manganese oxide, with some quartzite pebbles above.

The question arises as to whether these pisolitic grains, averaging about ¼ inch in diameter, are of concretionary or detrital origin. I broke a large number of them and found that they consisted of the various sorts of ore found in the quarry and sometimes even contained spessartite. Hence they can hardly be of other than detrital origin. But the pisolites in the mica-schist must of course be of secondary, concretionary origin.

The overburden in the north-east corner of the quarry consists of alluvial clay passing down into talus. In this clay are many fragments and pebbles, amongst which are some well-rounded pebbles of white quartz up to 6 inches and more in diameter.

The working of the deposit.

The methods of working at the time of my visit in 1904 were of the usual crude kind. The ore was quarried and carried out of the quarry by hand, cleaned, and stacked ; and the waste material run in trucks along tram-lines to the new dump-heap shown in the sketch plan (Plate 37). The lines were so laid that the trucks descended by gravity to this dump-heap and had to be pushed back to the quarry by hand. The old dump-heaps and the huts were put in the position shown, partly because it was not at first realized what was the size and strike of the deposit, and partly because by the time these factors were ascertained a rival firm had obtained a prospecting license over the ground situated round the small area originally secured by the Central Provinces Prospecting Syndicate on mining lease. Now that this prospecting license has expired the Central Provinces Prospecting Syndicate are removing the old dump-heaps ; for



SKETCH-PLAN OF THE MANGANESE-ORE QUARRY AT BELDONGRI, NÁGPUR DISTRICT.
(FEBRUARY 1904.)

Scale, 1" = 200'

not only are they too close to the deposit, but some of them lie actually on the line of strike of the deposit. By December 1906, some of these dumps had been removed to a safe distance. Although the pit was quite shallow, not more than 20 to 30 feet deep in 1904, yet a considerable amount of water accumulated every night in the deeper parts of the pit and had to be removed every morning by baling with kerosine tins. A 10-inch Tangye duplex pump has now been set up at the mine. The ore from this deposit is carted to Salwa Railway Station, Bengal-Nagpur Railway, distant about seven miles.

Output. The output from this deposit during the years 1901 to 1907 is as follows:—

Year.	Long tons.
1901	3,114
1902	4,094
1903	5,347
1904	1,585
1905	1,344
1906	3,553
1907	7,257

16. Nagardhan.

At the time of my visit in February 1904, only a small pit 3 feet deep had been dug in a field. It showed 2 feet of alluvial clay resting on one foot of talus-ore, the pebbles being one to three inches in diameter. The ore was a hard crystalline variety containing scattered prismatic aggregates of a fairly soft mineral (pyrolusite). This pit was situated only 64 paces west of the boundary of Nandapuri village and the ore in it had doubtless been derived either from the Nandapuri deposit, which lies immediately the other side of the village boundary, or from an extension of this same deposit into Nagardhan limits. The work that was commenced here by the Central India Mining Company has been abandoned.

17. Nandapuri.

(CENTRAL INDIA MINING COMPANY.)

This deposit is held on mining lease by the Central India Mining Company. The accompanying figure (65) shows all that was visible at the time of my visit. The only ore of possible value then exposed

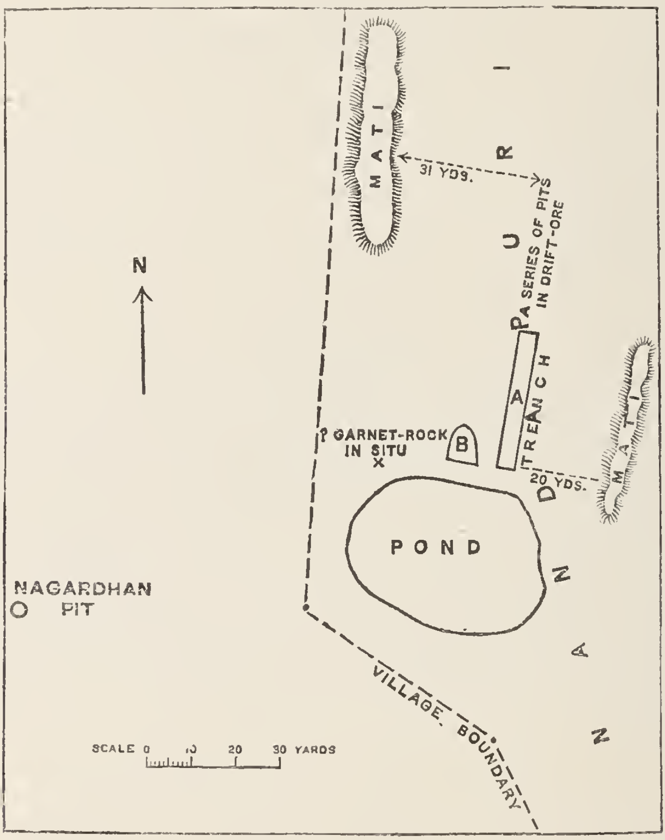


Fig. 65.—Sketch-plan of the Nandapuri workings.

was the talus- or pebble-ore seen in the shallow pits at the north end. Sample 27 was taken from ore collected from these pits. The ore was partly the fine-grained braunite-psilomelane mixture and partly coarsely crystalline braunite. The analysis carried out at the Imperial Institute is as follows :—

Sample No. 27.

Manganese peroxide	52·40
Manganese protoxide	23·10
Ferric oxide	8·74
Silica (combined)	5·15
Silica (free)	0·00
Phosphoric oxide	0·21
Moisture at 100°C.	0·22

This is equivalent to :—

Manganese	51·05
Iron	6·12
Silica	5·15
Phosphorus	0·09
Moisture	0·22

The above analysis indicates that the braunite and psilomelane are present in about equal proportions, and shows that the talus-ore is of fairly good quality.

A section seen in one of these talus-ore pits was as follows :—

2 feet soil,

2 to 3 feet pebble-ore,

3 feet fine gravel of manganese-ore pisolites,

1 foot + decomposed coarse muscovite-quartz-felspar-rock (? pegmatite or gneiss).

The trench shown on the plan was 12 feet wide and 6 to 10 feet deep and showed a few feet of gravel of manganese-ore and quartz of the size of peas resting on talus-ore and this on rock *in situ*. The latter was composed largely of fine-grained buff-coloured gondite with bands, lenticles, and patches, of quartz. This rock was often changed to manganese-ore in patches, or along a network of fine lines. The rock also contained a fibrous chocolate-brown mineral — apparently a pale-yellowish amphibole (?) impregnated along cracks with oxides of manganese and iron. In the excavation B the same rock was exposed, the spessartite-garnets being in places as large as $\frac{1}{8}$ inch in diameter.

Neither the strike nor the dip of the rocks was seen, but, judging from other deposits along this belt, the strike should approximate to east and west, with the dip to the south side.

This deposit was abandoned owing to the small quantity of ore obtained from it; but, in 1907, 537½ tons of ore were won.

Output.

18. Lohdongri.

(CENTRAL PROVINCES PROSPECTING SYNDICATE.)

(*See Plates 38 to 40.*)

This property is held on a mining lease by the Central Provinces Prospecting Syndicate. The accompanying rough sketch-plan (Fig. 66) constructed by means of a pocket-compass and pacing, illustrates this deposit as it was in February 1904. Since then the deposit has been very actively worked and has been so cut up that it is no longer possible to unravel its structure easily. The deposit formed a low flat grassy mound about 380 yards long from east to west and 200 broad, by about 30 to 35 feet high. It is interesting to note that the name means 'iron-

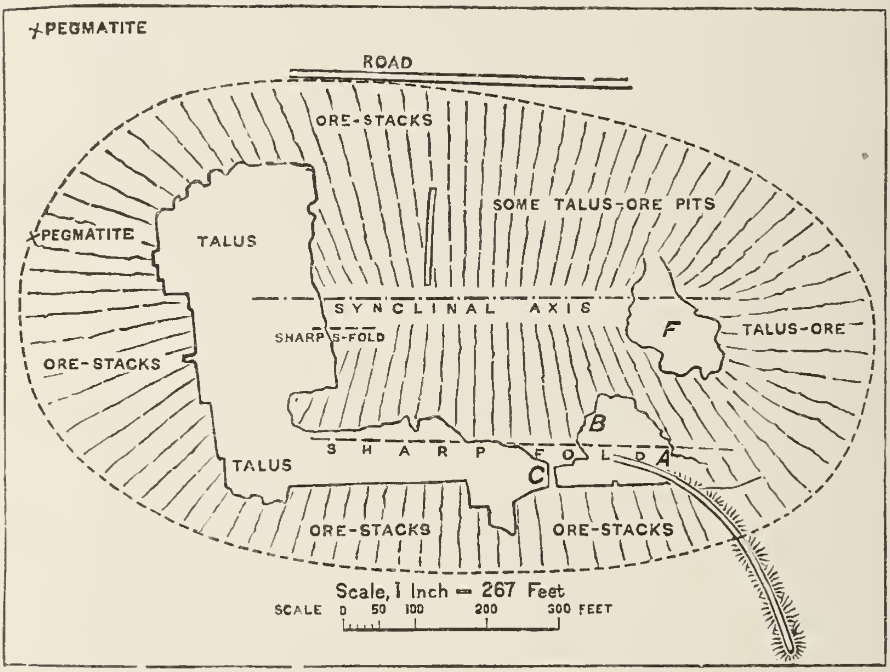


Fig. 66.—Rough sketch-plan of the Lohdongri manganese-ore deposit (Feb. 1904).

hill' in the vernacular. This mound consisted of a mass of 'beds' of manganese-ore, crumpled as shown in the section in Plate 40, and covered at the surface by detritus derived from these 'beds' giving rise to loose fragments scattered all over the mound. The ore-layers varied in thickness from about 2 inches to 2 feet and more, and in addition to being crumpled about axes or lines parallel to the strike, which is east and west, they showed in places some small crumplings about axes at right angles to the strike. The total thickness of the ore-beds may be about 60 feet, but it is impossible to estimate this with any accuracy. Its limits are obscured on all sides by talus-ore, but the breadth of the ore-body near the surface is probably not much greater than the actual breadth exposed in the workings, which is about 110 yards; for the ore-beds at both the north and south boundaries are dipping steeply, with practically no overlying layers to be accounted for.

The immediate 'country' of the ore-body was not exposed in February 1904, nor even in December 1906; but two pits dug to the north of the ore-body showed a coarse muscovite-pegmatite containing deep violet-blue to violet-black tourmaline.

By my third visit—December 1907—however, the rock underlying the ore-beds had been exposed. It was the usual mica-schist with some associated quartzite. In another place a 1-foot parting of mica-schist in the ore-body had been exposed.

A very large proportion of the ore-body consists of manganese-ore, but there are a few layers of various quartzites, the varieties seen being dark-grey coarse-grained vitreous, white vitreous, and grey sandstone-like, quartzites. Some layers are composite. That is, one side of the layer may consist of braunite and psilomelane whilst the other is quartzite, there being a passage from one to the other in the interior of the layer. There are also, in various parts of the deposit, irregular veins of quartz. At the very east end of the south part of the quarry the ore is sometimes fluted parallel to the strike, this being, probably, a sort of slickensiding phenomenon. At about the point A there was exposed, along a joint plane roughly at right angles to the strike, the section illustrated in figure 67. The ore-beds thus folded were a little shattered, and very much so in the middle of the fold. Along the quarried wall of manganese-ore at B there was a considerable quantity of vein-quartz (?) in the manganese-ore. At C, the section from the south edge of the deposit to the fold-

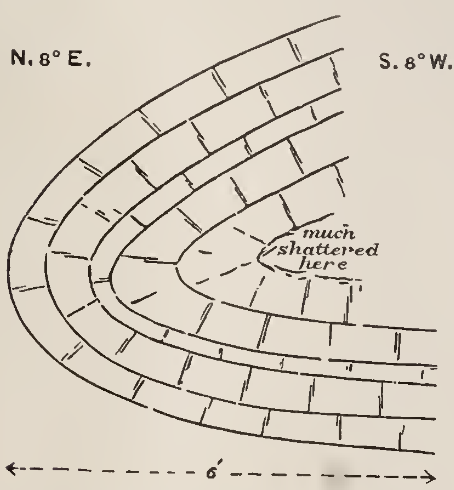


Fig. 67.—Diagram of a sharp fold in the manganese-ore layers at Lohdongri.

axis shown on the plan, was as in figure 68, which shows the course of two ore-beds. The cliff, just to the west of C, formed by quarrying, cut these beds along the line D E and it is this fold that is shown in the photograph forming Plate 39, figure 1.

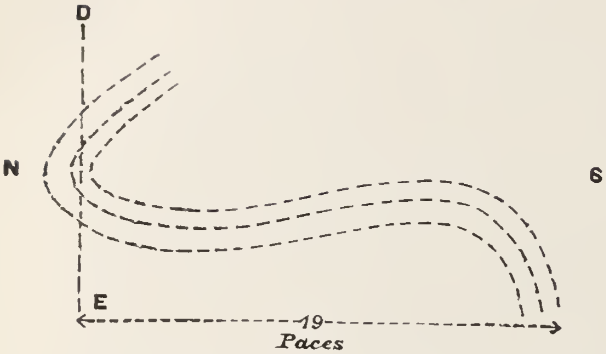


Fig. 68.—The course of two 'ore-beds' at C (See plan of Lohdongri, fig. 66.)

The quarrying across the west end of the mound gave a practically continuous section across the ore-body and it was from the evidence of these exposures that the section shown in Plate 40 was constructed, the southern part, however, being based on the sections seen along the east-west part of the quarry running along the south side of the mound. Plate 38 is a photograph of the ore-layers as exposed by the quarrying across the west end of the hill. Practically all the rock seen is manganese-ore, and the floor of the quarry on which the chaprási is standing is composed of ore *in situ*; in fact, the quarrying had nowhere been carried sufficiently deep to pass through the ore-beds into the underlying rock, when this was taken (1904). Fig. 2, Plate 39 shows a view of the southern part of this western section, Plate 38 showing the northern part of the section. This second view, being taken from a greater distance, also shows, in the foreground, a large quantity of quarried manganese-ore piled into rectangular stacks.

Spaces in the ore-body.

There is often a space between the layers of ore. The width of these spaces may be only a small fraction of an inch or it may be as much as 1 to 3 inches. This space is, as a rule, filled with clay of a reddish colour, which usually contains numerous pisolites of manganese-ore. I fractured a large number of these and found that at least a large proportion of them were of detrital origin. Both they and the clay had probably been washed down cracks or joints, of which there are many to be seen in various parts of the deposit, these vertical cracks also containing red clay full of pisolites. It seems probable, however, that some at least of these pisolites are of concretionary origin. The spaces between the ore-layers do not, however, always contain clay, but are sometimes empty. There are also some irregular open spaces in the ore-body that may once have acted as water channels. One of these, seen in December 1906 on the south side of

Photographed by L. L. Fermor.

Bemrose, Collo., Derby.

MANGANESE-DEPOSIT AT LOHDONGRI, NÁGPUR DISTRICT. C. P.

the ore-body, was a horizontal channel, about a foot in diameter and height, which ran for some feet into the deposit. The surfaces of the layers of ore in the clay-filled spaces are sometimes covered with fine crystals of braunite. By offering rewards to his quarry-men, Mr. E. L. Young, who is in charge of this deposit, has succeeded in obtaining several fine crystallizations, which he has kindly permitted me to examine. The faces shown are the tetragonal pyramid, the di-tetragonal pyramid, the basal plane, the prisms of the first and second orders and possibly one or two other forms. The most commonly developed face is that of the pyramid, and when this is alone the mineral takes the form of the tetragonal octahedron, of which a fine example with faces two inches across is figured on Plate 2.

Braunite crystals.

As already noted (page 915), practically the whole thickness of the ore-deposit consists of manganese-ore, nearly all of which is marketable under favourable market conditions. There are two chief varieties of ore. One, the comparative abundance of which distinguishes this deposit from nearly all the other deposits of the Nágpur-Bálághát area, is a coarsely crystalline variety showing hard shining facets of braunite up to ½ inch across, usually associated with a fair amount of dull psilomelane. All the pieces of this variety contain, here and there, cavities, lined with soft substances, either black or red, probably oxides of manganese and iron, respectively.

Nature and quality of the ores.

The second, and more abundant variety, is the fine-grained hard grey crystalline ore showing patches of somewhat more coarsely crystalline braunite. This contains a much larger proportion of psilomelane and is also somewhat cavernous with soft whitish, red and black substances in the cavities.

In addition to the above two varieties there is also a small quantity of ore somewhat like the soft blackish variety found at Sátak (see page 899). A specimen (No. 1089) of the crystalline ore was analysed at the Imperial Institute with the following result :[1]—

Specimen No. 1089.

Manganese peroxide	47·63
Manganese protoxide	33·63
Ferric oxide	8·78
Alumina	0·03
Baryta	0·84
Lime	0·85
Magnesia	0·58
Silica (combined)	6·83

[1] The following additional constituents have since been determined :—

NiO, Co_3O_4, CuO	0·032
K_2O	0·14
Na_2O	0·17

Silica (free)	0·01
Phosphoric oxide	0·08
Arsenic oxide	0·005
Combined water	0·78
Moisture at 100°C.	0·07
Carbon dioxide	0·05
	100·165
Specific gravity	4·58

This is equivalent to :—

Manganese	56·12
Iron	6·15
Silica	6·84
Phosphorus	0·035
Moisture	0·07

In terms of mineralogical composition the analysis can be re-written as follows :—

Apatite		0·18
Calcite		0·11
Braunite (including 8·78°/$_o$ Fe_2O_3)		68·54
Psilomelane—		
$Al_4(MnO_5)_3$	0·08	
Ba_2MnO_5	1·12	
Ca_2MnO_5	1·32	
Mg_2MnO_5	1·32	
H_4MnO_5	3·01	
Mn_2MnO_5	24·63	
	31·48	31·48
Quartz		0·01
As_2O_5		0·005
Moisture		0·07
		100·395
Subtract oxygen assumed		0·23
		100·165

The duplicate half of the specimen analysed does not seem to contain such a large proportion of psilomelane. Judging by the eye it contains at least 80 per cent. of coarsely crystallized braunite in plates, varying from $\frac{1}{4}$ to 1 inch, but usually about $\frac{1}{2}$ inch across. This may indicate that the braunite does not correspond to the formula $3Mn_2O_3.MnSiO_3$, as was assumed in making the foregoing calculation, but to one of the other formulæ $7Mn_2O_3.2MnSiO_3$ or $4Mn_2O_3.MnSiO_3$ (see page 70).

At the time of my first visit (February 1904) there were some 9,000 tons of ore stacked. A sample of some 300 lbs. of ore was collected by pacing over the stacks and picking up pieces of ore at regular intervals. The sample thus collected was found to consist largely of the second variety of ore noticed above, with a fair proportion of the coarsely crystalline

Fig. 1.—FOLDING IN THE LOHDONGRI MANGANESE-DEPOSIT.

Photographed by L. L. Fermor. *Bemrose, Collo., Derby.*

Fig. 2.—LOHDONGRI MANGANESE-DEPOSIT WITH ORE-STACKS IN THE FOREGROUND.

braunite (the first variety). A complete analysis of this sample made at the Imperial Institute showed the following result:[1]—

Sample No. 28.

Manganese peroxide	49·70
Manganese protoxide	23·59
Ferric oxide	10·29
Alumina	2·70
Baryta	0·85
Lime	5·60
Magnesia	1·64
Silica (combined)	3·55
Silica (free)	0·86
Phosphoric oxide	0·16
Arsenic oxide	0·015
Combined water	0·75
Moisture at 100°C.	0·30
Carbon dioxide	0·17
	100·175

This is equivalent to:—

Manganese	49·73
Iron	7 20
Silica	4·41
Phosphorus	0·07
Moisture	0·30

The surprising feature of this analysis is the low percentage of combined silica, indicating as it does only 35 per cent. braunite. The manganese percentage is also lower than might have been expected; this is due no doubt to the large proportion of psilomelane, in which the base portion of the manganate contains a larger proportion of calcium and magnesium than usual.

As typical of the ore despatched from this mine, Mr. W. H. Clark has kindly provided the analytical figures given below. The complete analysis was made on a proportional mixture of the 7 samples, the range of analysis of which is given after the complete analysis; the total tonnage represented is 2,246. This and the other analyses given below were all made by Mr. R. D. Connell, Chemist to the Central Provinces Prospecting Syndicate.

Manganese peroxide	46·49
Manganese protoxide	25·35
Ferric oxide	12·81
Alumina	1·86
Baryta	0·92
Lime	2·22
Magnesia	0·75

[1] The following additional constituents have since been determined:—

NiO, Co_3O_4, CuO	0·02
K_2O	0·19
Na_2O	0·13

Silica	6·78
Phosphoric oxide	0·204
Arsenic oxide	0·049
Sulphuric oxide	0·080
Nickel and cobalt oxide	traces
Combined water	1·90
Moisture	0·40
Total	99·813
Manganese	49·03
Iron	8·97
Phophorus	0·089

The following are the partial analyses supplied :—

Date of analysis.	January, 1906.	November, 1906.
Details of sample.	Range of seven samples.	(1)
Tonnage.	156 to 450.	6,000.
Manganese	47·12 to 49·78	50·64
Iron	8·22 to 10·62	7·32
Silica	6·40 to 7·45	7·05
Phosphorus	0·054 to 0·098	0·090

At the time of my first visit, in February 1904, work had been completely stopped, because the price of manganese was then only $8\frac{1}{2}$ pence per unit and the produce from this ore-body averages only 48 to 51 per cent. manganese. With the subsequent rise of prices the 9,000 tons of ore then stacked have been removed and exported. This ore was formerly sent to Salwa station some 7 miles distant and blended with higher grade ores like those of Beldongri. But the deposit has now been connected up with the tramway system of the Central India Mining Company, and the ores are now railed *viâ* Kácharwáhi and Waregáon to Tharsa station, Bengal-Nágpur Railway, a total distance of $9\frac{1}{2}$ miles; trains of 25 to 40 trucks are drawn by small locomotives, each truck carrying 1 to $1\frac{3}{4}$ tons according to size. For this service the Central India Mining Company charges the Central Provinces Prospecting Syndicate Rs. 1-4 per ton, the saving to the Central Provinces Prospecting Syndicate being about Re. 1 per ton over the former cost of carting. To work the deposit must be a very simple problem; for not only is the ore well bedded, but the beds are broken up by cross joints. Hence no blasting is required, but simply crowbars and picks to prize out the ore. As this is pretty uniform in quality, very little is rejected, and, since the country has hardly been touched, practically all that it is necessary to throw away is the refuse from the

The working of the deposit.

1 For this sample some ore was taken from every truck-load despatched during October 1906, each truck-load being about $1\frac{1}{2}$ tons.

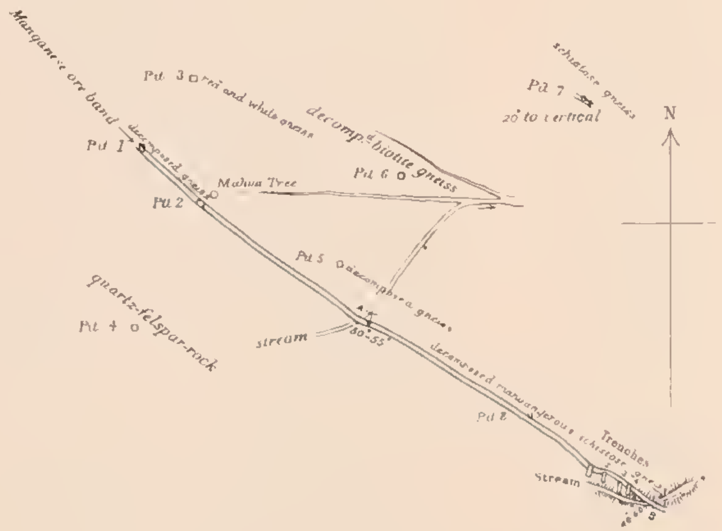


FIG. 1.—SKETCH-PLAN OF THE GOWARI WARHONA MANGANESE-ORE DEPOSIT, CHHINDWÁRA DISTRICT.

Scale:- 0 100 200 400 800 Feet

FIG. 2.—PLAN SHOWING THE EXTREMELY VARIABLE STRIKES AND DIPS OF THE TWO ORE-BANDS AT MÁNDRI, NÁGPUR DISTRICT.

Scale:- 0 50 100 Yards

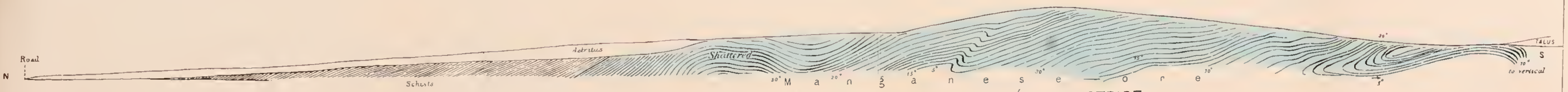


FIG. 3.—SECTION ACROSS THE LOHDONGRI MANGANESE-ORE DEPOSIT, NÁGPUR DISTRICT.

Horizontal Scale, 1" = 30 ; Vertical Scale, 1" = 45

detrital ore accumulations on the slopes of the mound, and the quartzites, red clay, and vein quartz, occurring in the ore-body. Hence the dumps or *mati*-heaps at this deposit are smaller in proportion to the amount of quarrying done than at any other deposit visited. It is a pity that no attempt is made here to find out the depth to which these ore-beds extend. As has been already explained, the ore-beds are at some places horizontal or but slightly dipping. If a pit were put down at such a point, it should soon penetrate into the underlying 'country,' unless there were a phenomenally great thickness of ore-beds at the point chosen. By my third visit (December 1907) the working of the ore-bed had just uncovered the underlying mica-schist in 2 or 3 places. Work was begun on this deposit in 1900, and up to the end of 1906 over 107,000 tons of ore were extracted. It is surprising that a mining company could go on working such a deposit as this for 7 years before finding out how deep the ore went, when the geological conditions were so favourable that a pit some 20 or 30 feet deep would have shown this some years earlier!

Output.

The output from this deposit from 1900 to 1907 is as follows:—

Year.	Long tons.
1900	3,404
1901	15,395
1902	19,140
1903	7,207
1904	1,331
1905	20,922
1906	39,970
1907	40,418

Workings west of the village.

Towards the end of 1906, a trench some 30 yards long was dug at a point about ½ a mile due west of the Lohdongri mine, and immediately to the west of the village of this name. This revealed the existence of manganese-ore *in situ*. What I saw was a small thickness of ore-layers resting on micaceous schists, with a layer of coarse-grained vitreous quartzite separating the two, the strike being probably east and west. The ore itself was medium-grained, hard and crystalline, with cavernous black spots. There was also some dull dirty black ore formed by the replacement of the layer of quartzite mentioned above. A specimen of ore brought from here consists of psilomelane mixed with a crystalline mineral looking like facetted braunite, but rather strongly magnetic. In one place I found vein-quartz containing radiate limonite. A pit dug 15 yards to the north of the trench showed very schistose muscovite-gneiss.

Mr. Young has obtained from this pit some trapezohedral crystals of spessartite, the occurrence of which is of especial interest because not a sign of this mineral has been seen in the main Lohdongri quarry, although over 100,000 tons of ore have been extracted from it.

Although the ground between this pit and the main deposit has not been examined for ore, yet it seems probable that this occurrence is only an extension of the main ore-body. Moreover, someone has dug some shallow pits at intervals for about ½ a mile further to the west, in which fragments of loose ore and spessartiferous rock have been found. At a point about a mile west of Lohdongri village there is an outcrop by the roadside, just on the Lohdongri side of a nálá, of darkened spessartite-quartz-rock. All the facts enumerated above point to a more or less continuous run of manganiferous rock or manganese-ore between Lohdongri and Beldongri, although, in many places, this supposed manganiferous band must be buried too deeply beneath the surface to be economically workable.

19. Kácharwáhi.

(CENTRAL INDIA MINING COMPANY.)

(See Plate 41.)

This deposit, worked by the Central India Mining Company on a mining lease, is situated about 1⅜ miles almost due east of Lohdongri village and is about ¾ mile south by east of Kácharwáhi village. It is situated in cultivated fields and is worked by an excavation in the alluvial soil. In the irregular excavation the ore-body was exposed for a length of about 100 yards and a width of 92 feet measured horizontally. Neither wall of the deposit could be seen, so that the full thickness had possibly not been exposed.[1] Taking the average dip as 60°, the above horizontal width corresponds to a true thickness of 80 feet. The actual dips seen were at 60°—70° to the S. 5° E. on the south side near the west end, curling round to S. 40° E. towards the middle, and further along returning to a dip of 55°—70° to S. 10° E.; this latter may be regarded as corresponding to the average strike of the deposit, namely E. 10° N. Some shallow trial pits, which had been put down on the extension of the strike to the east, had passed through alluvial clay and failed to strike the ore-body; hence it is possible that the ore-body being worked was once a small hill that has been since buried in the alluvium of the Súr River.

[1] I revisited this deposit in December 1906. The quarry had then been considerably deepened (to 60 feet or more in places) and widened and the 'country' on the south side had been exposed and possibly that on the north as well. If so, the figure given above is the true width.

In February 1904, the bands of rock associated with the ore-layers seemed to consist mostly of thick- and thin-bedded quartzites, of dark grey colour, of either coarse or fine grain, and often containing disseminated manganese-ores. In December 1906, the excavations had in many places reached a depth of about 60 feet and the ore-body was much better exposed.

Constitution of the ore-body.

Many additional rocks to those seen in 1904 had thus become uncovered. They included very friable rather fine-grained rocks composed of white quartz and mica flakes arranged in folia so as to render the rock schistose. These micas usually show some shade of rich brown, copper, brownish red, or even crimson, and are probably manganiferous varieties. Another rather common rock is a fine-grained granular rock of white quartz with numerous scattered prismatic granules varying in colour from pale rose to rich deep crimson, the colour of this mineral often showing a gradual change from pale to deep in one hand-specimen. In one place a band of felspar-rock was found intruded between two layers of this rock, and it was then seen that the above-mentioned mineral is deepest in colour at the contact with the felspar-rock, lightening in colour away from the contact.[1]

Excluding the rocks intrusive in the ore-body and to be noticed later, the ore-body may therefore be described as consisting of layers of manganese-ore interbedded with hard vitreous quartzites, often black in colour, and soft friable schistose rocks—usually consisting either of manganese-mica-quartz-schist or of blanfordite (?)-quartzite, but sometimes containing various granular minerals, not yet examined, in the same friable quartzite matrix. The ore-layers take the form of beds 5 to 10 feet thick separated by perhaps equal thicknesses of the rocks mentioned above, the actual layers of rock varying from an inch to one or 2 feet in thickness, and being often replaced by manganese-ore. The ore-layers themselves are often rendered worthless by thin inter-laminations of quartzite, etc., or patches of vein-quartz or felspar. From a hasty examination of this quarry in 1906 it did not seem as if more than ⅓ of the width of the ore-body could consist of layers of ore worth extracting; this is, however, possibly an under-estimate due to the ore-bands being obscured by wet detritus. The ore extracted is said to be of as good quality as it ever was, and this statement is corroborated, as far as manganese contents, by the figures given on page 927.

'Country.'

The rock exposed in the south wall of the quarry at the time of my second visit is probably the wall-rock of the ore-body, rather than a layer interbedded in it. This

[1] Subsequent microscopic examination has shown that the crimson mineral is an amphibole allied to juddite, and that the rock containing it, and also many of the micaceous schists, contain felspar as well as quartz.

wall-rock is a soft felspathic mica-schist or very schistose micaceous gneiss, similar to that seen at Beldongri, and includes some layers of a pale green soapy schist that may be talcose. The north wall at this time showed a friable mica-quartz-schist, which may only be another of the layers so abundant in the ore-body, or may actually form the north wall of the quarry.

Overburden.

Resting on the ore-body there is an overburden of 3 to 5 feet of alluvial clay, containing scattered grains of manganese-ore and quartzite, and this is separated from the ore-body by a variable thickness of manganese-ore, gravel, and detritus.

Blanfordite, braunite and albite.

Near the east end of the quarry I found an exposure of rocks of extraordinary interest. One of these is a coarsely crystalline, white albite-rock containing scattered crystals up to one inch long, and dense aggregates, of a brown altered form of the mineral I have called *blanfordite* (see page 125). This rock passed into one made of finely granular braunite with abundance of fresh blanfordite of crimson colour, up to $\frac{3}{8}$ inch long. In places the rock might be called blanfordite-rock: thin sections of it show interstitial apatite and a certain amount of a monoclinic amphibole with pleochroism as beautiful as that of the blanfordite; this I have called *juddite* (see page 159).

Another type is a felspar-rock containing both aggregated and isolated crystals of braunite. Some of these are octahedra up to $1\frac{1}{2}$ to 2 inches in diameter, and are often twinned on (101), as explained on page 58, to form either butterfly or interpenetration twins. Others are barrel-shaped crystals showing both the tetragonal and di-tetragonal pyramid. They are mostly doubly terminated and are sometimes twinned on (101). The strike of the braunite-albite-rock seemed to be about E. 20° S. It was impossible to see if this rock were an intrusive in the ore body, as seemed more probable, or if it were interbedded with the ore-layers. In the latter case it would be necessary to suppose a local flexure in the strike of the ore-body, which is at this end of the quarry about E. 10° N. The amount of this rock exposed is small and might have been overlooked, had I not first found the blanfordite-braunite rock on one of the ore-stacks. The coolies were able to show whence they had quarried the ore in this stack, for it had just been rejected by the contractor for containing too much 'silica,' as all visible impurity is designated by many of the contractors.

On my second visit in December 1906, the rock carrying the braunite and blanfordite crystals was much better exposed, and seemed to be arranged parallel to the strike of the other rocks; it is hence probably an intrusive parallel to the bedding planes. Many of the braunite crystals obtained were of large size, up to 3 or 4 inches across, and showed all the faces noticed on the Lohdongri crystals (see page 917).

Nature and quality of the ores.

The ores found in this deposit consist partly of the fine-grained psilomelane-braunite mixture and partly of more uniformly crystalline material of both fine and medium grain. Both varieties usually show black films, and cavities containing either ferruginous matter or a black powder.

A specimen of ore composed of the former variety, with some patches of the crystalline medium-grained variety, was analysed at the Imperial Institute with the following result :[1]—

Specimen No. 1093.

Manganese peroxide	41·34
Manganese protoxide	42·16
Ferric oxide	4·48
Alumina	0·39
Baryta	0·00
Lime	1·41
Magnesia	0·83
Silica (combined)	8·18
Silica (free)	0·46
Phosphoric oxide	0·20
Arsenic oxide	0·005
Combined water	0·63
Moisture at 100°C.	0·05
Carbon dioxide	0·09
	100·225
Specific gravity	4·73

This is equivalent to :—

Manganese	58·74
Iron	3·14
Silica	8·64
Phosphorus	0·09
Moisture	0·05

The analysis can be expressed mineralogically as follows :—

Apatite	0·46
Calcite	0·20
Braunite (containing 4·48 Fe_2O_3)	82·04
Mn_2MnO_5	14·46
Impurities :—	
Al_2O_3	0·39
Cao	1·04
Mgo	0·83
H_2O	0·63
Quartz	0·46
As_2O_5	0·005
Moisture	0·05
	100·565
Subtract oxygen assumed	0·34
	100·225

[1] The following additional constituents have since been determined :—

NiO, Co_3O_4, CuO	0·08
K_2O	trace
Na_2O	0·23

This interpretation of the analysis indicates that the psilomelane present has the composition Mn_2MnO_5.

A complete analysis of the braunite crystals noticed on page 924 is given on page 68. It shows the presence of :—

Specimen No. 1110.

Manganese	57·86
Iron	3·85
Silica	8·60
Phosphorus	0·035

Some of the ore that was stacked looked as if it were of very good quality ; but most of the stacks would have been the better for recleaning. Hence the sample (No. 29) taken from these stacks cannot be regarded as representative of the ore as it would be when properly cleaned. The pieces in the sample often contained ferruginous and siliceous matter, and were of both the varieties mentioned on page 925. The partial analysis by the Imperial Institute was as follows :—

Sample No. 29.

Manganese peroxide	39·43
Manganese protoxide	35·64
Ferric oxide	10·86
Silica (combined)	5·70
Silica (free)	2·23
Phosphoric oxide	0·18
Moisture	0·38

This is equivalent to :—

Manganese	52·58
Iron	7·60
Silica	7·93
Phosphorus	0·08
Moisture	0·38

and indicates that the sample contained about 57% braunite and 40% of psilomelane. Such ore is, of course, easily marketable.

Seven partial analyses by Messrs. J. and H. S. Pattinson, of various types of ore from this deposit, kindly supplied by Messieurs Jambon and Cie. and H. D. Coggan, show the following limits and mean :—

	Limits of 7 analyses.	Mean of 7 analyses.	
Manganese . . .	48·96 to 57·60	52·81	Dried at 212° F.
Iron . . .	2·42 to 10·16	6·55	
Silica . . .	6·43 to 9·60	7·57	
Phosphorus . . .	0·049 to 0·103	0·069	
Moisture . . .	0·22 to 0·41	0·28	

One of these being an analysis of a sample of the general stock of this deposit at a particular time is given below separately :—

Manganese	51·77
Iron	7·40
Silica	6·43
Phosphorus	0·076
Moisture	0·24

A sample of the stocks of Kácharwáhi and Waregáon ore at Thársa station in 1903 was analysed by Messrs. J. and H. S. Pattinson, with the following result :—

Manganese	53·01
Iron	6·64
Silica	7·20
Phosphorus	0·058
Moisture	0·35

The character of the ore obtained from this deposit is, however, best seen from the following figures, supplied by Mr. H. D. Coggan, showing the average analysis of the ore raised during the three years 1904 to 1906 :—

	1904.	1905.	1906.
Manganese	50·83	53·53	53·53
Silica	8·85	7·51	8·25
Phosphorus	0·065	0·081	0·147

These figures represent the analysis of the total output from the deposit for each year.

The working of the deposit.

The photograph (Plate 41, figure 1) illustrates the disastrous effects that may result from allowing a deposit to be worked by contract without proper supervision on the part of the lease-holder. In this case the contractor had set his coolies to work all the good ore-bands and leave as upstanding ridges the valueless bands of quartzite, etc., the sole object being to extract the maximum quantity of ore in the minimum of time, without any regard to the future working of the deposit. As a result of this policy the *mati* or waste had been dumped quite close to the edge of the excavation, and later this had been increased in size so that the waste was in many places actually slipping back into the quarry. It is customary on the Indian manganese mines to pay the coolies so much per 1,000 cubic feet for the manganese-ore as measured in the stacks and also per 1,000 cubic feet of the volume of the cavity made in excavating, the latter payment being for the purpose of recompensing the coolies for the work of removing the worthless material as well as the valuable ore. At the time of my visit (February 1904) the contractor had stopped this second payment and as a result the coolies, who had, of course, to do a certain amount of dead-work to get at the ore, were, instead of removing the refuse to the dumps, piling it on the ridges and pinnacles of quartzite that had been left in the pit as the result of the previous bad work. This method of work explains the gravel-pit-like appearance of the excavation as shown in Plate 41, figure 1.

This was, of course, only a temporary phase of the working, and in December 1906 none of the waste was lying in the quarry, but had all been carried out. Although the depth had been greatly increased the same tendency to work at the ore-bands and leave the intervening layers of quartzite, etc., as upstanding ridges was noticeable. Such a method of work is of course largely due to the natural objection the coolies take to quarrying the barren quartzites, etc., for which they are paid at a much lower rate than for the manganese-ore, and unless constantly supervised they invariably, both here and at all the other mines, work at the ore as long as they can and only remove the ' country ' or barren rock when they can no longer get at the ore with ease. During 1907, however, a commencement has been made in working away the ' country ' on either side of the deposit in a series of horizontal slices or steps, the intention being to work the deposit regularly bench by bench. The question is—How long will it pay to work in this way both this and many other deposits, without resorting to mining?

A 4-inch centrifugal pump driven by a small vertical engine has been put in to remove the water that enters the pit and forms pools of water in all the deeper parts. The water is baled from the various pools to the sump, two men throwing the water from one pool to another by means of a kerosine-oil tin fixed to the middle of a couple of ropes, the opposite ends of which are held by the men. From the sump the water is pumped out of the quarry.

The ore is carried to Thársa station, a distance of about 7 miles, over the Central India Mining Company's steam-tramway.

Output.

The output of manganese-ore from this deposit from 1904 (when the figures were first kept separate from those of Waregáon and other deposits) to 1907 is as follows :—

Year.	Long tons.
1904	3,063
1905	8,379
1906	5,340
1907	3,938

FIG. 1.—MANGANESE-QUARRY AT KÁCHARWÁHI, NÁGPUR DISTRICT, C. P.

Photographed by L. L. Fermor. *Bemrose, Collo., Derby.*

FIG. 2.—MANGANESE-ORE STACKED AT PRINCE'S DOCK, BOMBAY, READY FOR SHIPPING.

During 1907 the existence of manganese-ore between the Kácharwáhi and Waregáon deposits, at a distance of 6 or 7 feet below the surface, has been proved by means of a trial pit. The occurrence is being opened up by Messrs. Jessop and Company. Such work as had been done at the time of my visit, showed a steep dip to the N. 20° E. The rocks and minerals exposed were manganese-ore, quartzite, gondite, and muscovite-rock. The ore was braunite with much residual spessartite, and did not look of much value.

Jessop and Company's Kácharwáhi.

20. Waregáon.

(CENTRAL INDIA MINING COMPANY.)

This deposit is situated a little over a mile east by north from Kácharwáhi, and is connected by a light tramway of 2-foot gauge to Thársa station. Bengal-Nágpur Railway, 5½ miles to the south. It is the junction for the lines from Lohdongri and Mánegáon and from here some 300 tons of ore a day can be carried to Thársa. Work was started at Waregáon in March 1902. In quarrying the ore, a large excavation has been dug in the alluvium. It was, at the time of my visit in February 1904, 360 feet long and 160 broad, and contained water at a depth of 22 to 25 feet. The ore-band had been exposed for a length of about 300 feet, and the horizontal width where it was apparently widest was 48 feet. The strike is about E. 20° N. and the dip very variable (30° to 50°), but averaging about 40° to the S. 20° E. Taking this dip, the true thickness of the ore-band works out as 31 feet. By means of a pumping-engine to remove the water, the quarry had been excavated to a depth of 35 to 40 feet, when it was found necessary, early in 1904, to discontinue the work. This was partly owing to the fact that all visible ore of good quality above the water-level had been extracted, that still left in the bottom of the pit being difficult to win on account of the 10 to 15 feet of water above it,[1] and partly because the ore was getting more siliceous and somewhat arsenical with increasing depth. To extend the pit along the strike was impossible, except at great expense, owing to the fact that huge piles of waste had been dumped at both ends of the quarry, as well as along its sides. At a point about 200 feet west of the west end of the quarry—*i.e.*, on the further side of the dump lying across the west end of the quarry—a small trial-pit that had recently been dug (February 1904) revealed the existence of good-quality ore at a depth of only 3 to 4 feet from the surface. The several small pits that had been put down as the result of the discovery showed that the strike of the ore in these pits would, if it did not curve round, carry the ore to the north of the main quarry, indicating it to be either a parallel band of ore to that exposed in the main quarry, or

[1] There are said to be springs along the bottom of the pit.

the same band of ore brought up by a fold. Sample No. 30 was taken from the ore being worked here.

Owing to the water in the main pit I could examine it round the edges only, where there was the usual overburden of alluvial clay and pebble-ore resting on mica-schists, which apparently form both the hanging and foot walls of the deposit. The following section, seen at the east end, may be taken as typical of the overburden:—

Nature of the ore-band.

$7\frac{1}{2}$ feet alluvial clay with scattered pisolites of manganese-ore,
$2\frac{1}{2}$ feet rather small talus-ore with some quartzite pebbles,
8 feet of a mixture of small pebbles of manganese-ore and quartzite, with clay and débris of mica-schist,
10 feet waved mica-schists of various colours, red, yellow, white, and black, due to impregnation with oxides of iron and manganese. (In one place the mica-schist contained altered magnetite crystals up to $\frac{1}{4}$ inch diameter.)

Along the south edge of the quarry the mica-schist was seen to rest on interbanded dark-grey to black quartzites, and poor quality manganese-ore, with bands of spessartite, etc., in both ore and quartzite. This dark-grey to black quartzite is seen under the microscope to owe its colour to very abundant minute inclusions of idiomorphic crystals of some black manganese-mineral. It also, in one case, contains a pyroxene having pleochroism in pink and green. At the west end of the pit, the rock that corresponds to the ore-band occupying the middle of the pit has been left unquarried and consists of very massive spessartite-rhodonite-rock, only partly altered to manganese-ore. Along the north side of the pit were exposed, interbanded with one another, mica-schist, manganese-ore, gondite, and quartzite; it was not quite certain that the full width of the deposit had been exposed in that direction. At one place near the south edge of the quarry there was exposed a large mass of soft white rock of quartz and felspar, with many black manganiferous patches, due doubtless to impregnation or replacement of this rock by manganese oxide. This quartz-felspar-rock is probably an intrusive in the ore-body.

From the waste heaps, both of the main quarry and of the new excavations, some fine specimens of coarsely crystallized spessartite-quartz-rock were obtained. The spessartite crystals would some of them, if perfect trapezohedra, be $1\frac{1}{2}$ to 2 inches in diameter. Besides the usual trapezohedral faces, which are, as at Chárgáon, often striated parallel to the faces of the rhomb-dodecahedron, a few crystals show tiny hexoctahedral faces; while on one, rhomb-dodecahedral faces are rather well developed (see pages 171 to 174).

Spessartite crystals.

As already noticed no ore of good quality was visible in the main pit. It is said that when this pit was first started the ore analysed 52 per cent. manganese

Nature and quality of the ores.

on cargo lots, and then decreased to 50 per cent., and after that to 47 per cent., on the last cargo sent, which was reported to be very arsenical. Eight partial analyses by Messrs. J. and H. S. Pattinson of various types of ore from this quarry, kindly supplied by Messieurs Jambon and Cie, show the following limits and mean :—

	Limits of 8 analyses.	Mean of 8 analyses.	
Manganese . .	45·16 to 56·10	50·45	Dried at 212° F.
Iron . . .	4·46 to 14·24	8·22	
Silica . . .	1·23 to 9·56	6·88	
Phosphorus . .	0·053 to 0·088	0·068	
Moisture . . .	0·26 to 0·78	0·50	

The manganese-ore being extracted from the new excavations mentioned on page 929 was the hard grey finely crystalline variety with bands of softer ore. Sample 30 was taken here, and many of the pieces of ore included in it had slight ferruginous and clayey coatings. The analysis by the Imperial Institute gave the following result :—

Sample No. 30.

Manganese peroxide	48·66
Manganese protoxide	25·73
Ferric oxide	9·88
Silica (combined)	5·16
Silica (free)	0·80
Phosphoric oxide	0·16
Moisture (at 100°C.)	0·65

This corresponds to :—

Manganese	50·73
Iron	6·92
Silica	5·96
Phosphorus	0·070
Moisture	0·65

which is sufficiently close to the mean of the 8 analyses of ores from the main pit to show that the ore from these new pits is of the same quality as that from the old quarry. The above analysis indicates a composition for the ores of about equal parts of braunite and psilomelane.

For an analysis of Waregáon and Kácharwáhi ore stacked at Thársa station, Bengal-Nágpur Railway, previous to despatch, see page 927.

The analysis of the ore sorted from the waste heaps during 1906 is given by Mr. Coggan as :—

Manganese	52·14
Silica	8·34
Phosphorus	0·081

At my second visit in December, 1906, the quarry was filled with water to within a few feet of the top. This water is said to be mainly due to springs and only partly to the rains, and in consequence the water remains at a high level right through the hot weather, since the quarry has been abandoned. It is by no means certain, however, that all the merchantable ore has been extracted, and indeed it seems probable that, if the waste-heaps at the east end of the quarry were removed and the excavation extended in that direction, an extension of the ore-body would be found. At the time of this second visit the waste heaps were in part being worked over for the recovery of ore previously thrown away, as the prices then permitted of the export of a lower grade ore than previously. The excavations to the west of the main quarry were again being worked and a certain quantity of ore being won.

Output. The output from this deposit from 1904 to 1907 is as follows :—

Year.	Long tons.
1904	2,973
1905	..
1906	2,538
1907	528¼

Previous to 1904 some 30,000 tons are said to have been extracted ; but till 1904 the output figures of the different deposits were not kept separately.

21. Khandála.

(D. LAXMINARAYAN.)

This deposit is situated a mile east by north from Wáregáon. The outcrop starts from the right bank of the Súr River and is traceable for 218 paces in a W. 25° S. direction and may be as much as 24 yards wide. The outcrop consists of spessartite, quartz, and rhodonite, some of the garnets being up to ¼ inch in diameter. The spessartite-rock is often partly converted to manganese-ore and is usually blackened. But there is nowhere sufficient ore to be worth working, and as far as can be judged from the outcrop, this occurrence is of no economic value. One sample taken from here by Messrs. Ogilvy, Gillanders & Co., of Calcutta, and analysed by E. Riley of London, showed :—

Manganese	37·54
Iron	5·48
Silica	24·66
Phosphorus	0·14
Moisture	0·36

The immediate country of the deposit was not seen ; but a little to the north and south of the band were outcrops of a white quartz-rock (vein-quartz) containing muscovite.

Manganese-laterite.

Immediately to the south of the point where the manganese-silicate-rock reaches the river, there is seen in the bank, for 62 paces going down stream, a layer 5 to 6 feet thick of vesicular manganese-laterite, mottled brick-red, orange, and black, and containing pebbles of the muscovite-quartz-rock, suggesting that the laterite has been formed by the breaking down of this rock with introduction of iron and manganese from without.

'Country.'

It will be interesting to record the rocks to the south of the ore-band, exposed along the river-bank, because this is the only place along the whole length of the Dunri Kalán—Khandála band of deposits where the rocks accompanying the ore-deposits are at all well seen.

In order going down stream they are as follows :—

1. White vein-quartz containing muscovite. Perhaps a very coarse quartzite.
2. Muscovite-schist.
3. Rocks obscured by the manganese-laterite.
4. Felspathic quartzite.
5. Muscovite-quartz-schist.
6. Tourmaline-bearing quartzite.
7. Muscovite-schists intruded by coarse pegmatite, composed of pale pink felspar, quartz, and muscovite, with a little tourmaline.
8. Fine-grained white gneiss containing a little muscovite.
9. Medium-grained tourmaline-granite, probably intrusive.
10. Very coarse pegmatite with felspar individuals up to 1 foot long.

The dip seen is 45° to 50° in a direction varying from S. 5° W to S. 5° E.

The following output has been reported from this deposit :—

Year.	Long tons.
1907	$220\frac{1}{2}$

GROUP V.

22. Mándri.
22A. Panchála.
23. Mánegáon.
24. Guguldoho.
25. Bhandárbori.

This group of deposits lies in hilly country about 7 miles to the east-north-east of Rámtek and about 7 miles due north of the Waregáon deposit. The Mánegáon and Guguldoho deposits, although apparently not continuous with one another, probably represent one band of original manganiferous sediments. Together they form a band over 3 miles in length. The Guguldoho deposit continues into the Bhandára district to a distance that has not been ascertained, and may correspond in horizon to the ore-band seen at Asalpáni, some 13 miles to the east-north-east in the Bhandára district. Similarly the Mándri and Panehála deposits are probably continuous, the total length of these two deposits being over 2 miles. It is not known what is the connection between the Mánegáon-Guguldoho, and the Mándri-Panehála ore-bands. They are roughly parallel to one another. The Borda deposit lying over 9 miles to the west-north-west of the west end of the Mándri deposit is possibly a continuation of the Mándri-Panehála band in that direction. This group of deposits is served by a branch of the light 2-foot gauge railway constructed by the Central India Mining Company. It is 8 miles from Mánegáon to Waregáon and a further 5½ miles from Waregáon to Thársa station, Bengal-Nágpur Railway. The railway passes through the Mándri deposit. The ores of Panehála and Guguldoho are first carted as far as the railway.

22. Mándri.

(CENTRAL INDIA MINING COMPANY.)

(*See Plate 40.*)

The Mándri manganese-ore deposit is situated some 6 miles north of Waregáon. It lies on the north side of the Rámtek range of quartzite hills, and is on the same line of strike as the Borda deposit situated about 9½ miles to the west-north-west. The accompanying rough

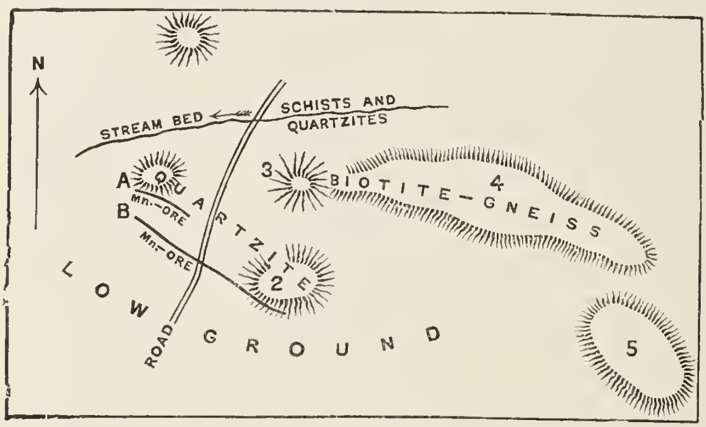


Fig. 69.—Sketch-plan of ore-bands and hills at Mándri.

sketch-plan (Fig. 69) shows the relation of the ore-bands, which are two in number, to the neighbouring low hills. The schists indicated are hornblende and mica-schists, and the quartzites accompanying these schists often contain hornblende or pale green mica. The biotite-gneisses are often well banded and slickensided. The quartzites forming the two small hills on the north-east side of the ore-bands are viterous, greyish, whitish, and brownish, in colour, of medium to coarse grain, and often contain muscovite scales. They also are often slickensided; the accom-

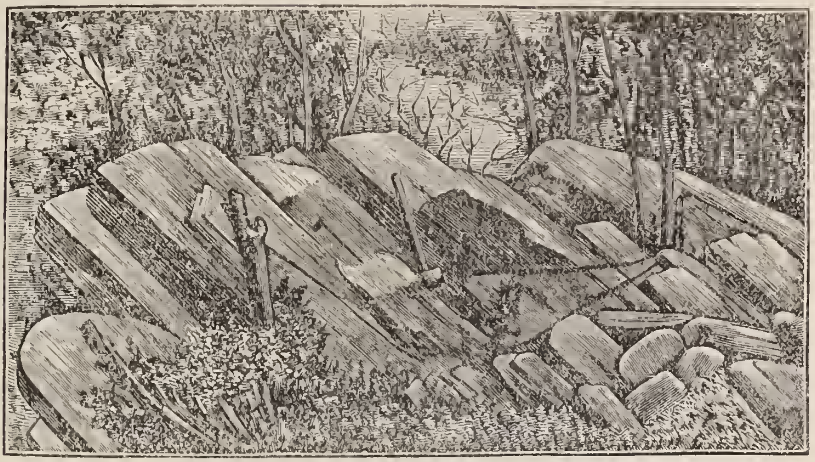


Fig. 70.—Slickensides-grooving in quartzites at Mándri. From a photo.

panying figure, which is from a photograph of an outcrop of these quartzites on top of hill No. 1, does not show the grooves as well as it might. The direction of these slickensides-groovings is S. 28° W. at 41°, but in most other places, as in the ore-band, it varies from S.15° to 45° E. at 25° to 40°, and hence is, on the average, directed along the strike of the ore-bands.

The ore-bands, which are two in number, may be designated as the north band (A) and the south band (B), respectively. They are roughly parallel and about 100 yards distant from each other, the character of the intervening rock being hidden by surface débris. The ore-bands are bent and contorted in a most unusual manner, as indicated in figure 2 of Plate 40; but they have a general strike of E. 34° S. for band A and E. 25° S. for band B. Both bands had been, at the time of my visit, exposed along their strike by workings of any depth up to 10 to 15 feet, following all the curves and bends of the ore-bands. These workings, besides the variable strike, also showed that in both bands the dip, which is almost always fairly steep, is constantly changing, being sometimes towards the north-east and sometimes towards the south-west side of the band, indicating frequent overturns of the ore-bands. The 'country' consists of the above-mentioned quartzite on the north side and of mica-schists on the south side of each band; and, throughout, both ore and 'country' are much slickensided, as noted above.

The northern band (A).

The northern band (A) is 285 paces long as measured in a straight line and 323 as measured along all the bends. It varies in width from 6 to 14 feet and lies on the south side of the top of the small quartzite hill, No. 1. At its western end the ore-band, as far as can be judged from surface indications, terminates abruptly against quartzite, from which it is possibly separated by a fault indicated by the presence of some vein-quartz. At the east end the ore-band descends to low ground and possibly dies out in lenticular fashion, for there is no trace of it on the quartzite hill, No. 2, lying immediately to the north of ore-band B. In one place the ore-band is divided into two parts by a 1-foot-parting of soft fine-grained mica-schist. The rock composing the ore-band is softish black manganese-ore, usually showing remains of yellow spessartite. In one place was found a horny-looking spessartite rock with veins and layers of pinkish rhodonite.

By December 1906, these excavations had been much deepened; in one place a depth of 50 feet down to the surface of the water was measured, and the water was said to be 10 feet deep, giving a total depth of 60 feet from the surface. The ore is said to be just as good at this level as at the surface. At this spot, *i.e.*, near its western end, the band had been faulted, so that steeply dipping ore-layers, with an underlying layer, 2 feet thick, of a friction-breccia of quartzite fragments and pulverized mica-schist, etc., rested against the edges of ore-layers having only a shallow dip (nearly horizontal).

The southern band (B).

The southern band (B) is 650 paces long as measured in a straight line and 707 as measured along all the bends. It varies in width from 24 to 40 feet. There is no reason why this band should not continue for some distance to the east; it is simply a question of removing the over-burden of pebble-ore and soil in order to find out. It may also continue to the west, except that if band A be terminated by a fault, then this same fault may also cut off band B. The western portions of this band lie on low ground, but the eastern end runs across the southern slopes of the quartzite hill, No. 2, nearly reaching the top of it at C (Fig. 2. Plate 40). At this point a pit shows that the ore has been overturned in exactly the same manner as is shown in fig. 59 for Mansar. At H (Fig. 2, Plate 40) a thickness of 4 feet of mica-schist divides the ore-band into two parts, 6 feet lying to the north and 18 feet to the south, of the mica-schist parting. The ore-band is composed mostly of dirty ores, very frequently spoilt by bands of spessartite, rhodonite, dark grey quartzite, white quartz and micaceous films.

Nature and quality of the ores.

The ores consist of the usual mixtures of braunite and psilomelane. The former tends to predominate, and occurs as minute grains, set sometimes in hard psilomelane and sometimes in a soft black matrix. It is this latter constituent that imparts to such a large proportion of these ores their sooty character, so that, unlike the majority of the ores of this district, the Mándri ores almost invariably soil the fingers. There is also a certain proportion of good hard grey ore. A sample was taken of some 1,680 tons of ore stacked at this deposit in February 1904.

An experiment in cleaning.

Such a large proportion of the pieces, however, contained yellow spessartite that I thought it would be interesting to make an experiment on the cleaning of the ores. The sample was consequently coned and quartered twice, and one quarter, weighing 58 lbs., of the original sample was set aside as sample No. 31. I then cleaned one half of the original sample, forming sample No. 32, weighing 57 lbs., of the cleaned ore; and sample No. 33, weighing 38 lbs., composed of the portions of ore rejected, these being mostly very garnetiferous pieces. Complete analyses of these three samples were made at the Imperial Institute with the following results:[1]—

	Sample 31.	Sample 32.	Sample 33.
Manganese peroxide	54·60	56·64	48·65
Manganese protoxide	21·55	19·70	21·95
Ferric oxide	10·79	9·73	9·58
Alumina	1·81	2·17	3·80
Baryta	0·55	0·71	0·62
Lime	0·83	0·95	1·70
Magnesia	0·45	0·38	0·40
Silica (combined)	5·09	4·25	5·48
Silica (free)	0·67	1·35	3·35
Phosphoric oxide	0·18	0·20	0·26
Arsenic oxide	0·004	0·005	0·022
Water (combined)	2·55	3·01	2·71
Moisture at 100° C.	0·69	0·49	1·10
Carbon dioxide	0·11	0·15	0·12
TOTAL	99·874	99·735	99·742
Manganese	51·26	51·11	47·80
Iron	7·55	6·81	6·71
Silica	5·78	5·60	8·83
Phosphorus	0·078	0·087	0·113
Moisture	0·69	0·49	1·10

On studying these figures it is seen that there is a decided difference between the original sample 31 and the rejected material 33, the latter showing an increase in the amounts of silica and phosphorus and a decrease

[1] The following additional constituents were subsequently determined:—

	31	32	33
NiO, Co_3O_4, CuO	Trace	0·005	Trace
K_2O	0·34	0·26	0·21
Na_2O	0·25	0·19	0·25

in the amount of manganese. This is of course what one would have expected, except that it is not so great as the character of the rejected material suggested. Sample 32 should however have shown a decided improvement in analysis over that of sample 31. But the figures show very little difference between the two. In preparing the sample for analysis duplicate lots of the final powder were bottled. Thinking that a mistake had been made in labelling, and that the two samples sent for analysis as 31 and 32 were either both 31 or both 32, I sent one of the remaining samples to Messrs. J. and H. S. Pattinson of Newcastle for analysis. The result is shown below :—

Sample No. 32.

Manganese peroxide	57·27
Manganese protoxide	19·66
Ferric oxide	9·86
Alumina	1·58
Baryta	0·53
Lime	1·15
Magnesia	0·43
Potash	0·73
Soda	0·17
Combined silica	4·20
Free silica	0·25
Sulphur	0·025
Phosphoric oxide	0·179
Arsenic oxide	0·066
Cobaltous oxide	*Nil.*
Nickelous oxide	*Nil*
Cupric oxide	Trace.
Lead oxide	*Nil.*
Zinc oxide	*Nil.*
Titanic oxide	0·08
Chlorine	Trace.
Fluorine	*Nil.*
Combined water	3·00
Moisture at 100° C.	0·70
Carbon dioxide	*Nil.*
	99·880
Manganese	51·44
Iron	6·90
Silica (total)	4·45
Phosphorus	0·078

This analysis is remarkably close to that of sample 32 carried out at the Imperial Institute, and shows that no mistake was made in the bottling of the samples.

Taking the analyses of samples 32 and 33, it is evident that if they were mixed in the proportions of the weights of ore to which they correspond, namely 3 to 2, the analysis of the original sample would not be as good as that shown for sample 31. Taking only the four constituents

Mn, Fe, SiO_2, and P, the calculated analysis of the sample before cleaning works out as follows :—

Manganese	49·78
Iron	6·77
Silica	6·89
Phosphorus	0·097

Comparison of this with the analysis of sample 31 indicates that the two portions into which the original sample was divided were not exactly alike, and that either (1) for the amount of ore taken the pieces of ore should have been broken to a somewhat smaller size than they were to ensure the final sample obtained on reduction being truly representative of the whole, or (2) the weight of the original sample should have been considerably larger, if the size of the pieces of ore was to be kept the same, namely 1 to 2 inches in diameter, for the first halving. Considering then only the portion of the sample which was subjected to the cleaning operation, that is considering only analyses 32 and 33, it is evident that the result of cleaning is to raise the analysis of the sample from 49·78 per cent. of manganese to 51·11 per cent. This improvement is, however, much less than I should have expected and shows that a relatively large amount of visible spessartite can be present in the ores without the quality of the sample being very seriously lowered, although, when prices rule low, a difference of 1½ per cent. in the percentage of manganese present may make all the difference between whether the ore can be exported at a profit or not. The conclusion to be drawn from this experiment is that when the prices are high a fair amount of spessartite-bearing material may be allowed to remain in the ore, but that when the prices are low it may be advisable to clean out this foreign material and raise the quality even at the cost of a considerable rejection of ore (in this case 40 per cent). The result of this experiment should not, however, be taken as generally applicable as regards the amount of improvement to be effected by cleaning. It merely indicates the method to be adopted in determining the advisability of subjecting the ores of a particular mine to rigid cleaning. Each case should be decided on its merits by means of an experiment similar to that described here. For convenient cleaning the pieces of ore should be not smaller than one inch in diameter. That is to say the pieces in the sample before the initial division of it into two portions, one to be reduced without cleaning, and the other to be cleaned, should not be smaller than the size mentioned above. As the size of the pieces of ore must not be too large in proportion to the size of the sample to be halved, it would be as well to take about 1,000 lbs. of ore for the initial halving, and so avoid the difference obtained in my experiment between the analyses of the two halves of the sample, the one given by sample 31 and the other calculated from samples 32 and 33.

Five analyses of specimens and samples of ore from Mándri, by Messrs. J. and H. S. Pattinson of Newcastle, kindly supplied to me by Messieurs Jambon and Cie., showed the following limits and mean :—

———	Limits of 5 analyses.	Mean of 5 analyses.
Manganese	51·83 to 55·04	53·23
Iron	3·83 to 5·82	5·27
Silica	5·05 to 7·06	6·04
Phosphorus	0·062 to 0·156	0·106
Moisture	0·49 to 1·15	0·73

while another specimen, described as 'yellow stuff, bad looking,' and doubtless spessartite-rock only partly altered, gave the following result :—

Manganese	25·22
Iron	16·61
Silica	16·00
Phosphorus	1·05

Mr. Coggan has also supplied me with the following figures showing the average analysis of the ores raised at this deposit during the years 1905 and 1906 :—

———	1905	1906
Manganese	51·87	48·21
Silica	6·30	7·38
Phosphorus	0·097	0·120

It will be noticed that the 1905 ore, when prices were comparatively low, corresponds roughly with that of my cleaned sample 32, whilst that of 1906, when prices ruled high, corresponds roughly with that of the material rejected in the cleaning of sample 32. This suggests that the poorer quality of the ore despatched during 1906 may not be the result of the deposit deteriorating in quality with increasing depth, but may be due to the fact that poorer ore could be exported at a profit in 1906 than in 1905, in consequence of which the ore was perhaps not so carefully cleaned.

The working of the deposit.

Owing to the tortuosity of the ore-bands and their consequent very variable strike and dip, the working of the Mándri deposits is perhaps a somewhat more difficult problem than usual. They had up to December 1906 been worked by means of narrow cleft-like openings following down the ore, whilst very little, and in some places none, of the 'country' had been touched.

The consequence is that now that a depth of 30 to 60 feet has been reached in several parts, it is becoming increasingly difficult to win the ores. The waste has often been dumped on the very edge of the working. To ensure the life of this deposit it will now be necessary to carry out large amount of dead-work, consisting both of the removal of the old waste to a respectable distance and the quarrying of the 'country'. As the ground slopes away in many places towards the south side, it would pay to carry several cross-cuts in from the south-south-west right up to the ore-band. With rails along these cross-cuts, both the ore and the waste could be readily removed to a safe distance to the south of the deposit.

A centrifugal pump is to be put in to remove the water which now accumulates in some quantity in the deeper parts of the workings, and rails have already been run out to various parts of the deposit to bring the ore to the tramway from Mánegáon to Thársa, which crosses the Mándri ore-bands near their western end.

During 1907 a beginning has been made in removing the 'country' of a portion of the deposit in a series of steps, to enable the lower portions of the ore-body to be worked. It becomes a question as to how deep it will pay to follow the two comparatively narrow ore-bands by open-cast methods before working them by underground mining methods.

Output.

The output from this deposit from 1904 to 1907 is shown below :—

Year.	Long tons.
1904	11,745
1905	12,769
1906	4,471
1907	7,055¾

The effect of the previous methods of working this deposit is reflected in the output figures. For these have decreased considerably during 1906 and 1907, in spite of the high price of manganese during these two years.

22A. Panchála.

(CENTRAL INDIA MINING COMPANY.)

During 1906, manganese-ore has been discovered by the Central India Mining Company within the limits of the village of Panchála, and the deposit secured on prospecting license. This ore is found over a length of perhaps ½ a mile. The western end of this deposit is situated some 600 yards to the east-south-east of the east end of the Mándri workings, *i.e.*, almost exactly on the continuation of the line of strike of the Mándri ore-band, B. As the strike of the Panchála deposit is about E.20°S. on the average, there can be little doubt that it is really a continuation of the Mándri band. In all probability, when the intervening ground is opened up, the Mándri and Panchála deposits will be found to be continuous. At the time of my visit, December 1906, very little work had been done on the Panchála ores. It showed, however, that instead of dipping steeply to the deep as at Mándri, the ore-band is probably rolling gently about axes running east-south-east, and is therefore probably kept at the surface over a considerable width. Thus, at the eastern end there were two openings situated about 150 yards apart measured across the strike. In each of these openings the rock was evidently rolling, gentle anticlines and synclines being visible. It is therefore possible that the intervening ground is occupied by these rolling ore-beds. It is also possible that these excavations are on separate ore-bands.

There seems little doubt that there is a large quantity of manganiferous rock in the Panchála area. A considerable portion of this consists of very hard rhodonite and spessartite-bearing rocks, massively bedded, and often partly altered to manganese-ore, the rocks being very similar to those of Mánegáon. There is also a large quantity of ore, partly hard and crystalline (braunite-psilomelane mixture), and partly sooty and speckled in appearance like that of Mándri.

In the workings at the western end the ore-beds were seen to rest on felspathic mica-schist, whilst in one place two lenticular masses of mica schist, each a few yards long and up to 3 feet thick, were seen to be included between the layers of ore. The maximum thickness of the ore-layers seen was perhaps some 15 feet, but this is not necessarily the full thickness. Mr. Coggan informs me that the analysis of the ore extracted during 1906 is as follows:—

Manganese	47·58
Silica	8·57
Phosphorus	0·109

The ore has to be carted ½ to 1 mile to the steam-tramway at Mándri.

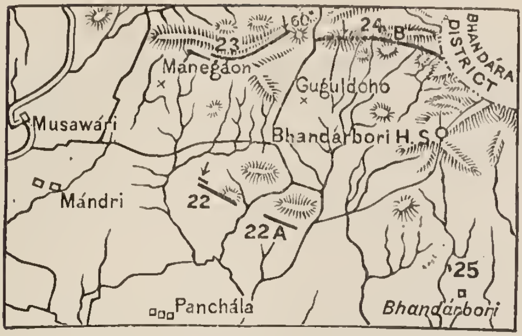
Output. The output for 1906 and 1907, the two years during which this deposit has been worked, is as follows:—

Year.	Long tons.
1906	1,791
1907	535¾

23. Mánegáon.

(CENTRAL INDIA MINING COMPANY.)

The principal ore-band is about 1½ miles long and is considerably bent along its strike, as shown in the accompanying



Scale 1″ = 2 miles.

Fig. 71.—Map showing the position of the Mándri (22), Pancháia (22A), Mánegáon (23), Guguldoho (24), and Bhandárb ri (25), deposits.

figure (71). It lies mostly on the southern slopes of a wooded ridge of micaceous quartzites running approximately east and west. At the eastern end a ravine divides this ridge from its continuation to the east, which is an isolated hill rising to about 200 feet above the ravine and composed of vitreous quartzites sometimes containing mica-scales and tourmaline needles, with an intercalated thin band of muscovite-schist. This isolated hill separates the Mánegáon ore-band from what is probably its eastward continuation, the Guguldoho deposit. The ore-band apparently dies out between these two deposits or else dives below the above-mentioned isolated quartzite hill. In the ravine is seen purplish gondite with mica-schists immediately to the south and probably quartzites to the north. The ore-band then rises straight up the ridge to the top, reaching an elevation of about 180 feet above the outcrop in the ravine. Going westward, the ore-band is found to leave the crest of the ridge and gradually descend the southern slope of the quartzite ridge nearly to the base, after which the western part of the band gradually climbs again to about half-way up the slope, and then disappears.

The main ore-band.

The dip of the main ore-band varies of coarse with the strike, being almost invariably to the south side at angles which are nearly always high—50° to 75°—, but sometimes approaching the vertical. The strike itself, although conforming on the average to the direction shown on the map, is locally very variable. Figure 72 shows a good example of local twisting of the strike seen towards the middle of the length of the ore-band, where it rises to form a small hillock on the flank of the quartzite ridge, the ordinary strike about here being E. 15°N. The rocks of the ore-band, on the hill at the east end of the deposit, often show slickensides striations. The direction varies from E.15°S. to S.35°E. at angles of 25° to 30°.

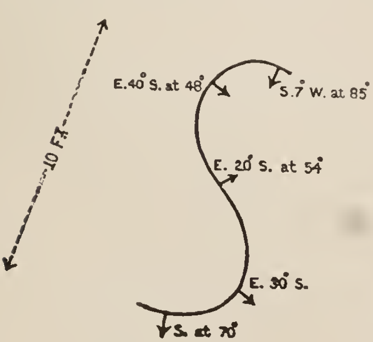


Fig. 72.—Plan showing local twisting of strike of ore-band at Mánegáon.

The thickness of the main-band was, in February 1904, nowhere fully exposed; but, on the hill at the east end of the deposit, a clearing down the south slope showed a thickness of 92 feet, measured horizontally, with a dip of about 60°. This corresponds to a true thickness of 80 feet. This gives the thickness only of the band exposed on top and down the south slope of the hill. The ore-band certainly also crops out for a little way down the north slope; but how far could not be ascertained on account of débris. But the total thickness of the ore-band may be as much as 100 feet at this point. There are indications of almost as great a thickness in other parts of the band; but in between the points of great thickness the ore-band probably contracts considerably in width, for in places it practically disappears at the outcrop. Even by the time of my second visit in December 1906, a complete section of the ore-body had nowhere been rendered visible by cross-cutting the ore-band. The extreme eastern end of the ridge was however being opened up. This opening showed a thickness of 51 feet, the dip being vertical. The north wall of the deposit was not, however, exposed, so that the full width of the deposit must be greater than 51 feet; but it hardly seemed likely that it could be as much as 100 feet. The thickness of 51 feet included a layer, 6 feet thick, of mica-schists, with some sandy white quartzite, situated near the southern wall of the ore-band, whilst there were also some thin layers of mica- and quartz-schists acting as partings between the ore-layers.

The subsidiary ore-band.

At the western end there is a parallel band, the eastern end of which lies some 50 yards to the south of the main-band, and extends for some 600 yards in a west-north-west direction, its western extremity lying further to the west than that of the main ore-band. This subsidiary ore-band is represented by two parallel outcrops, probably due to a synclinal fold. They crop out 25 to 40 yards apart, except at the western end, where the outcrops run together at the surface. This band, also, was not properly exposed; but in one place where the dip was 50°, it was at least 30 feet wide measured horizontally, corresponding to a true thickness of 23 feet.

The 'country'.

The main mass of the hills on which these ore-bands occur consists as already mentioned, of vitreous quartzites, usually micaceous. There is also a certain amount of felspathic quartzite, and of a very acid pyroxenic gneiss. The actual 'country' of the ore-bands is but poorly exposed. But in two places the main ore-band is seen to rest on mica-schists, which in one place form the overlying rock also; whilst in another place the south wall-rock is 1½ feet of fine-grained quartzite overlain by coarsely crumpled mica-schists. The 'country' of the subsidiary band was nowhere exposed, but will perhaps also be found to be mica-schist.

Hence we may regard the ore-bands as being immediately enclosed in mica-schists and these, in their turn, in quartzites.

Character of the ore-bands.

Although the main ore-band is so thick, yet at many points only a comparatively small proportion of it consists of merchantable manganese-ore. Apart from the bands of quartzite and soft micaceous sandstone-like quartzite that are found interbanded with the manganiferous rocks, a very considerable proportion of the latter is either quite fresh or only partly altered to manganese-ore. Among these manganiferous rocks there is a very large quantity of rhodonite-bearing rocks. In places the rock is entirely composed of this mineral, then being of a beautiful rose-pink, often veined and mottled with black, owing to partial alteration. Sometimes the rock contains scattered orange spessartite, and at others forms a very tough massive, rhodonite-spessartite-rock, often partly altered to manganese-ore. There are also many varieties of spessartite-rock and spessartite-quartz-rock (gondite). Many of the varieties of rhodonite-rock, if they could be obtained in sufficiently large pieces, would make a handsome ornamental stone. Similar rhodonite- and spessartite-bearing rocks are also found in the subsidiary ore-band.

Nature and quality of the ores.

There are several varieties of manganese-ore found in this deposit. One is a finely crystalline ore of magnetic braunite, varying from friable to hard, according as the cement is soft black oxide, or hard grey psilomelane. Another variety is hard psilomelane, with only a small percentage of scattered braunite grains. A third is very dirty and shows rather large braunite grains, partly in a sooty matrix and partly in a psilomelane matrix. The ore often contains remains of orange garnet or blackened rhodonite. Sample No. 34, representing some 1,900 tons of ore, was taken from the ore-stacks and consisted of all the above varieties, several pieces showing remains of garnet and some of quartz, and it looked as if the quality of the ore stacked could easily be raised by more careful cleaning of the ore. The analysis carried out at the Imperial Institute shows :—

*Sample No. **34**.*

Manganese peroxide	49·45
Manganese protoxide	23·04
Ferric oxide	14·66
Silica (combined)	2·61
Silica (free)	2·70
Phosphoric oxide	0·21
Moisture at 100°C.	0·35

This is equivalent to :—

Manganese	49·15
Iron	10·26
Silica	5·31
Phosphorus	0·09
Moisture	0·35

and indicates an abnormally low percentage of braunite—about 25 per cent.

The following figures supplied by Mr. H. D. Coggan show the average analysis of the ores raised at this deposit during the years 1904 to 1906 :—

	1904.	1905.	1906.
Manganese	49·87	50·26	49·67
Silica	6·10	8·36	6·85
Phosphorus	0·128	0·095	0·106

They agree very closely with that of my sample.

Four other analyses of Mánegáon ores, supplied by Messieurs Jambon & Cie., two made by Messrs. J. and H. S. Pattinson & Co. of Newcastle, and two by Messrs. W. H. Pearson of London, show the limits and mean values given below. Two of the analyses were made on hand-specimens and two on samples of a considerable amount of ore. These analyses, whilst showing that higher grade ore than that usually exported can be obtained at this deposit, are not to be regarded as typical.

	Limits of 4 analyses.	Mean of 4 analyses.	
Manganese	53·31 to 56·31	55·00	Dried at 212°F.
Iron	3·46 to 4·63	4·20	
Silica	6·95 to 8·66	7·83	
Phosphorus	0·063 to 0·112	0·085	
Moisture	0·17 to 0·19	0·18	

The working of the deposit.

At the time of my first visit in February 1904 the ore-bands had been opened up for a considerable portion of their length by means of irregular excavations, the usual carelessness being shown in the disposal of the waste. On a subsequent visit in December 1906 it was found that this mistake had been rectified and the handling of the ore greatly facilitated by means of a system of tramlines and ore-shoots, although the ore-shoots were no longer in use. These lines connect up with the line running to Thársa *viâ* Mándri and Waregáon, the total distance being 13½ miles. All the talus-ore deposits on the south side of the ore-band were being carefully worked over. As will be judged from the figures given above for the length and width of the deposit a very considerable quantity of manganese-ore (averaging 50 per cent. manganese and upwards) should be obtained from Mánegáon before it is worked out. The situation of the ore outcrop on the slope of a ridge will possibly make it a little more difficult than usual to work by open-cast methods. Thus, in many places it will not be possible to make deep trenches across the deposit in order to show its true width and character, owing to the fact that the north end of the trench would have to be cut out of solid quartzites. Still the slope of the hill is usually not too steep for the necessary dead-work to be done to allow the deposit to be scientifically worked, for it must not be overlooked that being on a hill side it will be possible to work it to a much greater depth, as far as drainage troubles are concerned, than a deposit situated in alluvial fields.

Output. The figures of output from this deposit from 1904 to 1907 are shown below:—

Year.	Long tons.
1904	5,576
1905	8,227
1906	15,525
1907	11,270

24. Guguldoho.

(JESSOP & CO.)

The situation of this deposit is shown in figure 71 on page 943, from which it will be seen that this is probably only a continuation of the Mánegáon ore-band, which, as explained on page 943, either dies out temporarily or dives below the quartzite hill separating these two deposits. The Guguldoho portion of the band was traced for another mile and a half to the east to the boundary between the Nágpur and Bhandára districts and then on the other side of the boundary for some 300 to 400 yards.

The total length of the portion of the Mánegáon-Guguldoho band lying in the Nágpur district is thus about 3 miles. The Asalpáni deposit, lying some 13 miles east by north from this point on the Nágpur-Bhandára boundary, may possibly be a continuation of this band, especially as ore is reported as having been found recently in the interevning ground.

The strike of the ore-band averages east to west at the west end and curls round to east by south at the east end. The dip is usually very steep, often vertical, and invariably, as far as seen, to the south side of the strike.

The most western exposure of the Guguldoho part of the band is where it reappears, in the ravine marking the boundary between Mánegáon and Guguldoho, from beneath the quartzite hill dividing the two deposits. But it is not well seen until the high ridge, which can be called Guguldoho Hill (hill to west of '24' in fig. 71), is ascended. Spessartite-bearing rocks run along the top of this ridge for about $\frac{1}{4}$ mile to the east, and then reach the workable part of the ore-deposit, which extends for some 350 yards along the crest of the ridge practically to its east end, where the descent begins. The band then runs down the east end of the ridge, forming a very well-marked outcrop at least 20 feet wide and mostly composed of spessartite, rhodonite, and quartz. After crossing the stream-bed at the base, where there is a little hard crystalline manganese-ore, it rises again up the west end of another ridge, the outcrop here consisting of externally blackened rhodonite-quartz-rock, in places altered to hard crystalline ore or to the softer sooty variety. This outcrop often stands up like a vertical ruined wall—in one place 20 feet wide—almost buried in trees, bamboos, and long grass. The outcrop then continues across several low spurs on the south slopes of a second long east to west ridge (B in fig. 71). The outcrop has now changed from rhodonite-quartz-rock to spessartite-rock partly altered to ore. An interesting rock found here is sage-green spessartite-rock with a band of pale amethystine quartz. Under the microscope there is seen to be in places in the spessartite-rock a very large quantity of apatite.

Description of the ore-band.

The outcrop then gradually slopes down to the valley, crosses the road shown, and enters the Bhandára district at a point 75 paces south of where this road crosses the forest lane dividing the two districts; from here it was traced 300 to 400 yards further into the Bhandára district.

At this point the ore-band was exposed as an outcrop of pinkish buff spessartite-quartz-rock striking E.25°S.; it evidently continued past where I abandoned it. It might be worth the while of some mineral prospector to track it through the Government Forests of the west end of the Bhandára district; for it might again change in character to another deposit of merchantable ore.

The small hillocks and hills occurring to the south of the ore-band are composed of muscovite-gneisses, usually having a fairly steep dip in a southerly direction. The ridges on which the ore-band is found consist of quartzites, often micaceous, with bands of mica-schists; and, as at Mánegáon, it is the latter with which the ore-band is more particularly associated. The excavations made in the ore-body on top of Guguldoho hill show that the north wall

'Country'.

of the deposit consists of ordinary mica-schists, while the south wall in one place is of mica-schist and in another of interlaminated mica-schist and quartzite. In the absence of cross-cuts it is not possible to say what is the thickness of the mica-schists in which the ore-body is apparently immediately enclosed. But it cannot be very thick, because outcrops of quartzites are seen quite close in on both sides.

The workable part of the ore-band.

This, as noted on page 948, is situated on the very top of Guguldoho Hill, the summit of which is some 350 to 400 feet above the level of Sonegáon village. Messrs. Jessop and Company had made a large number of irregular, shallow excavations along this part of the ore-body at the time of my visit in February 1904.

They showed that here also a considerable part of the ore-body consists of unaltered or only partially altered rhodonite-spessartite-quartz-rock or rhodonite-rock (often pale greenish in colour). The thickness of the ore-body varies from 15 to 40 feet measured horizontally, the solid manganese-ore being in one place as much as 16 feet wide. The dip is very steep, 50° to vertical to the south side, and the strike somewhat variable — between W. 22° N. and W. 30° S., and averaging about east and west. Towards the west end of this portion of the deposit (350 yards long) the back of the ore-band dives below the surface for about 100 yards, then reappearing from beneath the schists.

Nature and quality of the ore.

The manganese-ores consist largely of sooty varieties, especially common being an ore composed of fairly large granules of a bright very magnetic mineral set in a sooty matrix containing a certain proportion of psilomelane. This is the ore to which I have often referred as ‘ speckled ore ’. There is also a certain amount of the hard grey ore composed of tiny braunite grains set in a fairly hard matrix of psilomelane. This ore shows fairly numerous cavities containing ochreous matter. The speciality of this deposit is, however, the large amount of concretionary ore showing every variety of stalactitic, botryoidal, mammillated, and concentric, structure. Plate 6, fig. 2, shows specimen of a botryoidal variety. This ore occurs especially near the surface, and also in geodic cavities in the varieties of ore first mentioned, at intervals right to the bottom of even the deepest excavation (21 feet). It is probable that it was formed by the secondary solution and re-deposition at the surface of the ordinary braunite-psilomelane ores. If such be the case then this concretionary psilomelane will probably become much scarcer deeper down, where the manganese-ore, if it still persist, may be expected to consist of the various varieties of the braunite-psilomelane mixtures.

As the speckled variety of ore is found at several deposits, a piece of it was sent to Messrs. J. and H. S. Pattinson and Co. of Newcastle for analysis. The result is shown below :—

Specimen No. 1155.

Manganese peroxide	46·23
Manganese protoxide	16·83
Ferric oxide	31·64
Alumina	2·35
Baryta	0·13
Lime	0·25
Magnesia	0·24
Potash	0·05
Soda	0·06
Combined silica	0·30
Free silica	0·05
Sulphur	0·025
Phosphoric oxide	0·076
Arsenic oxide	0·001
Cobaltous oxide	0·05
Nickelous oxide	*Nil*
Cupric oxide	Trace
Lead oxide	*Nil.*
Zinc oxide	0·05
Titanic oxide	0·13
Chlorine and fluorine	*Nil.*
Combined water	1·00
Moisture at 100°C.	0·55
Carbonic oxide	*Nil.*
	100·012
Manganese	42·27
Iron	22·15
Silica (total)	0·35
Phosphorus	00·33

It is evident, both from the fact that the ore contains only 0·30 per cent. of combined silica, and from the strongly magnetic character of the granules of hard bright mineral, that the latter cannot be braunite. They must be either mangan-magnetite or vredenburgite.

From a comparison of this analysis with that of vredenburgite given on page 909, it will be seen that there is a striking resemblance between the two analyses, especially in the amounts of manganese and iron. As, however, the amount of the granular mineral in the ore cannot be more than about 50 to 60 per cent., it is evident that if it is to contain all the iron it cannot be vredenburgite, because it would also need all the manganese in the analysis. But a portion of the manganese must be in the matrix in the psilomelane and the sooty oxides. The latter may of course also contain a portion of the iron. For the present, until some of this mineral can be isolated and separately analysed, it will be better to regard this mineral as mangan-magnetite. Owing to the presence of such a large amount of soft oxides that do not correspond to any definite mineral, and the composition of which is not known, it will not be possible to rearrange this analysis in terms of the mineral composition of the ore. The striking points about this sort of ore, from the commercial point of view, are its freedom from silica and its low percentage of phosphorus. In spite of this, however, the manganese amounts to only 42 per cent., being to a considerable extent replaced by iron. If such ore could be stacked separately in considerable quantity it would form a valuable ferruginous manganese-ore, although under present circumstances it could not be exported at a profit. It is very exceptional for the sum of the percentages of manganese and iron in a manganese-ore to be as high as 64 per cent.

A specimen was also selected for analysis of a piece of very homogeneous psilomelane, forming a large hepatiform mass of concentric structure. The analysis of this is given on pages 100 to 106, where the composition of the mineral is also discussed. It is found to be a potash-psilomelane. I will reproduce here only the constituents of commercial importance :—

Manganese	57·78
Iron	1·05
Silica (total)	0·25
Phosphorus	0·366

It will be seen that except for the high phosphorus this is an ore of exceedingly good quality.

About 900 tons of ore had been stacked and from this I took sample No. 36, which was composed of about equal parts of concretionary psilomelane and the sooty psilomelane-braunite ore. The analysis, by the Imperial Institute, shows :—

	Sample No. 36.
Manganese peroxide	62·63
Manganese protoxide	8·75
Ferric oxide	23·34
Silica (combined)	1·58
Silica (free)	1·32
Phosphoric oxide	0·42
Moisture at 100°C.	0·54

This is equivalent to :—

Manganese	46·24
Iron	16·34
Silica	2·90
Phosphorus	0·183
Moisture	0·54

and indicates that the ore contains only about 16 per cent. braunite on the average. It is evident from this analysis that the ores being high in both iron and phosphorus, with a corresponding reduction in the percentage of manganese, are akin in chemical composition, as in physical aspect, to those of the Vizagapatam district, rather than to those of this area.

To work this deposit economically it would probably be necessary to put in an aërial ropeway, or a gravity incline if the slope be not too steep, to bring the ore from the top of Guguldoho hill to its base, so as to save the coolie labour that would otherwise be necessary to carry the ore down in baskets. Further, to get the ore to Thársa station, Bengal-Nágpur Railway, some 15 miles distant, it would probably be advantageous to connect this deposit by tramlines to the Mánegáon-Waregáon system, belonging to the Central India Mining Company. Otherwise bullock-cart transport would be required. Owing, however, to the character of the ore, this deposit could probably be worked at a profit only when prices were very favourable. At the time of my visit, when the price of manganese was 8½ to 9 pence per unit for 50 per cent. ore, the place was deserted, and none of the ore that had been extracted had ever been removed. During 1906, however, a considerable amount of ore has been exported from this deposit. It is carted to a point on the tramway system of the Central India Mining Company about a mile south of Mándri and then railed to Thársa station.

The working of the deposit.

Towards the east end of this band, at the foot of the spurs on which spessartite-quartz-rock was found cropping out, a little quarrying had been done on the talus deposits. One quarry showed, on its north side, a vertical depth of 10 feet of débris consisting of manganese-ore—some of good quality, but often spoilt by spessartite, quartz, etc.— and quartzite. This talus thinned rapidly, so that on the south side of the excavation it was only 2 feet thick. Some 95 tons of ore had been extracted from this and another similar excavation some 130 yards further west. Sample No. 35 was taken from this ore, which consisted of the hard grey psilomelane-braunite mixture, one or two pieces containing a little rhodonite or quartz. The analysis made at the Imperial Institute is as follows :—

The talus-ore deposits.

Sample No. 35.

Manganese peroxide	48·75
Manganese protoxide	26·55
Ferric oxide	12·24
Silica (combined)	5·61
Silica (free)	1·38
Phosphoric oxide	0·34
Moisture at 100°C.	0·28

This is equivalent to :—

Manganese	51·43
Iron	8·57
Silica	6·99
Phosphorus	0·15
Moisture	0·28

and indicates that the ore contains about 56 per cent. braunite, most of the remainder being psilomelane.

It is interesting that the talus should contain marketable manganese-ore, while the outcrop on the spurs above is fairly fresh manganese-silicate-rock. It means, of course, that the part of the band denuded away at this point was composed largely of manganese-ore, the underlying partly altered or quite fresh rock being now left.

Output. The output from this deposit during 1906 and 1907 is given as follows :—

Year.	Long tons.
1906	1,121
1907	2,269[1]

The 1906 output must include the 900 tons I found extracted in 1904.

25. Bhandárbori.

(JESSOP & CO.)

About half a mile north-north-west of the village I was shown three or four shallow holes (about 2 feet deep), from which some dark purplish boulders and pebbles of rather soft gondite, partly altered to manganese-ore, had been dug, while I had also seen some loose blocks of similar rock to the north-west of this place. It is quite possible that there is a band of such rock, somewhere in the neighbourhood, but I had not time to search for it. It is noticeable, moreover, that these pits are almost directly on the line of strike of the Mándri and Panchála deposits, which lie about 2½ miles to the west-north-west.

Messrs. Jessop and Company return the following figures of output for 1906 and 1907 :—

Year.	Long tons.
1906	3,600
1907	890

I do not know whether by Bhandárbori they mean a part of what I call Guguldoho, or whether they have found a deposit of considerable size in Bhandárbori limits.

[1] Including 596 tons from Bhandachur-Guguldoho Hill.

CLASS II.

Deposits characterized by the association of Piedmontite with the Ore, which occurs in Crystalline Limestone.

GROUP VI.

26. Mohugáon.
27. Páli
28. Ghogara (Pench River).
29. Mándvi Bir.
30 Junawáni.
31. Junapáni.
32. Rájkota.

These seven occurrences are not grouped together as being geographically close to one another; but because of their dissimilarity from all the other deposits in the Nágpur district, and similarity to one another as regards both mode of occurrence and mineralogy. Since the associated rocks are identical in each case, it seems possible that they all represent one horizon in the metamorphic series, this horizon having been broken up into widely separated outcrops by the system of faulting that almost certainly exists transverse to the general strike of the rocks of this district. It also seems possible, however, that the Pench River exposure represents one band, and the other six occurrences a separate band of the same rocks.

The manganese-ore usually occurs as nodules of varying size, often elongated and twisted, and located in bands, in a piedmontite-bearing crystal-line limestone. Occasionally the ore is in the form of lenticular masses or even of small beds. In one case—the Pench River exposure—there are nodules of piedmontite associated with the ore. It hence seems possible that some of the ore may have been formed by the alteration of the piedmontite; but I think the main bulk of the ores is original and has been formed by the compression of original manganese oxides, deposited at the same time as the sediments from which the limestones have since been formed by metamorphism—sometimes direct, and sometimes with passage through a gneissic stage with subsequent chemical alteration. See pages 300 to 303.

The ores themselves are usually mixtures of braunite with one of the manganates, usually the crystalline form hollandite, but sometimes the amorphous form psilomelane.

Associated with the piedmontite-bearing limestones there is often a black or dark brown limestone, seen under the microscope to owe its colour to the deposition of oxides of manganese along the cleavage and twinning planes of the calcite, in the same way as I have described for the Chhindwára district.[1]

As shown by the analysis of the specimen given on page 956 the amount of manganese in these black limestones may rise to nearly 18 per cent. This same rock often contains spessartite also. The limestone sometimes contains bright shining specks of manganese-ore, probably representing original rhodonite. These are of considerable interest; for when this rock undergoes silicification, *i. e.*, is partly or almost entirely replaced by silica with the formation of chert, as so often happens amongst the limestones of this region, the manganese-ore is left as bright shining specks in the resulting chert, to the history of which it affords a ready clue.

At Páli, in addition to the ores mentioned above, there is also found some very beautiful pyrolusite of secondary origin, noticed in detail on page 959.

Considering the mode of occurrence of the manganese-ore, it can seldom be profitably worked, involving as it does the quarrying of a large amount of limestone to obtain a relatively small amount of manganese-ore. When, however, the manganese-ore occurs in lenticular masses or small beds then it may pay to work it; moreover, by the weathering away of the limestones at the surface residual accumulations of nodules of ore of considerable size may be formed. These too would often pay to work.

26. Mohugáon.

The outcrop of manganiferous limestone is about 1 mile east-south-east of Mohugáon village and occurs in some low ridges of crystalline limestones striking E. 10° N. The actual ridge in which the manganese occurs is about one furlong in length and is composed of parallel bands of rock of varying composition dipping at about 40° to S. 10° E.

These bands, reckoning from north to south have outcrop widths as follows :—

(1):—12 feet pink limestone with green accessories;
(2):—30 feet grey limestone with manganese-ore nodules and piedmontite;
(3):—9 feet brownish black limestone with spessartite-bearing patches;
(4):—36 feet same as (1);
(5):—24 feet same as (3).

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[1] *Rec. G. S. I.*, XXXIII, p. 201, (1906).

Separated from the crystalline limestones by a shallow depression,

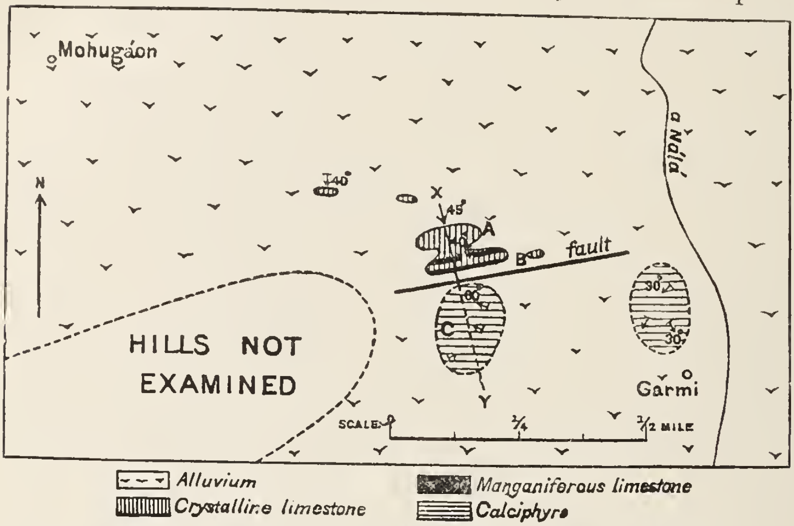

Fig. 73.—Sketch-plan of the Mohugáon manganese-ore deposit.

there occurs to the south an outcrop of what may be described as calciphyre with very little calcite; and as these calciphyres strike so as to run into the limestones, the two rocks must be separated by a fault, as shown in the section (fig. 73).

The late Mr. Gow Smith made a few shallow pits on and to the south of the above outcrop of crystalline limestones, and these showed a foot or two of manganese nodules and limestones débris mixed, resting on the fresh rock; therefore there is little hope of any marketable ore being obtained here.

The ore itself is dark grey, crystalline, and is probably a mixture of braunite and hollandite. The specific gravity varies from 4·00 to 4·80.

That the black crystalline limestone is of no commercial value is shown by the following analysis by myself:[1]—

MnO_2	20·99
MnO	5·83
Fe_2O_3	1·99
BaO	0·04
CaO	35·89
Insoluble siliceous residue	3·47
P_2O_5	0·12
Water (combined)	2·86
Moisture at 100°C.	1·27
CO_2	27·46
	99·92

[1] In the form in which this analysis was first reported [*Rec. G. S. I.* XXXI, p. 47, (1903)] the presence of 17·27 per cent. SrO was shown; owing to the lack of requisite chemicals in the Geological Survey laboratory I had to divide the alkaline earths into CaO and SrO (which was supposed from qualitative tests to be present) by weighing first as carbonates and then, after calcination, as oxides. This method is of course unsatisfactory, and later, feeling doubtful of the presence of so much strontium, I examined the rock spectroscopically and could not detect the presence of this constituent.

Manganese	17·79
Iron	1·39
Phosphorus	0·05
Specific gravity	2·97

27. Páli.

(CENTRAL INDIA MINING COMPANY.)

(See Plate 42.)

The crystalline limestones in which the manganese-ores are contained are situated on the east side of the Pench River, to the north and north-east of Páli village. They have a dip that varies in amount from 15° to nearly 90°, averaging about 45°, and which varies in direction from east-south-east, in the southern part of the band, to south-south-east or even south, where the band of limestones has curled round so as to strike east-north-east to east. These limestones rest on a great thickness of quartz-pyroxene-gneisses, which lie on the north-west side of the crystalline limestones and rise to form several small hills. Intrusions of tourmaline-pegmatite and tourmaline-granite are seen in many places in both the quartz-pyroxene-gneisses and the crystalline limestones. The limestones are usually medium-to coarse-grained and vary in colour from white, grey, pink, and yellowish, to brown and black. They are sometimes free from accessory minerals, but often contain some or all of the following minerals :—quartz, diopside, amphibole, garnet (yellow), epidote, and piedmontite. In many places the rock is black due to the deposition of a dust of manganese-oxide along the cleavage and twinning planes of the calcite. This black limestone often contains, besides spessartite and apatite, abundant shining black grains of a manganese-ore (braunite). In many places the limestone has been silicified so as to be converted into a black chalcedonic chert. The spessartite often remains unchanged, and in cases where black manganese-ore grains were present in the original black limestone, these have persisted as shining black specks in the resulting black chert. In many places the limestones, especially those with piedmontite, contain nodules and small lenticles of crystalline manganese-ore. As at Mohugáon these could not be profitably extracted from the solid limestone. At one place, however, at the east end of the manganiferous limestone, two pits exposed an accumulation of nodules, formed no doubt by the removal in solution of the containing limestone. The quantity was, however, not large; a sample taken here was analysed at the Imperial Institute with the following result: —

Sample 15.

Manganese peroxide	50·76
Manganese protoxide	24·05
Ferric oxide	7·75
Combined silica	3·21
Free silica	2·24
Phosphoric oxide	0·21
Moisture at 100°C.	1·32
Carbon dioxide	1·14

This indicates the ore to be composed of a mixture of braunite and psilomelane (or hollandite). Stated in the usual way the analysis is as follows :—

Manganese	50·78
Iron	5·42
Silica	5·45
Phosphorus	0·09
Moisture	1·32

Piedmontite and piedmontite-gneiss.

Piedmontite is very abundant in many of these limestones and in some places occurs in nodules up to 1 inch in length. Sometimes it is uniformly distributed through both pale-coloured limestones and gneisses in such abundance that the rock appears pink. In some specimens collected, piedmontite is found in a fine-grained rock composed of plagioclase, orthoclase, and quartz, with a little mica, some spessartite, and abundance of apatite and sphene. Secondary calcite is being formed at the expense of the felspars, and this rock is taken as evidence that the piedmontite-bearing and other manganiferous limestones have been derived from original piedmontite-and spessartite-bearing gneisses, in the same way as the crystalline limestones of Class I of the Chhindwára district (the pale-coloured crystalline limestones of the Nágpur district) are regarded as having been derived from original quartz-pyroxene-gneiss[1]. See also Part II, pages 300—303.

Both ends of the outcrop of these limestones are obscured by alluvium. The total length is about 1,400 yards and the breadth varies from 60 to perhaps 100 yards. The mineralization is irregular, but generally speaking, the black limestone, its silicified form the black chert, and the limestone containing lenticles of manganese-ore, occur about the middle of the thickness of limestones.

The workings.

Several small pits had been dug by Messieurs Jambon & Cie., at various points along the outcrop. They revealed either the black limestone, the black chert, or the manganese nodules. At about where the strike of the limestones changes from north-north-east to east-north-east, a large pit (shown in Plate 42) had been excavated. It was of irregular shape, some 45 paces long by 10 broad, and showed an unevenly weathered surface of crystalline limestones, of which portions had been dissolved away leaving upstanding pillars and masses of limestone between. The banding of these limestones had also been brought out by the differential weathering, the bands containing accessory minerals, such as pyroxene and epidote, standing out as ridges, while the bands composed mostly of calcite were represented by furrows or grooves between these ridges. This is well shown

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[1] Fermor, *Rec. G. S. I.* XXXIII, pp. 168—170.

by Plate 42. A considerable part of the limestone was once black and has since been largely converted into black chert, but some of the black limestone still remains. The most interesting feature of this quarry is, however, the occurrence in the limestone of pockety masses of most beautiful pyrolusite (Plate 3). These masses have apparently been formed by the solution of the non-manganiferous and consequently light-coloured limestones with formation of cavities in which manganese dioxide was deposited by waters carrying manganese-salts derived from the neighbouring manganiferous limestones. But whether the cavities were first formed and then the pyrolusite subsequently deposited in them, or whether it was a case of simultaneous solution of the limestone and deposition of manganese oxide, cannot of course be definitely determined. In the former case, however, we might have expected some of the cavities to be filled only partly with pyrolusite. I was unable to find any such cavities and am inclined to think that the second theory is the true one and that the action was similar to the reaction by which manganese dioxide is precipitated in the Pattinson process for estimating manganese. The equation would then be somewhat as follows :—

Pyrolusite.

$$Mn\,H_2(CO_3)_2 + CaCO_3 + O_2 = MnO_2 + CaH_2(CO_3)_2 + CO_2$$

The masses of pyrolusite seem never to be very large and are probably nearly all connected to each other by thin veins and bands. When a mass of pyrolusite is broad, it is apparently never more than 1 to 3 feet deep and when it fills a cleft in the limestone it is never more than 2 feet wide. A large proportion of the pyrolusite is found in beautiful radiate masses with concentric, more or less spherical, surfaces of parting, which are roughly at right angles to the radiations. These spherical surfaces are 1 to 2 inches in diameter. They have a beautiful dark steel-grey colour something like that of a black-leaded stove, and the effect is improved by the fact that the spherical surfaces are not quite smooth, but are made up of little circular scales of ore. These masses are often of great purity. As pure a piece as could be picked out was analysed at the Imperial Institute with the following result :—

Specimen No. 932.

	Per cent.
Manganese peroxide (MnO_2)	95·57
Manganese protoxide (MnO)	0·41
Ferric oxide (Fe_2O_3)	0·06
Alumina (Al_2O_3)	0·43
Baryta (BaO)	1·34
Lime (CaO)	0·00
Magnesia (MgO)	0·09
Combined silica (SiO_2)	0·33
Free silica (SiO_2)	0·00

Specimen No. 932.—contd.	Per cent.
Phosphoric oxide (P_2O_5)	0·01
Arsenic oxide (As_2O_5)	0·012
Combined water (H_2O)	1·46
Moisture at 100°C.	0·12
Carbon dioxide (CO_2)	0·09
	99·922

This is equivalent to :—

Manganese	60·79
Iron	0·04
Silica	0·33
Phosphorus	0·004
Moisture	0·12
Specific gravity	4·88

The ore is, however, not always pure, but is often mixed with crystallized quartz; and sometimes the rock takes the form of quartz containing spherical aggregations of pyrolusite. The pyrolusite is also often extremely fine-grained, so as to be almost amorphous. A sample of pyrolusite weighing 28℔ was broken from *in situ*. It consisted mostly of the botryoidal-radiate ore with compact pyrolusite between. Some pieces contained a little chalcedony. An analysis made at the Imperial Institute showed the following :—

Sample No. 16.	Per cent.
Manganese peroxide	72·71
Manganese protoxide	2·98
Ferric oxide	2·98
Combined silica	5·31
Free silica	13·17
Phosphoric oxide	0·13
Moisture at 100°C.	0·43
Carbon dioxide	0·15

This is equivalent to :—

Manganese	48·33
Iron	2·09
Silica	18·48
Phosphorus	0·06
Moisture	0·43

Owing to the mode of occurrence of the ore it will be seen that it could not, even if the average manganese contents were very high, pay to extract it for use as a source of manganese in the manufacture of ferro-manganese, owing to the great expense that would be incurred in blasting the limestone. Both physically and chemically, however, the average ore is not suited for this purpose; but owing to its high percentage of manganese peroxide (MnO_2), 72·7 per cent. in the above sample, it is well suited for the manufacture of chlorine. Picked pieces, similar to that of which the complete analysis is given above, would, on account of the remarkably low percentage of iron, be especially suited for use in the manufacture of glass. Just before the time of my visit, some 25 to 30

Photographed by L. L. Fermor. *Bemrose, Collo., Derby.*

EXCAVATION FOR PYROLUSITE IN CRYSTALLINE LIMESTONE AT PÁLI, NÁGPUR DISTRICT, C P

cart-loads of this ore are said to have been removed for sale for chemical purposes. It should be noticed that this pyrolusite was found quite by accident, the quarry having been started so as to investigate the nodule-ore, and it is quite possible that similar pyrolusite might be found at other places along this belt of rock if it were carefully prospected.

28. Ghogara (Pench River).

About 2 miles north-east of Pársioni there is a very fine exposure of crystalline limestones in the Pench River stretching for some quarter of a mile across the strike of the limestones, which is at right angles to the course of the river. The limestones, except in the rains, afford a means of crossing the river, which is forced at one point to flow through a narrow gorge. This natural ford is known to the natives as Ghogara and with their usual appreciation of the beauties of nature they have sanctified certain portions of it. Thus in the rains, only one small pinnacle is said to remain uncovered by water. This is known as *Máhádeo.* In another place the visitor is shown the wheel-marks of Mahadeo's *gári*, these being the parallel banding in the limestones; while the footprints of the bullocks are represented by nodules of manganese-ore in the crystalline limestone.

This must be the exposure referred to by Captain Jenkins under the name of Gokula.[1] He describes the scene in very picturesque language and says :—

> [1] 'The limestone . . . . passes into a quartz rock, coloured by manganese-ore; the dark stripes given by which are very variously contorted.'

This occurrence was also noticed by H. W. Voysey[2] who says :—

> 'At *Nayakúnd*, *Par úni*, and the bed of the *Pesh* river, granite and gneiss of various kinds, also quartz rock and sandstone; and foliated black manganese ore is in great quantity.'

These crystalline limestones form a barrier stretching from the west bank in an E.5°N. direction, the rocks themselves dipping to the N.15°W. at 50°. In the cold season the water, which occupies only a portion of the bed of the river, reaches this barrier near its western end, and then flows eastward along this steep dip-surface of rock until it reaches a gap through which it falls in several small waterfalls; it then continues its way southward in a deep narrow channel across the strike of the limestones, until it again reaches an entirely alluvial bed with some rock exposures in the banks. In this exposure the rocks have been most wonderfully carved out by the water into numerous upstanding masses separated by narrow channels. All the surfaces have been cut into intersecting concave depressions, most perfectly smooth, and where

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1 *As. Res.*, XVIII, p. 210, (1833); and *Glean. Sci.*, I, p. 227, (1829).

2 *As. Res.*, XVIII, p. 127, (1833); and *Glean. Sci.*, II, p. 28, (1830).

the water was flowing at the time of my visit (in the cold weather, when the water is low) it could be seen to follow all the scallopings of the rock. Huge potholes are abundant. In one of them was a central upstanding knob, and the stone that had carved out the circular hollow round it was still in its place. All these rocks are very beautifully banded, this being due in some places to the varied colours of the limestones—pink, white, yellowish, brown, and black—and in others to the accessory minerals arranged in lines, in one place crimson piedmontite, in another yellow-green epidote, in a third orange spessartite, and in a fourth black manganese-ore. In some places there are, intercalated in the limestones, bands of calciphyre and quartz-pyroxene-gneiss. These rocks are often much banded, and the layers that contain much calcite are weathered into grooves some 3 inches deep with upstanding ribs of rock consisting largely of quartz, felspar, pyroxene, and epidote. As these rocks are often much waved along the strike, these water-corroded outcrops simulate nothing so much as gigantic clam-shells.

The dip of the rocks is almost constantly steep (vertical in places) to about N. 10°—20° W. Although the economic value of this locality as a source of manganese-ore is practically *nil*, it will be necessary to devote a considerable amount of space to its consideration, for such a beautifully clear exposure is not often found in this part of India.

The following section was measured roughly by pacing southwards across the strike from the barrier. It includes all the bands of manganiferous limestone :—

16 yards.	Pink limestone within thin bands of green accessory minerals, such as epidote and diopside.
17 yards.	Grey limestone containing abundant nodules and irregular masses of manganese-ore and abundant tiny grains of piedmontite, often arranged in lines. Also small nodules of piedmontite.
8 yards.	Similar to proceeding, but the limestone white in colour. Contains a band very rich in piedmontite.
7 yards.	Black limestone, with numerous streaks of quartz striking across the limestone, mostly to the S.35°E.
8 yards.	Black limestone interbanded with white, with lenticles and streaks of manganese-ore and piedmontite bands.
8 yards.	Pink limestone.
18 yards.	White limestone.

The remainder of the section (some 350 yards) consists of various non-manganiferous limestones with intercalations of quartz-pyroxene-gneisses. It will be seen from the above that the manganiferous limestones measure some 40 yards horizontally across the strike. Assuming an average dip of 60°, this corresponds to an actual thickness of about 35 yards or about 100 feet.

As at Páli and Mohugáon, one finds here the black crystalline limestone, the piedmontite-bearing limestones, and lines of manganese-ore nodules, occurring both in the piedmontite-bearing and the piedmontite free limestone. Besides spessartite in the black limestones, there are also white limestones containing abundance of spessartite in small yellow and orange grains, and at one place there is an indication that the black limestones have been formed from the greyish white ones by impregnation with manganese oxide. Figure 74 is a rough sketch of an actual example. It was seen on the upper surface of the rocks and is practically equivalent to a section at right angles to the dip. AB is the direction of bedding of the rocks, and it seems as if waters containing manganese salts in solutions must have percolated along the cracks CD and EF (they were not as straight as shown in the figure) and taken advantage of the bedding planes, such as AB, by creeping along them, and impregnating the limestones by the deposition of oxides of manganese along the cleavage and twinning planes of the calcite, with consequent blackening of the rock. Where the white and black limestones are interbanded, the latter sometimes occur as bands swelling out—in one case from 9 to 18 inches. It only needs an extension of the process to account for the formation of masses of such rock 10 to 20 feet thick. As these black limestones nearly always contain spessartite, it seems probable that this action is purely local and that the manganese oxide is derived from the decomposition of spessartite in one part of a bed of limestone, with the re-deposition in another part of the manganese thus taken into solution.

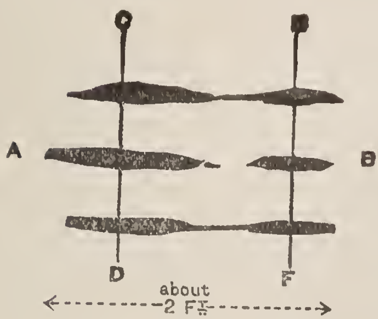

Fig 74.—Section showing manganese impregnations in limestone.

The manganese-ore nodules usually occur arranged in lines. and may be of any size up to 6 inches long, but are sometimes in thin bands up to 2 or 3 feet long. They weather out with a smooth surface. The usual shape is that of a lenticle or flattened lenticular band with the ore arranged in layers parallel to the outside of the nodule. But they are often strangely contorted into S-shaped forms, and occasionally into curves of several turns. In some places they are even faulted, as shown in the accompanying sketch, the different parts of the nodules being separated by limestone. This, of course, indicates that the limestones have been folded since the formation of these manganese-ores.

Fig. 75.—Diagrammatic sketches of some manganese-ore nodules.

One nodule was separated into several pieces by parallel cracks $\frac{1}{64}$ to $\frac{1}{32}$ inch wide, filled with a light crimson mica, which showed the following pleochroism under the microscope:—

𝔞 = lilac;
𝔟 = yellowish pink;
𝔠 = light rose to lilac-rose.

Nature and quality of the ores.

It is a fortunate thing, considering the unique interest and beauty of this exposure, that these manganese-ore nodules can never be economically extracted. A sample was, however, taken by chipping from the outcrop of the nodules. The ore thus obtained was all extremely fine-grained, dark steel-grey, and usually showed concentric banding due to the structure of the nodules. Some of it could be scratched with little difficulty and some could not be scratched at all with a knife. Some looked quite pure and some contained little streaks of calcite, while a little limestone and piedmontite was attached to some pieces. Some pieces, rejected from the sample, consisted of alternate layers of ore and limestone. The result of a partial analysis at the Imperial Institute is as follows:—

Sample No. 18.

Manganese peroxide	50·06
Manganese protoxide	13·67
Ferric oxide	6·89
Silica (combined)	6·78
Silica (free)	3·24
Phosphoric oxide	0·09
Moisture at 100°C.	0·21
Carbon dioxide	3·49

This is equivalent to:—

Manganese	42·28
Iron	4·82
Silica	10·02
Phosphorus	0·04
Moisture	0·21

The analysis and physical characters of the ore indicate a mixture of braunite and a manganate, in some cases psilomelane and in others hollandite.

Piedmontite.

The limestone in which the nodules occur is usually the variety containing piedmontite. The latter, besides being abundantly disseminated through the limestone in minute grains, is also often found as deep crimson-coloured nodules up to 3 and 4 inches long arranged in bands in the limestone. These nodules are sometimes coarsely crystalline, but are more usually either finely crystalline or else fibrous in structure, the water-smoothed surfaces of the nodules then resembling crimson silk. In many cases the nodules consist of piedmontite on the periphery and manganese-ore internally (see Plate 14), and as micro-sections of this manganese-ore often show what is apparently residual piedmontite, it seems as if this manganese-ore, and by inference many of the other manganese-ore nodules, may have arisen from the alteration of original piedmontite, the change beginning in the middle of the nodules and extending outwards. [Some of the ores have, I expect, been formed by the direct consolidation of original concretions of manganese oxide (see page 302). These piedmontite nodules are usually associated with a white felspar (albite-oligoclase) and quartz, and are often abruptly terminated at one end, or broken into two parts separated by calcite, so that it seems as if they must have been fractured during the last set of earth-movements to which these rocks were subjected.

See page 396 for psilomelane deposited at the waterfall.

The Mándvi Bir-Junapáni Band.

The manganese-ore deposits of Mándvi Bir, Junawáni, and Junapáni, consist of a series of lenticular masses and nodules of manganese-ore enclosed in a band of crystalline limestones, together with the overlying residual accumulations of loose nodules of ore in clay, formed by the removal of the limestone in solution by meteoric waters and the consequent concentration of the once sparsely distributed ore-nodules. At the eastern end, however, according to both Mr. Goodchild and Mr. Vredenburg, the manganese-ore forms a definite bed. The whole of the band lies within the Junawáni Forest Block, but has been divided into three portions named after the deserted villages of Mándvi Bir (the western portion), Junawáni (the middle portion), and Junapáni (the eastern portion). At the time of my visit in February 1904 I was able to examine only Mándvi Bir and the western portion of Junawáni. By the courtesy of Messrs. Shaw, Wallace and Company and Cooverjee Bhoja, however, I am able to make use of a report on all three of these properties made by Mr. J. H. Goodchild towards the end of 1905. My colleague, Mr. Vredenburg, has also visited these deposits—in September 1906—and has kindly put his notes and specimens at my disposal.

These deposits, as already mentioned, lie within Government Reserved Forest, in a hilly tract of country covered with jungle, which in places is quite thick, but usually takes the form of thin tree jungle with long grass. The area is, of course, included in the $\frac{1}{2}$-inch Revenue Survey map of the Nágpur district; but this scale is too small for detailed geological work, and fortunately there are some beautiful contoured Forest Survey maps of these jungles on the scale of 4 inches = 1 mile. The whole length of these deposits lies on sheet 73 $\frac{N.E.}{1}$.

It must have been these deposits to which Captain F. Jenkins referred as early as 1829.[1] He speaks of the village of Kumárí as being

'the last to be met in approaching the jungle, which here is very high and thick. 'On entering the jungle, the surface rock appears to be white mica schist, entirely disintegrated; and proceeding on three or four miles, the ridges of rocks, from which the specimens from *Kumárí* are taken, are met with.'

The specimens he collected included red limestone which

'constituted the principal mass of the rocks, which appeared to have an east and west direction, and to be vertically disposed; for, though there was no distinct appearance of stratification, the rocks were divided from each other and lay in sharp ridges...Towards the north of these the lime-stone passed (forming all gradations of colour, from a white grey to deep black) into a rock, composed almost entirely of manganese.'

K(h)umárí is situated a little over two miles nearer Nágpur than Chorbáoli, and is on the southern side of the Junawáni jungles. It is very curious that the first records of manganese-ore in the Indian Empire should be of the Pench River exposure at Ghogara and the comparatively inaccessible deposits in the Junawáni jungles; both being occurrences of nodules of manganese-ore in crystalline limestone.

The limestones are very impure and contain an abundance of accessory minerals. Quartz, mica, and apatite, are nearly always present; in addition to these the limestones often contain piedmontite, sometimes rhodonite, and spessartite, and in one case manganhedenbergite (page 971). They are sometimes white or grey with scattered accessories and at other times are blackened owing to impregnation with manganese oxides, in the same way as in the Chhindwára district,[2] and as at Páli and Ghogara; in still other cases they are chalcedonized to black chert. The non-manganiferous limestones associated with the manganiferous ones are often pink in colour, containing epidote, pyroxene, and sometimes hornblende, and then look exactly like the essonite-bearing limestone of Bichua in the Chhindwára district,[3] except that there is no essonite-garnet in the limestone of this area. The band of manganiferous limestone has been traced for 6 miles, the strike being east and west with a steep dip to the south side throughout the whole length of the band. At the western end Mr. Vredenburg traced the band for a mile further west than I had seen it and even then it had not disappeared. To the east the band goes as far as Junapáni hill (1,280 feet), which is about $\frac{1}{4}$ mile west of the main road from Nágpur to Jabalpur. Here, according to Mr. Vredenburg, the evidence seen in various pits points to the fact that the band doubles on itself and runs

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1 *Asiatic Researches*, XVIII, pp. 207, 208, (1833); abstract in *Gleanings in Science*, I, pp. 226, 227, (1829).

2 *Rec. G. S. I.*, XXXIII, pp. 200, 201, (1906).

3 *Ibid.*, p. 199.

west again as a parallel band situated about a furlong to the south of the main portion of the band. This southern band has been traced west as far as the Kund Nála, a distance of $1\frac{1}{4}$ miles; it probably corresponds to the limestone band that further west lies about $\frac{1}{2}$ mile to the south of the Mándvi Bir and Junawáni workings, but which was not noticed to be manganiferous where I crossed it. At the eastern end, where the band is apparently doubled at the surface, separate names have been given to the two portions. The northern is known as the *Kaskuri band* and the southern as the *Bhánádeo band*, the portions to which these names are given being both within Junapáni limits. Mr. Vredenburg's opinion with regard to this duplication of the bands at the surface is that the limestone is in the form of a definite bed, which has been folded into a syncline, so that the two bands are two outcrops of the same bed of rock. The termination of the manganiferous limestone at Junapáni is then explained on the hypothesis that the base of the syncline here comes to the surface. Everywhere the manganiferous portion of the limestone seems to be at or close to its base.

The limestone band is very easy to trace, because its position can be found from that of the underlying rock, which often gives rise to small ridges and hills. This underlying rock varies in composition from a rock composed almost entirely of epidote and quartz, when it can be called *epidosite*, to one in which there is a large amount of felspar present, usually microcline, when the rock can be called *epidote-gneiss*. Sometimes quartz is very scarce or practically absent, the rock being then composed almost entirely of epidote and microcline. The name of this rock would also be epidote-gneiss. The rock underlying the epidosites is probably quartz-pyroxene-gneiss.[1] The rock overlying the limestone band is also probably the quartz-pyroxene-gneiss. Other rocks occurring in this area, though less closely connected with the limestones, are fine-grained schistose biotite-gneisses, and mica-schists. There are also numerous intrusions of pegmatite and granite, often carrying tourmaline, in the limestones.

It will be seen from the descriptions given below that there exist at several places, especially in the Junapáni portion, considerable masses of ore, which seem, in most places, to be of lenticular shape. To judge from Mr. Goodchild's account of the Junapáni deposit there must be at this place a lenticular band or bed at least 40 yards long and some 4 to 6 or more feet wide; whilst I myself saw several ore-bodies of considerable width (up to 12 feet) in Mándvi Bir and Junawáni. In addition to these there are abundant small nodules *in situ* in the limestone that could not be profitably worked

The working of these deposits.

[1] *Rec. G. S. I.*, XXXIII, p. 188, (1906).

on account of the blasting that would be required to extract them, and the difficulty of cleaning off them, when extracted, all the adherent matrix. The considerable residual accumulations derived from the dwindling of these nodule-bearing limestones could, however, be easily worked. In fact it can be estimated that by working the various patches of loose ore scattered at intervals along this band of limestone, together with the masses of ore *in situ*, not less than 10,000 to 50,000 tons of ore could be obtained, and possibly a considerably larger quantity. Very careful cleaning of the ore would be required and then a product should be obtained that showed an analysis of about :—

Manganese	50—52
Iron	2—4
Silica	5—9
Phosphorus	0·05—0·12

This is good-quality ore, though rather low in manganese ; and the question arose as to whether it would pay to cart ore of this grade all the way to Kámthi, the nearest station on the Bengal-Nágpur Railway. Chorbáoli is about 23 miles from Kámthi and the various parts of the Mándvi Bir-Junapáni band are 2 to 7 miles from Chorbáoli. A local contractor at the time of my visit was willing to cart at the rate of Rs. 4 per ton, but this was probably an underestimate and Rs. 6 is probably nearer the true cost. Now, however, that the Bengal-Nágpur Railway branch to Rámtek with a siding to Kándrí has been finished, freight charges will be much reduced, because it will now be necessary to cart to Kándrí only, which is only about 7 miles from Chorbáoli. On account of the comparatively small amount of ore to be obtained as a rule from any given point, it is not probable that these deposits will lend themselves to much capital expenditure for plant, except perhaps for a light tramway along their whole length.

Output.

During 1906 and 1907, owing to the high prices of manganese, these deposits have been opened up by the Madhu Lall Doogar Mining Syndicate and a considerable quantity of ore despatched to the rail-head, the Junapáni end of the band furnishing most of the ore. The output for these two years is as follows :—

Year.	Long tons.
1906	4,258
1907	16,200

The 1906 figure probably includes the ore extracted in previous years.

29. Mándvi Bir.

(MADHU LALL DOOGAR MINING SYNDICATE)

The Mándvi Bir excavations can be divided into three, A, B, and C, reckoning from west to east. The first is situated on a little spur about 200 yards east-south-east of hill 1,371, situated about 3 inches south-south-east of 'Malám Jhiri' on the map. Several pits on this spur showed 1 to 4½ feet of ore nodules resting on decomposed pegmatite, vein-quartz, and tourmaline-granite, doubtless intrusive in the crystalline limestone. This spur joins to the north the main range of hills composed of epidosite and epidote-gneiss dipping at 65° to S.10°E. Between here and Mándvi Bir B, which lies about ¼ mile to the east, is an outcrop of the black manganiferous limestone. At Mándvi Bir B three pits stretched over a length of some 70 yards all showed ore *in situ*. In one pit the very siliceous ore-band was 12 feet wide and near another pit the outcrop of ore-bearing rock was 17 yards wide. The rock to the north of the ore-band was epidosite and to the south was crystalline limestone dipping at 50° to S.10°E. A few yards east of here on the line of strike of the above-mentioned ore-band there is an outcrop of crystalline limestone containing piedmontite and other accessories, as well as much contorted nodules and thin bands of manganese-ore.

Some little way east of B, probably in the *nálá* just to north-east of △ 1331 on the map, there is a rock composed of nodules of manganese-ore joined together by decomposed limestone. This is doubtless an example of crystalline limestone in process of being dissolved away so as to leave a residual deposit of ore-nodules.

The Mándvi Bir C pits mostly show nodule accumulations. But an excavation at the head of a *nálá* at ·1250 showed an irregular mass, 5 feet wide, composed of a mixture of hard grey ore and black limestone.

The total length over which the Mándvi Bir ores occur is ¾ mile; but the manganiferous limestone has been traced for 1¼ miles further west than Mándvi Bir A by Mr. Vredenburg.

Nature and quality of the ores.

The ore is nearly always crystalline, usually hard, but sometimes soft. It is probably a mixture of braunite and hollandite or psilomelane, as is the case of the Junawáni ores (see page 972). The ores often contain bands of siliceous matter, calcite, etc., and would need a lot of cleaning if worked. It would, probably, not pay to work the lenticles and nodules of ore *in situ* in the limestone; but a few hundred, or a thousand or two, tons of the loose accumulations of nodules might possibly be collected at various points along the outcrop. A sample was taken from the ore *in situ* at Mándvi Bir B. It consisted of hard fine-grained crystalline ore containing a little quartz, and was analysed at the Imperial Institute with the following result :—

Sample No. 21.	Per cent.
Manganese peroxide	49·50
Manganese protoxide	30·16
Ferric oxide	4·71
Silica (combined)	5·86
Silica (free)	3·14
Phosphoric oxide	0·32
Moisture at 100°C.	0·34
Carbon dioxide	0·06

Judging from the combined silica this sample must have consisted of about 59 per cent. braunite with about 37 per cent. of hollandite and 4 per cent. of quartz, apatite, moisture, etc. The analysis is equivalent to :—

Manganese	54·71
Iron	3·30
Silica	9·00
Phosphorus	0·14
Moisture	0·34

Samples taken by Mr. Goodchild gave the following results on analysis :—

	A.	B.	C.	D.
Manganese	51·67	53·92	27·75	41·54
Iron	3·35	2·38	9·49	2·72
Silica	2·40	5·65	33·75	8·65
Phosphorus	0·06	0·10	0·04	0·10

A. Average selected ore.
B. Loose ore from west end of deposit.
C. Siliceous ore from *in situ* towards west end of deposit.
D. Ore from *in situ* about middle of deposit.

In September 1906, Mr. Vredenburg found that a pit in the ore at C had exposed some hematite intercalated in the manganese-ore. Some of the specimens collected are massive and finely crystalline, and some are more coarsely crystalline, so that they could almost be called specular hematite.

Hematite.

30. Junawáni.

(MADHU LALL DOOGAR MINING SYNDICATE.)

This continuation of the Mándvi Bir band can be divided into 3 parts A, B, and C, reckoning from west to east. Junawáni A stretches for about 250 yards on either side of △ 1357. The most western pit shows bands of hard-grey crystalline ore in grey crystalline limestone.

There is also some granular soft ore containing mica. From one part of this pit I collected a large piece of manganhedenbergite (page 131), which contained spessartite and manganese-mica ; while a band of quartzite contained both rhodonite and a rich brown pyroxene. The middle pit showed a large quantity of manganese-ore nodules and bands in crystalline limestone, while at the east end of Junawáni A were several pits all showing the residual nodule deposit. A large quantity, nearly 2,000 tons, of ore had been collected here, and sample 23, the analysis of which is given later (page 973), was taken from the ore-stacks.

Junawáni B is some 750 yards east from A, and a pit here showed siliceous ore *in situ* in the limestone. The grey limestone is composed of calcite, with quartz, piedmontite, and a bronze-coloured mica (? phlogopite), and is associated with a sericitic quartzite.

Junawáni C, situated some 1 to 1½ miles further to the east, I did not visit.

The Junawáni ores are hence spread over a length of 1½ to 2 miles.

Nature and quality of the ores.

The nodules and bands of ore that occur in the limestones are usually lenticular in shape and are often composed of layers concentrically arranged parallel to the exterior of the nodule. These bands and nodules are sometimes folded. The ore itself is bright-grey finely crystalline and can be scratched with moderate ease with a knife. A specimen from the middle pit of Junawáni A was analysed at the Imperial Institute with the following result : [1]—

Specimen No. 1062.	Per cent.
Manganese peroxide	58·58
Manganese protoxide	23·23
Ferric oxide	6·11
Alumina	0·72
Baryta	3·66
Lime	2·15
Magnesia	0·00
Silica (combined)	3·16
Silica (free)	1·42
Phosphoric oxide	0·38
Arsenic oxide	0·009
Combined water	0·04
Moisture at 100°C.	0·36
Carbon dioxide	0·00
	99·819
Specific gravity	4·53

[1] The following constituents were subsequently determined :—

NiO, Co_3O_4, CuO*	0·048
K_2O	0·33
Na_2O	0·32

* Mainly nickel.

This is equivalent to:—

Manganese	55·08
Iron	4·28
Silica	4·58
Phosphorus	0·17
Moisture	0·36

The analysis can be expressed in terms of its mineralogical composition as follows:—

Apatite		0·88
Braunite		31·68
Hollandite or Psilomelane:—		
$Fe_4(MnO_5)_3$	12·01	
$Al_4(MnO_5)_3$	1·81	
Ba_2MnO_5	4·89	
Ca_2MnO_5	3·17	
H_4MnO_5	0·15	
Mn_2MnO_5	43·96	
	65·99	65·99
Quartz		1·42
Moisture at 100°C.		0·36
As_2O_5		0·009
		100·339
Subtract oxygen assumed		0·52
		99·819

The manganate is probably present as the crystalline form, hollandite, and not as the amorphous form, psilomelane.

The above analysis of a single specimen can be compared with that of a mixture of 14 samples of manganese-ore taken by Mr. Goodchild all along this belt in Mándvi Bir, Junawáni, and Junapáni. The analysis was carried out by James E. Ferguson of London, and is as follows:—

Dried at 212° F.	Per cent.		
Manganese peroxide	63·25	Mn	= 49·59
Manganese protoxide	12·42		
Ferric oxide	4·28	Fe	= 2·99
Alumina	1·65		
Baryta	4·59		
Lime	0·31		
Magnesia	0·19		
Silica	6·25		
Phosphoric oxide	0·153	P	= 0·067
Arsenic oxide	0·009	As	= 0·006
Sulphur trioxide	0·085	S	= 0·034
Carbon dioxide	0·240		
Copper oxide	0·086	Cu	= 0·069
Lead oxide	0·013	Pb	= 0·012
Zinc oxide	0·070	Zn	= 0·056
Nickel and cobalt oxides	0·030	Ni and Co	= 0·023
Combined water	2·90		
Alkalies and undetermined, by difference	3·474		
	100·000		

The interesting features of this analysis are the high percentage of baryta and the demonstration of the presence of copper, lead, zinc, nickel, cobalt, and arsenic. As the silica has not been divided into 'combined' and 'free', it is not possible to calculate the mineral composition of the sample. But the high proportion of manganese dioxide and baryta indicate that this ore contains an even larger proportion of hollandite or psilomelane than the picked specimen (1062) of which the analysis is given above.

The sample (No. 23) taken by me from the loose-ore beds of Junawáni A (see page 971) was of the same fine-grained crystalline ore and was analysed at the Imperial Institute with the following result :—

Sample No. 23.	Per cent.
Manganese peroxide	51·85
Manganese protoxide	26·81
Ferric oxide	4·69
Silica (combined)	5·55
Silica (free)	1·00
Phosphoric oxide	0·12
Moisture at 100°C.	0·23
Carbon dioxide	0·10

This indicates that the ore is about half braunite and half psilomelane or hollandite. The above analysis is equivalent to :—

Manganese	53·59
Iron	3·28
Silica	6·55
Phosphorus	0·05
Moisture	0·23

Two samples were taken by Mr. Goodchild from the same rich patch of nodules and loose fragments. Sample E represents ore, mostly small, excavated and selected in Mr. Goodchild's presence, while sample F 'was taken from a pile of 50 tons of re-selected ore from which still further rejections of siliceous pieces would be made on loading into carts'.

	E.	F.
Manganese	51·12	52·01
Iron	3·13	3·61
Silica	10·30	7·20
Phosphorus	0·045	0·048

It will be seen from the analyses given above that the quality of the ores in these nodule deposits is moderately good, the phosphorus especially being very low. There is no doubt that from this particular part of the deposit a few thousand tons of merchantable ore could be extracted.

31. Junapáni.

(MADHU LALL DOOGAR MINING SYNDICATE[1].)

The following account of this part of the Mándvi Bir-Junapáni band of manganiferous limestones is taken mostly from Mr. Goodchild's report (see page 965), but partly from Mr. Vredenburg's notes. This is described by Mr. Goodchild as the Chorbáoli concession, but Chorbáoli is the name applied to a part of the Government reserved forest on the east side of the main Nágpur-Jabalpur road, which runs within a short distance of the east end of this concession. The eastern end of the band cannot be more than about ¼ mile west of a point on the road near the 33rd milestone from Nágpur, the Chorbáoli Rest House being at milestone 31. The eastern end lies in a small hill (1,280 feet) near Junapáni, which rises to some 60 feet above the stream at its base. Solid black ore had been uncovered for about 40 yards along the strike.

The Kaskuri band.

The thickness of this ore varied from 4 to 6 feet, rising in one place to 10 feet. From a pit at the south-west end of the outcrop, where the ore-body is 4 to 6 feet thick, Mr. Goodchild took samples G, H, and J below :—

	G.	H.	J.	K.
Manganese	47·82	53·78	46·17	48·86
Iron	2·98	2·23	3·06	2·81
Silica	10·90	4·55	11·75	7·40
Phosphorus	0·060	0·040	0·055	0·059

Sample G was taken right across the ore face.
Sample H consisted of selected pieces from this pit.
Sample J represented the smalls made by working the ore with a pick.

From the north-east end of this outcrop, where the thickness of the ore was 4 feet, Mr. Goodchild took sample K above. This ore could be improved by dressing. Just beyond this point towards the north-east the ore pinches out altogether.[2] 'The hill is capped by an irregular layer of loose nodules and clay often accompanied by bands of quartz pebbles'. Samples L and M below 'were taken here as the working of this layer by means of shallow excavations might be more profitable than working the black ore of the pockets, although the selected ore, after separating clay, etc., would not average more than 20% of the whole

[1] This syndicate has been actually working at Junawáni and Junapáni; but the Central India Mining Co. claims prior rights to a portion of the area.

[2] As explained on page 967, Mr. Vredenburg thinks this is the end of a synclinal.

material excavated. The greatest thickness visible of this layer was 10 feet.'

	L.	M.	N.
Manganese	50·93	48·94	52·87
Iron	2·89	3·56	2·59
Silica	4·80	6·80	4·65
Phosphorus	0·073	0·112	0·009

Sample L 'was taken at a point where the pieces were larger and better looking but not abundant'.

Sample M 'was mostly rubble lying pretty thickly'.

Mr. Goodchild expresses the opinion that by working the pocket of black ore and the cap of loose stuff a few thousand tons of 50% ore could be obtained. It is noticeable that the loose ore contains rather more phosphorus than that *in situ*.

A specimen of Junapáni ore obtained for me by Babu Nensi Ramji of Rámtek showed the same concentric layers and finely crystalline character as the ores of Mándvi Bir and Junawáni.

Further 'pockets' (*i.e.*, lenticular masses) of ore were seen 100 and 200 yards respectively towards the south-west from the above hill. From the second, where a pit shows the thickness of ore to be about 2 feet, Mr. Goodchild took sample N above.

About 300 yards further west from here begin the 'Kaskuri workings' which extend for nearly ½ mile westward. There is here a very marked outcrop and Mr. Goodchild thinks this is the most promising part of the whole Mándvi Bir-Junapáni band, and that a considerable quantity of ore might be obtained from the loose ore and the outcropping boulders. These boulders consist of 'nodules cemented together forming a hard conglomerate.' I suggest that the rock is probably decomposed limestone containing abundant nodules of manganese-ore and is similar to what I myself saw at Mándvi Bir. Mr. Goodchild took here sample O from the loose ore and sample P from the outcropping boulders. The analyses were as follows:—

	O.	P.
Manganese	50·61	49·12
Iron	3·11	2·92
Silica	6·85	5·00
Phosphorus	0·039	0·074

According to Mr. Goodchild, about half a mile south of the Kaskuri workings there is another patch of loose ore derived from what must be a second band of limestone parallel to the main band. It is near the place marked on the Forest Survey map as Teli Deo. Mr. Goodchild refers to these as the Teli Deo workings, Teli Deo being situated at the point indicated. It is probable, according to Mr. Vredenburg, that Teli Deo has been mistaken for Bhánádeo, which is the name given to a small hill close to the southern band near the Kund Nálá; the southern band being only $\frac{1}{8}$ to $\frac{1}{4}$ mile south of the Kaskuri band. 'A good deal of ore is found lying in the bed of the stream. Just above the stream where a few pits have been made, the limestone has been laid bare standing in pillars with nodules of ore' both *in situ* in the pillars and embedded in the clay filling the spaces betwe n them. A sample, Q, taken from these pits gave the following analysis:—

The Bhánádeo band.

Manganese	51·24
Iron	3·75
Silica	7·55
Phosphorus	0·049

No manganese-ores have been reported for the length of about 1 mile between the Kaskuri workings and Junawáni C, but no doubt manganiferous limestones and nodules of manganese-ore exist.

Mr. Vreden urg's specimens show that the rocks associated with the manganiferous limestone in the Kaskuri and Bhánádeo bands are the same as in the Mándvi Bir and Junawáni portions of the area, the limestones being underlain by epidosites and epidote-gneisses and these in their turn by quartz-pyroxene-gneisses, whilst they are overlain by quartz-pyroxene-gneisess. Mr. Vredenburg found, however, that there is often some mica-schist intervening between the limestone and these underlying epidotic rocks. Owing, moreover, to the reappearance of epidosites at Ghátmára Deo about $\frac{1}{4}$ mile to the south of the Bhánádeo band, he thinks that the structure of the rocks in this neighbourhood is to be explained by folding, so that the Kaskuri and Bhánádeo bands correspond to the same bed of ore and manganiferous limestone, as already explained on page 967. He notes also that hematite occurs in the north-east pit on the Kaskuri band on Junapáni hill in association with the manganese-ore, as at Mándvi Bir.

32. Rájkota.

At a distance of about 2 miles to the east of the main road from Nágpur to Jabalpur, and practically on the continuation of the Mándvi Bir-Junapáni band of manganiferous limestones, there is a hill named Rájkota. Specimens brought from here by Mr. Vredenburg show the existence of crystalline limestone containing piedmontite, in association with quartz-pyroxene-gneisses sometimes passing into calciphyres. If the syncline of manganiferous limestones comes to the surface at Junapáni so as to disappear to the east, it is evident that still further east (namely at Rájkota) what was once a part of the same band reappears.

The Nimár District.

When working in this district in the field season of 1902-03 I found four occurrences of manganese. one in the Chándgarh section of the district, and three in the Harsud tahsil. The four occurrences, curiously enough, belong to four different formations, the Lametas, Bijáwars, Deccan Trap, and Vindhyans, respectively. They are probably all examples of surface impregnation and replacement, and consequently can in no case be expected to continue to any depth. Moreover, the quality of the ores is very poor; hence in no case can the occurrence described be regarded as of any possible economic value.

The following is a list of the manganese localities :—

1. Chándgarh.
2. Jámdihi Nálá.
3. Bunkuta.

1. Chándgarh.

In the nálá situated about ¼ mile S. E. of Chándgarh, where it flows over Lameta rocks, there is in one place an exposure of a sandy facies of this formation. This rock is pinky yellowish, laminated, with black layers owing their colour to impregnation with oxide of manganese. One specimen collected contained a certain proportion of calcite as well as of manganese oxide (17·414 and 17·416).

2. Jámdihi Nálá.

In the Jámdihi Nálá at a point about 1¼ miles N. N. W. of the village of Gohugáon, and ¾ mile S. E. of the left bank of the Narbada river, there is a series of outcrops, for a distance of about 200 yards along the stream, of a manganiferous breccia. The breccia shows white angular fragments of quartzite, set in a black matrix, which is in some places soft like wad, and in others is hard grey psilomelane, the wad and psilomelane being usually mixed together. In places the rock is calcareous. Although the amount of this manganiferous rock must be considerable, yet it is improbable that it is of any economic value. As regards its origin I suggest that it is a surface replacement form of one of the siliceous breccias so common in the Bijáwar rocks of this area (17·324 and 17·325).

Further down the nálá, about ⅜ mile from its mouth, there is a small patch of calcareous grit of Lameta age, with basalt of Deccan Trap age resting upon it with a curved surface. Between the two there are some laminated shaly beds about 2 feet thick containing a hard layer about 1 inch thick, of a calcareous rock containing a manganese-garnet. This remarkable occurrence has not yet been carefully investigated and no explanation is offered here (17·562 and 17·601).

3. Bunkuta.

About half a mile higher up stream than the manganiferous breccia mentioned above, a small nálá joins the right bank of the Jámdihi Nálá at a point where it is running N. E. A little way up this nálá to the south of the deserted site of Bunkuta, marked on the 1-inch Revenue Survey map Nos. 10 & 11 E. of this area, there is an outcrop of Vindhyan shales that have been secondarily rendered manganiferous, and now show little patches of pyrolusite, and mammillations of psilomelane, and are blackened in many places (17·353).

The Seoni District.

A reference to Plate 43 will show that intervening between the manganese area of Chhindwára and that of western Bálághát lies the southern end of the Seoni district, which, like the manganese areas just mentioned, is occupied by the metamorphic and crystalline complex. Hence it seems probable that manganese-ores or the associated manganese-silicate-rocks of the gondite series occur also in the Seoni district. That this is probably the case is indicated by the fact that during 1907 Mr. T. B. Kantharia found a piece of manganese-ore in a nálá near Kurai, 20 miles south of Seoni town and 10 miles north of the Nágpur district boundary. The specimen consisted of psilomelane with hollandite, and a bronze-tinted mineral, probably sitaparite. During 1907 many prospecting licenses for manganese have been taken out in the Seoni district. As early as 1869

The Wun (Yeotmál) District.

T. W. H. Hughes[1] drew attention to the occurrence of manganiferous sandstone in the Kámthi series in the Wardha Valley coal-field. Later[2], he mentions the occurrence of manganese, as a 'coloring medium', some of the Kámthi sandstones holding as much as 6 per cent. of it, and says[3]—

'South of Sirpúr are the Malágarh hills, whose highest summit[4] is one of the most elevated points to which the Kámthis rise within the Wún division of the field. They are composed of fine granular sandstones of varying colours, sub-vitreous variegated sandstones, pink argillaceous shales, and a few conglomerate bands. Some of the sandstones are slightly manganiferous of a dark colour. General direction of dip, south-west.'

In 1874[5] he discovered manganese-ore in red clays at the base of Malagarh hill, on its east side, and therefore underlying the above-mentioned sandstones and shales.[6]

'These clays alternating with others, and occasional calcareous and ordinary sandstones, extend down to the Káwarsa stream, in whose banks they are well exposed. The ore is most abundant near the hill, but throughout the entire series of these clays, it is present in limited quantity; sometimes in concretionary lumps of moderate richness, but more generally sparsely distributed in strings and irregular laminæ that appear to bind the clay into masses of indefinite shape.'

An analysis by Tween[7] gave :—

Loss on heating	8·5
Oxide of manganese	44·6
Iron-oxide and alumina	6·8
Sand and clay	40·1
TOTAL	100·0

This occurrence is hence of no economic importance both because of the very poor quality of the ore and because of its limited quantity. The ore is psilomelane of bluish black colour.

1 *Rec. Geol. Surv., Ind.*, VII, p. 125, (1874).
2 *Mem. Geol. Surv., Ind.*, XIII, p. 68, (1877).
3 *Loc. cit.*, p. 76.
4 966 ft. above sea-level.
5 *Rec.*, VII, p. 125.
6 *Mem.*, XIII, p. 76.
7 *Loc. cit.*, p. 114; *Rec.*, VII, p. 125.

CHAPTER XXXVII.

DESCRIPTION OF DEPOSITS—*continued.*

Coorg, Goa, Haidarábád, and Kashmir.

Coorg.

Goa.—History—The grant of concessions—Geology—Origin of the ores—Nature and quality of the ores—Extent of the deposits—Communications and transport—Fanuswádi—Dab Dabba—Other deposits.

Haidarábád.

Kashmir.

Coorg.

No manganese-ore has yet been recorded from this province; but that it possibly exists is indicated by a very manganiferous iron slag found by Mr. W. S. Sullivan on the Kibberi Betta estate near Mercara.

Goa.

History.

It was not till the end of 1905 that the existence of manganese-ore in the Portuguese territory of Goa seems to have been discovered. The first claim is said to have been manifested on the 5th January 1906 by Haji Ismael Mirza Bagdadi. He was quickly followed by Mr. Boyce of Belgaum, Captain Lacerda, Mr. C. Jambon, and Messrs. Lam & Co. The numerous occurrences of manganese discovered as the result of the great activity displayed in prospecting Goa during 1906 and 1907 have led to the formation of several syndicates and companies. The following is a list, for which I am indebted to Mr. A. Ghose, of the principal concessionaires at the end of 1907,—Messieurs Jambon & Cie. having transferred their rights to the West Coast Manganese Syndicate:—

Concessionaire.	Local Office.
Mr. C. P. Boyce	Belgaum.
Graham & Co.	Mormugáo.
Goa Mining Co.	Sanvordem.
Killick, Nixon & Co.	Mormugáo.
Captain Lacerda	Nova Goa.
D. B. Lam & Co.	Sanvordem.
Lena Manganese Syndicate	Bicholim.
Shaw, Wallace & Co.	Mormugáo.
Shimoga Manganese Co., Ltd.	Bangalore.
Standard Manganese Syndicate	Mormugáo.
Tata, Sons & Co.	Bombay.
West Coast Manganese Syndicate	Bicholim.

The total exports of ore from the port of Mormugáo up to the 31st March 1907 amounted to 70,749 tons. Now the total of Mysore and Sandur ores exported through this port up to the end of 1906 was about 50,000 tons; hence, allowing for the amount that must have been exported during the first quarter of 1907, it seems very doubtful if any Goa ore had been exported up to 31st March 1907. When I visited Mormugáo in November 1907, however, there was a certain amount of ore lying on the stacking ground that was said to have been railed from Collem and Sanverdem stations on the West of India Portuguese Railway.

And I am informed by the British Consul at Goa that 99,962 tons of manganese-ore were shipped from Mormugáo during the year ending March 31st, 1908. Of this, some 7,000 to 8,000 tons represent the produce of Goa.

Perhaps 15,000 tons were mined in Goa during the same year.

The grant of concessions in Goa.

The regulations for the grant of rights to work minerals in Portuguese India are of course different from those in force in British India. Mr. A. Ghose, who has had special opportunities of becoming acquainted with their intricacies whilst acting as agent to Messieurs Jambon & Cie., tells me that the following is a rough outline of the process that a would-be concessionaire has to go through:—

On finding a deposit an application for a manifest (*manifesto*) has to be sent in. A claim thus manifested can be demarcated only after the expiration of at least three months from the date of granting of the manifest, and then only when the Government Mining Engineer is satisfied that the mineral sought for is actually in existence in the area. After demarcation a plan of work is given by the Mining Engineer to the owner of the claim on payment of a special fee to the demarcator, who may be the Mining Engineer himself or any authorized engineer or surveyor of the Government. One year after the date of the demarcation a full mining concession is granted. Work can start from the date of the manifest; but export cannot take place until the date of the mining concession, unless special sanction be obtained, but in no case before the grant of the plan of work.

Those who wish for further information about the mining regulations in Portuguese colonies can consult 'Portuguese Colonial Mining Laws, Decree of 1906'. This is a translation of the *Boletim Official do Governo General da Estado da India*, No. 84, dated October 23rd, 1906, and consists of 50 foolscap pages of print. This translation was made by Mr. R. A. Becher, His Britannic Majesty's Consul at Goa, and is dated Mormugáo, October 1906.

Geology.

Very little seems to be known about the geology of Goa. But as far as I can judge from the few exposures I saw round Bicholim, and the remains of rocks included in specimens of manganese-ores from different parts of Goa, the country consists mainly of Dhárwár rocks, very largely obscured by a covering of laterite. Judging from what is known of the geology of North Kanara, it is not improbable that some of the hills in Goa may consist of gneissose rocks, but of this I have no evidence except for the gneisses exposed in the railway cutting at Dudh Ságar railway station. On the eastern borders of Goanese territory, where it adjoins the Belgaum district, the country consists of Deccan Trap, this forming the Western Gháts. Of the rocks I have seen that are probably of Dhárwár age the following may be mentioned:—quartzite, magnetite-, hematite-, and limonite-quartzites, phyllite and basic igneous rocks, as well as quartz-veins traversing these.

Origin of the ores.

The manganese-ores occur partly in the laterite and partly in the underlying decomposed Dhárwár rocks. As far as I can tell from the three deposits visited, the manganese-ore found in the decomposed Dhárwárs has been formed by their superficial replacement. The laterite is of the low-level variety and is probably, in many places, as much as 50 feet thick; in rare cases it may be more, though I have not seen any such section myself. The laterite does not rest as a horizontal sheet on the underlying rocks, and is thus different in mode of disposition from most occurrences of high-level laterite I have seen; for it seems to have followed the contour of the land, and in quarries and other sections is seen to rest on the underlying rock with a very irregular surface and to include fragments of this underlying rock. From this, and the relations of the two, it seems to me clear that the laterite has been formed by a combination of impregnation and metasomatic replacement by means of ferruginous solutions acting indiscriminately on the Dhárwár rocks. The source of the iron is probably to be looked for in the abundant ferruginous rocks found amongst the Dhárwár rocks. In some cases the formation of the laterite has probably taken place by the mere re-arrangement on the spot of the iron-ores of the Dhárwárs. But in those cases where the laterite has formed on the top of non-ferruginous rocks, such as quartzites, the iron must have been brought in solution, at least from the nearest occurrence of ferruginous rock. In some cases the laterite has formed on the top of comparatively fresh rock, and in other cases on altered rock. Sometimes this altered rock seems to have been the quartzite partly replaced by manganese-ore referred to above. In such cases, at least a portion of the manganese in the overlying laterite must be taken as representing the manganese contained in the quartzite. It may remain in the laterite either in the form in which it was contained in the quartzite, or it may have been dissolved and re-deposited, or re-arranged by segregative tendencies. In other cases the manganese in the laterite may be brought in solution together with the iron at the time of the formation of the laterite. In either case the question arises—Where has the manganese come from that is now found in the laterite, and the underlying decomposed quartzite or other rock? The answer must be the same as in the case of most of the ores formed superficially on the outcrops of Dhárwár rocks in other parts of India:—The source is not evident, but probably the manganese was originally distributed in small quantities through the various rocks—especially iron-ores and phyllites—of the Dhárwár series, and has subsequently been concentrated under the influence of percolating waters and deposited in the form of manganese-ores in the situations where it is now found.

Nature and quality of the ores.

The commonest of the Goa ores seems to be pyrolusite; but a fair amount of psilomelane and wad are also found. The ores are usually very cavernous and often mixed with iron-ores, such as ochre and limonite; and, as might be anticipated from their mode of origin, they often contain residual patches of quartzite and other rocks.

The following analyses by Dr. Schulten of Calcutta, kindly supplied by Mr. Ghose, are the only ones of Goa ores I have :—

Average Samples.

	FANUSWADI.		Kolambi.	Morlem.
	No. 1.	No. 2.		
Manganese	47·65	49·45	54·38	42·70
Iron	10·63	8·59	3·62	17·08
Siliceous matter . . .	4·25	5·47	1·41	2·27
Phosphorus	0·150	0·151	0·156	0·167

Picked bad specimens of lateritic manganese-ore.

	Kulan No. 7.	Fánuswádi No. 8.	SERVONA.	
			No. 1.	No. 3.
Manganese	38·39	21·32	38·57	37·52
Iron	20·58	39·53	20·70	25·11
Siliceous matter . . .	2·24	2·70	2·16	2·09
Phosphorus	0·139	0·167	0·195	0·212

As far as I can judge from the appearance of the Goa ores, the manganese is not likely to be very high, its place often being taken by a considerable amount of iron. In fact I should think that the Goa ores are practically all third grade, and below; I have not seen any that looked as if they ran above 47% manganese, *i.e.*, were second grade. On account of their mode of origin, these ores are liable to run high in silica if the cleaning be not carefully carried out. This silica is in the form of quartz, and if the ores were carefully cleaned the silica percentage could often be reduced to very small amounts, though probably at the expense of a considerable loss of ore. Considering the resemblance of these ores in every respect to those of Mysore, one would expect the phosphorus to be low; but the foregoing analyses indicate the contrary.

Extent of the deposits.

Judging from the mode of origin and the spasmodic way in which the ores seem to be distributed in the workings, it is not likely that the Goa deposits will ever be found to be very large. In fact, considering their irregular mode of occurrence and low grade, it is rather fortunate they are situated so near the sea, for otherwise, in most cases, they would not pay to work. Indeed, even with such a favourable situation it is probable that only a very few of the deposits are really profitable to the lease-holders as producers of ore. In fact it is probable that those who have made money over the Goa deposits have not as a rule done it by the sale of the ore, but by the sale of the deposits.

Communications and transport.

Goa is served by one line of railway, the West of India Portuguese Railway, from Londa Junction in the Belgaum district, to Mormugáo. It is worked by the Southern Mahratta Railway. The ores of those deposits within reasonable distance of the railway are carted to the railway and thence railed to the port of Mormugáo. The stations that are most used for this purpose are, I believe, Collem, Kalay, and Sanvordem. But Goa is essentially a country of creeks running far inland, and these water-ways play a great part in the transport of the country. The manganese-ores of those deposits not near the railway are carried in boats to Vasco-da-Gama, from whence they are carried by rail to the port of Mormugáo, one station further on. The distances that the ores have to be carried in this way are in some cases considerable. Thus from Piligáon, some 2 miles from Bicholim, one of the chief manganese centres in Goa, it must be about 20 miles to Vasco-da-Gama.

1. Fánuswádi.

(WEST COAST MANGANESE SYNDICATE).

This deposit is situated nearly 2 miles east of Bicholim, on rising ground just to the north of the road to Sanquelim. It is in the Bicholim sub-division of the Sanquelim district. It was opened up in 1906 by Messieurs Jambon & Cie., and transferred in 1907 to the West Coast Manganese Syndicate. No ore was shipped by Jambon & Cie., but since the transfer some 1,800 tons had been shipped up to the time of my visit. The main pit is a large irregular excavation orientated roughly east and west. The surface rock is the ordinary cavernous ferruginous low-level laterite of Goa, containing remains of quartz, and sometimes of quartzite, but differing from the most common form of this laterite in also containing abundance of pyrolusite in the form of veinlets and patches. It extends downwards to variable depths in different parts of the quarry, being irregularly penetrated from below by tongues of a soft white very fine-grained quartzite. This latter is, of course, the original rock, and was probably once a hard grey quartzite. It is now much decomposed and is traversed by a network of veins and patches of pyrolusite, which in places is in large enough masses to be worth mining. In some places the white quartzite part of this mixture of quartzite and pyrolusite is stained reddish brown due to impregnation with oxide of iron; and to me it seems probable that the laterite has been formed by the replacement of the quartzite part of this mixture, the pyrolusite in the laterite representing, at least in part, the pyrolusite that had formed in the quartzite prior to the formation of the laterite. In some places the quartzite seems to have been replaced by a network of the brown compact limonite instead of pyrolusite. The ores of this deposit are now all pyrolusite (with a little wad), the pieces of which are sometimes mixed with brown horny limonite. But formerly, according to Mr. Ghose, concretionary nodules of psiomelane were sometimes found in the laterite. The ores of this deposit as shipped are probably fairly high in iron with a corresponding diminution in the quantity of manganese; and also high in silica, though below the commercial limit of 10%. The Fanuswádi ores are sent by cart to Kolambi, some 2 miles distant, and then by boat to Mormugáo.

2. Dab Dabba I.

(GOA MINING COMPANY.)

This deposit is situated about 1 mile S. E. of Bicholim on the east side of the road from Piligáon to this town. The deposit has been opened up by means of a large irregular pit, which is said to be one of the largest workings in Goanese territory. Nearly the whole of the rock exposed is laterite. Of this rock there seems to be a great variety, from the ordinary ferruginous laterite free from manganese-ore to rock showing all the structures of laterite, but composed almost entirely of pyrolusite. The ferruginous part of the laterite consists of some variety of limonite, either yellow ochre, or the brown compact limonite, or some intermediate variety. Some of the ferruginous portion may be ferruginous clay. Besides the pyrolusite, there is also a little psilomelane present in the form of thin veinlets in the ferruginous laterite. The excavations must be some 25 feet deep. In the lower parts a few patches of residual quartzite are to be seen. These quartzites are soft and white and show the same network of pyrolusite as at Fanuswádi; and, as before, the evidence points to the laterite having been formed by the impregnation and replacement by iron oxides of the quartzites, in which the manganese-ores had already formed. On this interpretation, at least a portion of the manganese-ore in the laterite, may, as at Fanuswádi, be taken as representing the manganese-ore contained in the quartzite before it was replaced. On the other hand a portion of the manganese in the laterite may have been introduced at the time of formation of the laterite. That portion of the manganese in the laterite that represents the manganese-ore in the quartzite need not necessarily have retained the precise form in which it was present in the quartzite, but has probably been largely re-arranged by segregative actions. The ore won here is practically all pyrolusite.

3. Dab Dabba II.

(SHIMOGA MANGANESE COMPANY, LTD.)

This deposit, which lies on the side of a low range of laterite hills, is situated just to the west of the road from Piligáon to Bicholim, a little further north than the Dab Dabba deposit belonging to the Goa Mining Company. In one opening a bedded limonitic rock striking S. 20° E., with a very steep dip to the east side, was exposed. This rock contains a large number of tiny sparkling octahedra, which turn out to be magnetite, and is seen through a lens to contain quartz also, the whole suggesting a magnetite-quartzite, a large proportion of the magnetite of which has been converted into limonite. In another place, close at hand, is a small cave in limonitic rock containing a great abundance of the tiny magnetite octahedra. In the workings this bedded limonitic rock is seen to be passing into laterite, processes and patches of which project irregularly into the limonitic rock. In places this laterite contains abundance of fine-grained blue pyrolusite. Judging from the stacked ore, the pyrolusite forms in the limonitic rock also, by direct replacement, without the formation of laterite. The whole of the surface of the hills just here shows lateritic rock, often containing abundance of angular and rounded fragments of the limonitic rock with some of phyllitic rock. This resembles the lateritic conglomerate of Rámandrug, and seems to have been formed by the superficial cementation of the loose pieces of the rock of this place by oxides of iron. The amount of ore in this deposit did not seem to be large.

Other deposits.

I was also able to examine some specimens of Goa ores in the possession of Mr. Ghose. The Vaotim (or Vaomti) deposit is situated about 1½ miles E. N. E. of Fanuswádi, and is held by the West Coast Manganese Syndicate. Mr. Ghose's specimens from here are mixtures of laterite, yellow ochre, and pyrolusite, with occasional psilomelane. One of them shows a patch of decomposed quartzite. The Kandiapár deposit, held by Captains Lacerda and Rollo and some of their friends, lies some 2½ miles N. E. of Ponda in the Ponda division of the Ponda district. The ore is said to be mainly psilomelane. A beautiful specimen from here showed compact psilomelane arranged in bands round a flat cavity lined with a soft black coat of minute felt-like crystals. From this deposit, said to be one of the largest in Goa, about 2,000 tons of ore have been despatched to Mormugáo. The ore is sent by cart to the coast and then by boat to Mormugáo.

Vaotim.

Kandiapár.

I have also been able to examine some samples brought by Mr. H. D. Coggan from the Embarbacem division of Goa. Amongst these I found remains of schistose micaceous hematite, and sericite-phyllite, both very characteristic of the Dhárwárs. The local-

Malan, Villian, Kumári, and Kajri.

ities from which Mr. Coggan's samples were obtained are Malan, about 2 miles north of Kalay station; and Villian, Kumári, and Kajri, near Peritem, these three places all lying some 16 miles to the south of Sanvordem station on the West of India Portuguese section of the Southern Mahratta Railway.

The fragments composing the samples consisted mainly of mixtures or intergrowths of psilomelane, pyrolusite, limonite, and a fibrous radiate mineral that is probably altered manganite. This manganite is sometimes intergrown with psilomelane, into which it possibly changes; whilst at others it is massive, passing into pyrolusite; it also often occurs as linings to cavities, when it takes the form of small radiate crystals. Some pieces contain a compact brownish black substance that gives a brownish black streak and is probably to be regarded as a manganiferous ochre. One very pretty specimen consists of columnar-radiate limonite, the columns of which are often pressed one against the other, but sometimes have spaces between them. In the latter case the columns of limonite are often covered externally with a thin coating of manganese-ore, which is sometimes psilomelane and sometimes altered manganite; whilst occasionally there are thin concentric layers of manganese-ore alternating with the limonite layers in the interior of the columns. Some specimens indicate that where both manganese- and iron-ores occur together the manganese-ore has been deposited subsequently to the iron-ore. Other specimens I have seen indicate the reverse order of deposition.

Amongst other deposits that have been found the following may be enumerated:—

Avodupalle, Chendo, Karapur, Kolambi, Korqui, Kulan, Kurado, Feringesey Bat, Malpona, Morlem, Servona.

Haidarábád.

Captain T. J. Newbold, F.R.S., first recorded the occurrence of manganese-ore veins in the laterite of the Bidar district in 1840.[1] Later[2] (1844) he gives a very full and lucid description of the find. He

[1] *Mad. Journ. Lit. Sci.*, XI, pp. 45, 245, (1840); XII, p. 24, (1840).

[2] *Journ. As. Soc. Beng.*, XIII. pp. 992-995, (1844); reprinted in 'Western India,' pp. 73-76, (1857). He also mentions this occurrence in *Jour. Roy. As. Soc.*, VII, p. 214, (1843); VIII, p. 234, (1846).

says that the lateritic bed of Bidar is 28 miles from E. S. E. to W. N. W. and 22 miles from W. S. W. to E. N. E., and has an average thickness of 100 feet, rising to a maximum of 200.[1] Bidar town is situated on it at an elevation of about 2,330 feet. After giving one of the best descriptions to be found anywhere of the physical characters and structure of laterite, Newbold comes to the occurrence of the manganese-ore. His description is worth quoting in full. He says[2]:—

'At the western base of the cliffs, about 16 miles W. by N. from Beder and 1½ miles from Hulfergah, on the left of the road leading down from the table land into the plain, the laterite is seen penetrated by a great number of veins, which at first sight, from their dark aspect and singular direction, might be taken for those of basalt. They are composed of black often earthy manganese combined with iron. The veins are extremely tortuous, and crossing each other in every direction, and give a reticulated appearance to the rock. On the sides of the veins the laterite is so hard as to stand out in relief from the weathered portions of the rock. The veins are usually thicker near the bottom of the cliff fining off as they ascend until they are gradually lost in the substance of the laterite: others are horizontal. As they diminish from an inch to a line in thickness, they gradually lose the deep bluish black colour, becoming mixed with the matter of the matrix and pass into a brown, yellowish brown, and lastly, a purplish thread which is lost in substance of the rock.

'The bluish black substance of the veins is compact and hard, in some parts; sectile and earthy in others, easily frangible'.

Newbold [3] also mentions a similar occurrence at Kalyána (Calliany of Newbold) in the Bidar district, and in another place [4] refers to—

'Veins of amethystine quartz in the vicinity of Hyderabad, near which I detected manganese'.

It is also said [5] that 'iron and steel sands with manganese' occur in the Hyderabad territories.

Kashmir.

Baden H. Powell [6] mentions the use at Lahore for decolourizing glass of peroxide of manganese, variously called 'jugní,' 'missí siya,' 'nijní', and 'injaní (or inganí)', said to be imported from Kashmir and Kábul.

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[1] *Op. cit.*, p. 989.
[2] *Ibid.* p. 93.
[3] *Journ. Roy. As. Soc.*, VIII, p. 234, (1846).
[4] *Mad. Journ. Lit. Sci.*, XI, p. 245, (1840).
[5] Reports by the Juries, Madras Exhibition (1857), page 3.
[6] 'Punjab Products', Vol. I, pp. 25, 113, (1868).

CHAPTER XXXVIII.

DESCRIPTIONS OF DEPOSITS—*continued.*

Madras Presidency—Bellary District and Sandur State.

Bellary district—The Dambal-Chiknáyakanhalli band—The Sandur-Copper Mountain band.

Sandur State—History—Geology—Foote's account—Phyllites, slates, and lithomarges—Ferruginous quartzites—Basic igneous rocks—Granites and gneisses—Relations of latter to the Dhárwárs—Lateritic rocks and hematitic breccias—The manganese-ore deposits—List of deposits—Place names—Deposits visited—Situation of the deposits—Outcrops lateritoid and lichen-covered—Prominence of the outcrops of manganese- and iron-ores—Manganese-ore deposits apparently beds; but really surface replacements—Evidence supporting the superficial replacement theory—The Naráyandevarkerra Ghát sections—Rámandrug Main Bed sections—The Rámandrug lithomarges—Summary of origin—Depths to which deposits extend—Width of the deposits—Length of the deposits—Quantities of ore—Are the quantities too large to have been formed by superficial replacement?—The manganese minerals present—Psilomelane and wad formed by replacement of phyllite—Pseudo-manganite in cavities—Botryoidal and lead-like psilomelane—Braunite? and hollandite?—Chemical composition of the ores.

Descriptions of deposits—The Rámandrug deposits—Sannasil Haruvu (Rámandrug No. 2)—Rámandrug No. 4—Rámandrug Main Bed—Rámandrug Barracks deposit (Manganese Cave)—The Kannevihalli deposits—The Kumáraswámi deposits—The Kamátaru deposits—Yelakála Gadda—Badapatti Banda—Alada-marada Banda—Durgámma Kolla—Pilál-Marada Gundu—Karada Badasála Kativi—Hunáse-marada Kativi.

Bellary District.

Foote [1], in his account of the geology of this district, describes four of the bands of Dhárwárs as lying at least partly within the Bellary district which they all cross in a general south-easterly direction. They are:—

1. The Dhárwár-Shimoga band.
2. The Dambal-Chiknáyakanhalli band, designated the Chitaldrug band by the Mysore Geological Department.
3. The Sandur-Copper Mountain band.
4. The Penner-Haggari band.

Manganese-ores have been found in each of the first three bands.

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[1] *Mem. G.S.I.*, XXV, (1895).

1.—THE DHÁRWÁR-SHIMOGA BAND.

This crosses the very west end of the district. Mr. A. Ghose, of Messieurs Jambon and Cie., tells me that the South Indian Mining Syndicate and Jambon and Cie. each have manganese concessions on a series of low spurs to the west of Teligi Hill, which lies about 10 miles N. N. E. of Harihar and is in the Harpanahalli taluk. Foote marks three bands of hematitic quartzite on the map at Teligi hill. A specimen from here shown me by Mr. Ghose was a cavernous mixture of pyrolusite and limonite, in which the pyrolusite was radiate-concentric and seemed to be subsequent in time of formation to the limonite. Nodules of psilomelane have been found by one of Mr. Ghose's explorers near 'Currabaguddy' Hill, some 8 miles N. W. of Teligi Hill.

2.—THE DAMBAL-CHIKNAYAKANHALLI BAND.

Mr. J. M. Maclaren, formerly of the Geological Survey of India, found an unimportant occurrence of manganese-ores at the northern end of a ridge of limonitic quartzites, about 2 miles south of Hamigi in the Dhárwár district, at a point about a mile east of Handigenura and 6 miles west of Huvinhadagalli in the Huvinhadagalli taluk of the Bellary district. [1]

3.—SANDUR-COPPER MOUNTAIN BAND.

No manganese-ores seem yet to have been discovered in the Copper Mountain portion of this band. The range has been explored by Mr. Ghose's scouts, but without success. In the Sandur portion of the belt, however, a large number of deposits have been discovered. Most of these lie within the limits of the Sandur State and are described under that heading. Outside this State, Messieurs Jambon & Cie. have obtained deposits in the N. W. end of the Sandur syncline, in the portion lying in Hospet taluk. The chief of these is Kalhalligudda. A small portion of the deposits at the southern end of the Sandur Hills lies outside the limits of the Sandur State in the reserved forest of Tonashagiri and Tumraguddi, in the Kudligi taluk of the Bellary

[1] *Rec. G.S.I.*, XXXIV, p. 129, (1906).

district. These also have been secured by Messieurs Jambon and Cie., but there seems to be some dispute as to the possession of a portion of them. One of these deposits—Pilal-marada Gundu—is noticed on page 1031, in describing the Sandur deposits.

It is probably to some of these that Foote refers in his Bellary Memoir, in the following words [1]:—

'The two other localities yielding manganese-ore occur some 7 and 8 miles, respectively, south-east of the Kannevihalli spur. The manganese nodules are seen exposed on a narrow terrace a little below the edge of the Kamaraswami plateau where crossed by the foot-paths leading from Tonashagiri and Somahalli respectively to Kammatarnou (Combudhurroo) at the eastern end of the plateau. The sections seen do not expose the rock sufficiently to show whether or not the nodules are plentifully distributed through the matrix or only of rare occurrence'.

Sandur State (Bellary District).

(*See Plates 44 to 46.*)

History.

Newbold [2] was the first to mention the occurrence of manganese-ores in the Sandur Hills, to which he variously referred as the 'copper mountain range in the Ceded Districts' and the 'hills' 'of the Ceded Districts'. Various manganese-ores from this area were exhibited at the Madras Exhibitions of 1855 and 1857 [3]. Mr. R. Bruce Foote, formerly of the Geological Survey of India, mentioned the occurrence of manganese-ores at Rámandrug in the Sandur Hills in 1889 [4], and later [5] gave a more detailed account of the ores at this and a few other localities.

Mr. A. Ghose, agent to Messieurs Jambon & Cie., having discovered Newbold's reference to the occurrence of manganese-ores in these hills, sent a couple of scouts there in 1904. The specimens they collected were analysed with disappointing results. In February 1905, Mr. Ghose himself went to Rámandrug, and there discovered the deposit now

[1] *Mem. G.S.I.*, XXV, p. 195, (1895).
[2] *Mad. Jour. Lit. Sci.*, X, p. 125, (1839); XI, p. 46, (1840); *Jour. Roy. As. Soc.*, VII, p. 214, (1843); VIII, p. 155, (1846).
[3] Reports by the Juries, (1856), p. 6; (1857), pp. 2, 4.
[4] *Rec. G.S.I.*, XXII, p. 26, (1889).
[5] *Mem. G.S.I.*, XXV, pp. 98, 100, 125, 194, 195, (1895).

known as the 'Main Bed'. On the way to Tonashagiri he discovered the Kámataru deposits and afterwards the Kumáraswámi deposits. During the remainder of the year he prospected the whole of the western and southern parts of the state and located some 90 deposits of manganese-ore. He started to open up the deposits now known as Rámandrug Main Bed and Rámandrug No. 4 in 1905, and during 1906-1907 mapped most of the deposits he had discovered. To Mr. Ghose belongs the credit for the discovery of the large ore-bodies *in situ*. The occurrences recorded by Mr. Foote were all of nodules, either loose, or *in situ* in argillites or schists.

The Rámandrug deposits were further opened up by a succession of managers, and the result of their work was to show that these deposits are of considerable size. In 1907, the interests of Messieurs Jambon & Cie. were transferred to a company known as the General Sandur Mining Company, Limited, with a capital of Rs. 48,00,000, the purpose of which is to work primarily the manganese-ores of the State, and, secondarily, should it prove feasible, the iron-ores, and to manufacture ferro-manganese, and iron and steel, in India. In consideration of a *salám* of Rs. 50,000 and a royalty of 6 annas a ton on manganese-ores, and ½ anna a ton on iron-ores, with a guaranteed minimum of Rs. 25,000 per annum, all to go to the revenues of the Sandur State, the Government has granted this company a monopoly of the iron- and manganese-ore deposits in the form of a mining lease for 25 years over the hilly portions of the State, in which all the deposits lie.

This arrangement does not apply to the deposits situated within the Jágirs of Swamihalli and Kamátaru ; on the ore from these deposits, also, a royalty of 6 annas a ton is to be levied.

Up to date a considerable amount of capital has been sunk by Messieurs Jambon & Cie. in fitting up the Rámandrug deposits with an aërial ropeway ; whilst the Southern Mahratta Railway has constructed a 5½-mile siding from Mariyamanhalli station on the Hospet-Kottur Branch of the Southern Mahratta Railway to the foot of the hill at Rámandrug, where the unloading station of the aërial ropeway is. A survey is in progress for a further extension of about 20 miles to the deposits round Kamátaru at the southern end of the State. The amounts of ore despatched from this area to the port of Mormugao during 1905 and 1906 were as follows :—

	1905.	1906.	1907.
	Long tons.	Long tons.	Long tons.
Rámandrug	1,200	447	15,455
Kannevihalli	*nil*	2,762	7,595

In September 1907 I was able to pay a very brief visit to these hills and cursorily examine a few of the chief deposits, Mr. R. O. Ahlers, then mines manager, showing me the Rámandrug deposits, and Mr. Ghose those of Kamátaru.

Geology: Foote's account.

Geologically, the Sandur Hills and Copper Mountain area consists of two great synclinal folds running from N. W. to S. E., and joined together at their centres. The rocks belong to the Dhárwár system, and, according to Foote[1], to whom we are indebted for a full account of the geology of the Bellary district, consist of alternating schists and hematitic quartzites, with contemporaneous trap beds and occasional argillites. The plains surrounding the Sandur Hills are occupied—except where they are joined by Dhárwárs to the Copper Mountain range—by a series of crystalline rocks, which Foote divides into 'plutonic granitoid' and 'metamorphic gneissoid'. The Sandur synclinal takes the form of a drawn out oval, pointed at both ends, with its long axis running N. W. and S. E. Its total length is about 36 miles and its width at the widest part about 12 miles. It is bounded by N. W.- and S. E.-running ridges that come nearly together at the N. W. and S. E. ends. It is thus in the form of an elliptical hollow surrounded almost continuously by high ranges of hills. The exceptions are at the N. W. end of the syncline, where a tributary of the Tungabhadra makes its escape, and about the middle of each of the two long sides of the syncline, where it is breached by a tributary of the Tungabhadra known as the Narihalla. The Narihalla cuts through the S. W. bounding wall of the basin by a gorge known as the Oblagandi, crosses the middle of the

[1] *Mem. G.S.I.*, XXV, 'Geology of the Bellary District'.

basin in a N. E. direction, and leaves it again through the N. E wall by a gorge known as the Bhimagandi. In the interior of the basin lies the little town of Sandur at an elevation of about 1,900 feet above sea-level. This is not much greater than the average level of the Bellary plains close to the outside of the syncline. The hills rise to 3,000 feet and over, in many places forming long ridges, the tops of which as seen from a distance often look remarkably level; this being due probably to cappings of a lateritic rock. Two of the highest points are the military sanitarium of Rámandrug, or Rámanamallai, 3,256 feet at the trigonometrical station, and Kumáraswámi's peak (probably that known as Hiregutti), which is 3,400 feet high (according to General Cullen). The State of Sandur consists of the interior of this basin and its bounding walls, the frontier lying in most cases at the base of the hills on the outer side, but rising up the slopes at the southern end. The N. W. end or point of the syncline lies, however, for a distance of 8 miles, in the Hospet taluk of the Bellary district; whilst the Kudligi taluk of the same district and the Chitaldrug district of Mysore State encroach on the S. E. end or point of the syncline.

Phyllites, slates, and lithomarges.

As the result of an examination of the rocks of such portions of the syncline as I had occasion to visit in connection with the examination of manganese-ore deposits, I find that some modifications of the nomenclature of the rocks as used by Foote are advisable in conformity with modern usage. Thus Foote's 'schists' I find are better described as 'phyllites', using this term to describe rocks intermediate in crystalline character between slates and schists. The varieties of phyllite I noticed are chlorite-phyllite, sericite-phyllite, biotite-phyllite and chlorite-calc-phyllite [1]. These phyllites almost invariably contain magnetite, often to be distinguished with a lens as tiny octahedral crystals, and easily detected in the powdered rock with a magnet. The 'argillites' of Foote seem to be phyllites that have been chemically altered at the surface with the leaching out of various constituents and the leaving of a light-coloured rock—white, buff, pink—that can now often be best described as 'lithomarge'; some of it in fact is probably nearly pure kaolin. There is to be seen every variety of rock from the fresh phyllite, through decomposed rock—probably Foote's argillite—

[1] I have not proved that the rhombohedral carbonate is calcite.

still retaining the slaty cleavage or incipient schistosity of the phyllite, to variegated lithomarges still showing banding as far as colour goes, but often devoid of any remnants of the structures of the original phyllite or slate. The 'ferreous schists' and 'argillites' of Foote I regard as iron-impregnated and replaced phyllites.

Foote's term 'hematite quartzite' must be regarded as generic and not as accurately describing the mineral composition of nearly the whole of the rocks that he includes under it. It would be better replaced by 'ferruginous quartzite', for the reason that these quartzites where I came in contact with them were at least as often magnetite-or limonite-quartzites. In fact I think it is probable that the original form of the rock in most cases was a magnetite-quartzite[1], in which magnetite occurred in scattered grains and bands in a quartzite, the siliceous matter being on the whole much more abundant than the magnetite. The 'quartzite' part of the rock is often so fine-grained as to be better called 'jasper'. It is possible that there are some original hematitic beds amongst these rocks, and consequently some original hematite; but the majority of the hematite occurrences I saw seemed, wherever the evidence was at all clear, to be of secondary origin and the result of the replacement of other rocks at the surface by ferruginous solutions. The rock replaced was in some cases probably once a quartzite, perhaps ferruginous, but was also often the altered phyllites. If this view of the origin of the hematite-ores of the Sandur Hills be correct, they will be found to thin out in depth, in the same way as those of the Jabalpur district—supposed by Mallet to be of enormous extent—were shown to do by the prospecting operations conducted by Mr. E. P. Martin and Professor H. Louis[2], and in the same way as the manganese-ore deposits yet opened up have been found to do. If, however, any of the outcrops of hematite in this state do represent original deposits,—by which I mean the iron oxides laid down at the time of deposition of the Dhárwárs and since compressed, and probably rendered crystalline, during the earth-movements by which the rocks of the Sandur syncline were folded and metamorphosed,—then they may continue to great depths, in fact to as great depths

Ferruginous quartzites.

1 By this I mean the original form as a quartzite; for the Mysore geologists have a theory that some of these ferruginous quartzites have been formed by the chemical alteration of a rock rich in the iron-amphibole, cummingtonite.

2 *Agricultural Ledger*, No. 3 of 1904.

as the accompanying phyllitic rocks, and hence occur in great quantity. But the existence of original hematite deposits must not be assumed. Cases have been exposed of hematitic rocks being of superficial origin; but none have yet been exposed in this state in which it would be considered as evident that the ores continue to any considerable depth.

Basic igneous rocks.

Foote also mentions the occurrence in the Sandur rocks of interbedded traps, as well as intruded dykes. All the basic igneous rocks of which I collected specimens were found on microscopic examination to have once been plagioclase-augite-iron-ore-rocks, the iron-ore being ilmenite in most cases, and probably in all. Often the rock has been converted by alteration into an epidiorite, with chlorite, epidote, zoisite, and uralite, as secondary minerals. When fairly fresh, however, the rocks could be termed dolerites or gabbros, according to the coarseness of grain, or augite-diorites, if the term gabbro be considered objectional in the case of a dyke-rock free from olivine.

Granites and gneisses.

The plutonic granitoids and metamorphic gneissoids of Foote are granites, gneissose granites, and gneisses, mostly biotitic, or with the biotite chloritized. In the granite of Bellary Fort Hill I found abundance of idiomorphic sphene, and in a gneiss from Gunda near the foot of the Rámandrug ridge, scattered pyrite.

Relations of the granites and gneisses to the Dhárwárs.

With regard to the relations of these crystalline rocks—granites, gneissose granites, and gneisses—to the Dhárwárs, Foote says, referring to the writings of Newbold [1]:—

'The principal point on which his views cannot now be accepted is his assumption that the schistose bands in the peninsula have been brought into their present positions by being broken through by great outbursts of granite. At first sight this appears to be the case, but on closer and more extended examination of the country this idea is found to be untenable, for the old granitoids are nowhere seen to be irrupted into the schists; on the contrary the latter were deposited on the former by quiet, long-continued sedimentary action. This is of course a total change in the relative positions of the two rock series: the granitoids assume their true position as the true fundamental rocks of the country, and the schists are seen to be vastly younger in age than Newbold supposed them to be.

[1] *Loc. cit.*, p. 22.

'The granitic intrusions in the schist series which Newbold regarded as intrusions of the granitoid mass are all found to be intrusions of much younger pegmatoid veins, and of very small extent and importance'.

It is curious how ideas change. During the last few years the Geological Survey of India has been arriving at the conclusion that these very crystalline granites, showing little or no evidence of having suffered structural deformation under the influence of tectonic movements, are really younger in age than the crystalline schists and foliated and schistose gneisses, which all show such abundant evidence of having been subjected to prolonged and severe compressive movements. Thus the Bundelkhand Granite is younger than the Bengal Gneiss, the Bellary Granite than the Salem Gneiss. Similarly the Dhárwár rocks, being less severely metamorphosed forms of portions of the ancient schists and gneisses, are now regarded by some as older than the Bundelkhand and Bellary Granites. The evidence of intrusive relations that Foote had not discovered have since been found in more than one part of India, as, for example, by myself at Jothvád in Nárukot State, and by the Mysore Geological Department at several localities in Mysore[1].

Lateritic rocks and hematitic breccies.

Capping the Rámandrug ridge, on which it gives rise to a plateau and also covering a considerable portion of the Kamátaru plateau, is a rock that Foote refers to as 'pseudo-laterite' in the following words [2]:—

'The summit of the Rámandrug ridge is very frequently much obscured by hæmatitic *débris* which occurs in two forms: firstly, as an ordinary pseudo-laterite, either massive or encrusting, and secondly, as a breccia of angular fragments of hæmatite rock, often very rich in iron and of a deep reddish or blackish purple colour. The enclosed fragments are of all sizes. Masses of the hæmatite rock *in situ* often protrude through the overlying breccia, and where the beds are much crumpled it is often hard to be sure whether the protrusions are parts of the breccia or part of the rock *in situ*. These protrusions are so frequent and large that the breccia cannot be shown on the map as a continuous deposit'.

As far as I could see there was every passage from this 'pseudo-laterite' into the hematitic breccia, the 'pseudo-laterite' being formed from the breccia by chemical alteration, in which the iron oxide of the hematite passes into solution and gets redeposited in the hydrated

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1 *e.g.*, *Rec.*, *Mysore Geological Department*, III, p. 16.
2 *Mem. G.S.I.*, XXV, p. 100.

limonitic form with all the structures characteristic of laterite. In fact I can see no reason why the rock should not be called 'laterite', without the prefix 'pseudo'. It is as true laterite as any other. The only difference is that here it can be seen in process of formation, the process being the chemical alteration of the hematitic breccia, and o the same rock *in situ*, and in some places of manganese-ore, the lateritization in the latter case being doubtless mainly one of replacement of manganese-ore by iron oxide. Some good examples of this lateritization of manganese-ores are to be seen amongst the outcrops of manganese-ores on the Kamátaru plateau, where irregular tubes, patches, and processes, of limonitic laterite are seen protruding down into the manganese-ore; sometimes when there has been an open space along the bedding planes of the manganese-ore the laterite has grown down the crack, doubtless enlarging the width of the space by replacing the manganese-ore. Specimens can be collected showing residual pieces and patches of manganese-ore in the laterite. It is true that this laterite is often in patches only a foot or two across; but that is because it starts to form thus, these patches growing till they join, and not because it is not laterite. At Rámandrug, on the other hand, although there are frequent projections of the underlying rock—not only hematite as noticed by Foote, but manganese-ore at least as often as iron-ore, the two looking very much alike until broken open—yet the laterite is often of considerable thickness; in fact, I saw it up to about 30 feet thick covering the manganese-ore deposit of Rámandrug No. 4. This lateritic capping to the Rámandrug plateau gives rise, like other lateritic cappings in other parts of India, to vertical and rugged scarps, although only of small thickness. This laterite is usually like the laterite of other parts of India in its freedom from manganese—except included pieces or residual patches of manganese-ore derived from the underlying manganese-ore deposits; but in a few cases it contains manganese that seems to have been deposited with the iron as a part of the process of lateritization, as, for example, on Prospect Point at Rámandrug, where there is some pisolitic laterite with black manganiferous outer layers to some of the pisolites. This laterite contains remains of altered phyllites. Sometimes these lateritic deposits are free from all included or residual fragments; but, as noticed by Foote, they sometimes take the form of breccias cemented together by oxide of iron.

In other cases the included fragments are rounded, suggesting that they have been water rolled before being cemented by the oxide of iron. This is probably the truth in some cases, but in others I am inclined to think that the rounding of the fragments is due, not to their being cemented detrital fragments, but to their being the remains of a rock that has been partly replaced by secondarily deposited oxide of iron, the replacement tending to leave the residual fragments with rounded outlines.

The manganese-ore deposits.

We can now pass to the consideration of the manganese-ore deposits. As already mentioned, Mr. Ghose has located some 90 of them. They all lie in the western and southern parts of the State. The North-eastern and Donimáli ranges forming the north-eastern boundary of the State have not yet been prospected, except for a couple of days spent by Mr. Ghose in the North-eastern range. This led to the location of one deposit (Hirai Gangádi) near Joga village; further prospecting of this and the Donimáli Range may lead to the discovery of many other deposits. The deposits located by Mr. Ghose may be divided into four groups:—

1. The Rámandrug deposits,
2. The Kannevihalli deposits,
3. The Kumáraswámi deposits,
4. The Kamátaru (or Kammátharuvu) deposits.

The Rámandrug deposits all occur within about a mile of Rámandrug, and are situated mostly on the edge of, or a little down the west slope of, the plateau. The Kannevihalli deposits are situated on the hills for a distance of about $1\frac{3}{4}$ miles on either side of the Oblagandi gorge, where the Narihalla enters the syncline. The Kumáraswámi deposits are situated partly on the top of the plateau, and partly down the outer slopes of the hills in the south western corner of the State. They are all within $2\frac{1}{2}$ miles of Kumáraswámi Pagoda. The Kamátaru deposits lie on the southern side of the State near its south-eastern corner, and are partly on top of the plateau, and partly on the S. E. and S. W. slopes of a bay in the hills projecting up from the south.

All these deposits lie within State lands, except some of those in the Kámaraswámi area that lie within the Swamihalli Jágir, and most of the deposits on the Kamátaru plateau, which lie within the Kammátharuvu Jágir. Both these jágirs are held by the Kumáraswámi temple, of which the Raja of Sandur is the hereditary trustee. Since all the manganese-ore deposits of the Sandur State lie in the hill ranges, which are forest-covered over nearly the whole of their length, all the deposits that lie outside the two jágirs mentioned above are in State Forests, a portion of which has been leased to the British Government for a number of years, in consideration of an annual payment to the Sandur State. The mining rights are, however, retained by the State.

List of deposits.

A map of this State, kindly supplied by Mr. Ghose and on which he has mapped in the manganese-ore deposits, shows 9 deposits in the Rámandrug area, 10 in the Kannevihalli area, 20 in the Kumáraswámi area, and 27 in the Kamátaru area. This makes a total of 66 deposits. In addition there are 20 other deposits of which the exact positions on the map had not been identified. By enquiry amongst the inhabitants of the areas where the manganese-ore deposits occur, Mr. Ghose has found that each of these deposits has a vernacular name. The name applies of course not to the deposits as such, but to the separate hillocks, hills, and outcrops, etc., in which they appear. The names are in Kanarese and are of a descriptive character, such as Yelakála Gadda meaning 'rocky place', and Alada-marada Banda meaning 'banyan-tree outcrop'. Mr. Ghose says that he confirmed these names by getting them from more than one person. For the sake of future reference I give below a list of the deposits discovered by Mr. Ghose with the names that he has assigned to each.

Group I.—The Rámandrug deposits.

1. Sannasil Haruvu.
2. Kurubara Matti.
3. Rámandrug No. 4.
4. Rámandrug Main Bed.
5. Rámandrug Cemetery.
6. Rámandrug Barracks.
7. Ramandrug Fortwall.
8. Faringhi Kotal.
9. No name assigned.

Group II.—The Kannevihalli deposits.

10. Gedel Tattu Haruvu.
11. Seshagiri.
12. Gedel Tattu.
13. Bora-marada Penta.
14. Achcha Kolla.
15. Mottu Kolla.
16. Ganigithi Kolla.
17. Alada-marada Banda.
18. Mudiki Thaggu.
19. Budana Gundu.

Group III.—The Kumáraswámi deposits.

20. Hatti Penta.
21. Iruku Kolla.
22. Ullu Basappana Maradi.
23. Sábe Kolla.
24. Boki Kolla.
25. Dumku Nír Kolla.
26. Nawalswámi Kativi.
27. Táreard-marada Kolla.
28. Subráyanhalli Nír Kolla.
29. Káradi Kolla.
30. Kaniga-marada Kolla.
31. Chennangi-marada Kolla.
32. Mottu Kolla.
33. Sillu Kolla.
34. Tápál Paddi.
35. Hulisatta Bandi.
36. Badial-marada Kativi.
37. Erakan Múle.
38. Yelusuttina Kote.
39. Bandijádi Kativi.

Group IV.—The Kamátaru (or Kammát Haruvu) deposits.

40. Pám-kollatha Tattu.
41. Dánada Thurumandi Banda.
42. Nágappana Banda.
43. Gale Banda.
44. Kare-marada Banda.
45. Yelakála Gadda.
46. Maleva Gadda.
47. Badapatti Banda.
48. Anne-marada Gadda.
49. Done Banda.
50. Kenchamman Dona.
51. Chtiradevara Gadda.
52. Alada-marada Banda.
53. Durgámma Kolla.
54. Kaldi Gundu.
55. Pilál-marada Gundu.
56. Karada Badasála Kativi.
57. Jaldi Kolla.
58. Mála Kolla Banda.
59. Jánál Haruvu.
60. Hanumánthana Kativi.
61. Pathargani Múle.
62. Chintamon Banda.
63. Hunáse-marada Kativi.
64. Kánakeri Wáde.
65. Yerindári.
66. Jogánnaditha Kolla.

Deposits whose position has not been accurately identified on the map.

67. Etti Már Kolla.
68. Mottu Kolla.
69. Alada-marada Haruvu.
70. Mát Kolla.
71. Jánekál Haruvu.
72. Done Kolla.
73. Bora-marada Dinne.
74. Káradi Kolla.
75. Kadlekan Haruvu.
76. Mín Kolla.
77. Ager Gundi.
78. Manal Haruvu.
79. Budana Gundu.
80. Chinna Budana Gundu.
81. Girenáth Kolla.
82. Gadigál Tattu.
83. Tambalnaikana Paddi.
84. Miásal Haruvu.
85. Kattedár Boilo.
86. Kabbangoi Tattu.
87. Hirai Gangádi.
88. Agasár Tattu.
89. Haltimara Doni.
90. Rám Kolla.

Place names.

The last word in each of the above names describes the sort of topographical feature. It would take up too much space to give the meanings of these names; moreover, this is unnecessary, because Mr. Ghose proposes, in a paper he has in hand on the manganese-ore deposits of the Sandur State, to give a section on the place-names, on account of the remarkable precision they indicate amongst the inhabitants of these parts in the distinction of different sorts of natural features one from another.

Although Mr. Ghose has named these as 90 different deposits, this is only because they are separate outcrops. Many of them are close together and on the same line of strike. Some of these, when opened up, will doubtless be found to be continuous with one another, whilst some, though close together, will probably be found to be separate.

Deposits visited.

In my brief visit I was able to visit only a few of these deposits. Near Rámandrug I saw Nos. 1, 3, 4, 6, and 9. Of the Kannevihalli deposits I probably crossed Nos. 10 and 12. At Kamátaru I spent two days only; but under the guidance of Mr. Ghose I was able to examine, though in most cases only cursorily, Nos. 40, 41, 45, 47, 52, 53, 55, 56 and 63.

Nevertheless, I saw all the deposits that had been opened up, namely, those at Rámandrug; and, according to Mr. Ghose, a typical selection of the remainder. I must confess that the Kámataru deposits, which seem to be the best yet discovered in these hills, seem all very much alike on their outcrops. The chief differences are in size and actual position, *i.e.*, on the plateau or down the slopes—and not in character of the ore. Consequently, I think I am in a position to judge of the mode of occurrence and origin of the Sandur deposits almost as well as if I had examined every one of them with the greatest care.

Situation of the deposits.

The Sandur deposits crop out either on the tops or edges of plateaus, such as those of Kamátaru and Rámandrug, or on the slopes of the hills; whilst detrital deposits, none of which are included in the foregoing list, may occur on the slopes or at the foot of the range below the deposits *in situ* from which the detritus has been derived. On the tops of the plateaus the deposits tend to be obscured by the lateritic deposits to which the plateaus seem to be due. Those deposits that occur on the slopes of the hills usually occur on the outer slopes facing the low-lying ground outside the syncline; but a few have been found, in the Kannevihalli and Kumáraswámi areas, on the inner slopes of the hills, facing the interior of the synclinal basin. Those deposits that crop out on or near the top of the ridges or plateaus are often 1,200 to 1,300 feet above the plains at the foot; whilst those on the slopes occur at lesser heights, but probably rarely less than 800 feet above the plains. Wherever a deposit crops out it tends to have a very rugged, rough, and irregular surface, so that at first sight it might often be mistaken for laterite.

Outcrops lateritoid and lichen-covered.

This character is not universal, however, for the outcrops often show signs of dip and strike; and, when they do, the indications are that the manganese-ore deposits agree in strike and dip with the other rocks of the syncline. But whether lateritoid in aspect or not, the outcrop is usually whitish as seen from a distance, owing to a coating of lichens. This lichen-coated outcrop is not confined to manganese-ores. The iron-ores have a similar outcrop, so that until one has had long experience of these outcrops, it is usually necessary to blaze every one of them to ascertain if the deposit be of iron or manganese. For sometimes where not lichen-covered, the manganese outcrop takes on a brownish or reddish colour, due to ferruginous coatings, and sometimes the iron outcrops are black in colour due to the ore being a compact metallic blue-black hematite. Mr. Ghose gives it as the result of his experience in these hills that an outcrop with white lichens invariably indicates either manganese- or iron-ore. I did not notice anything to contradict this whilst in Sandur. But in Mysore, where also iron- and manganese-outcrops are usually lichen-covered, I found examples of quartzite with a similar covering.

Prominence of the outcrops of manganese- and iron-ore.

Owing to the fact that the manganese- and iron-ores are both very resistent to weathering, whilst the associated rocks,—namely phyllites and slates, with only subordinate quartzites—are very soft and weather easily into clays, the manganese- and iron-ores seem to predominate and the other rocks to be insignificant in amount, their outcrops being covered either with soil or with the débris of the harder manganese- and iron-ores. One is very liable therefore to form an exaggerated idea of the enormous quantities of ores of manganese and iron to be obtained in this State. As an example I may mention that during two days' wanderings on the deposits round Kamátaru, I saw no other rocks than manganese-ores, iron-ores, and laterite. After discussing the origin of these deposits I shall show, however, that, although the quantities of manganese-ores in these hills are very large, yet they are not nearly so large as seems at first sight to be the case.

Manganese-ore deposits apparently beds, but really surface replacements.

From the outcrops one would imagine that the manganese-ore deposits are of the nature of beds; for they sometimes show fairly distinct signs of bedding, which is conformable with the bedding of the other rocks in these hills. Until some of the Rámandrug deposits had been opened up, it was not possible to say that this was not the truth. The work carried out by Mr. Ahlers in developing these deposits has shown that they are of superficial character, and probably do not extend to greater depths than 50 to 100 feet below the original outcrops. The best example is at Rámandrug Main Bed. The section across the deposit is probably somewhat as in figure 76. At the top is a capping of several feet of laterite, which occupies the surface of the plateau at this point. A little below the top the outcrop of manganese-ore begins and had been extensively quarried into at the time of my visit.

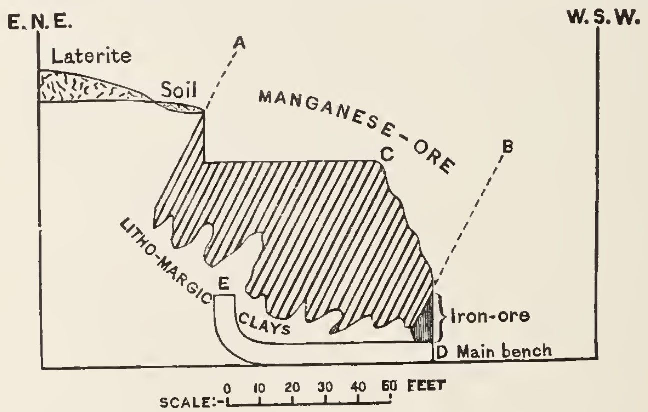


Fig. 76.—Section across Rámandrug Main Bed deposit.

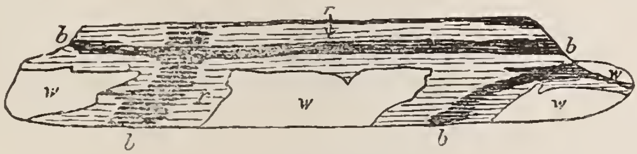
From the working faces in this quarry one would judge the deposit to be a true bed of manganese-ore dipping into the hill-side at an average angle of about 65°, and possessing a thickness of not less than AB, or about 90 feet. The outer or lower boundary of the bed was seen in the face CD, where the manganese-ore seemed to rest upon a few feet of iron-ore and this upon soft white lithomargic rock, the whole being apparently conformably bedded; but the inner edge of the supposed bed was not exposed, being covered by the lateritic rock. Hence 90 feet is only the minimum thickness of this apparent bed. To test the continuous-bed hypothesis Mr. Ahlers drove the tunnel DE into the working face below the level of the base of the manganese-ore in the face CD. I was driven in a total horizontal distance of 66 feet, with a total rise of 20 feet at the inner end, and had the 'bed' been continuous should soon have cut the manganese-ore. But, except for a few tiny segregations of manganese-ore, and veinlets of limonite, it showed not a trace of either manganese- or iron-ore. Instead of this it was all the time in variegated banded lithomargic clays, which did not have such a steep dip as the manganese-ore 'bed' on the outcrop. My explanation of this phenomenon is shown in the section in figure 76, in accordance with which I suppose the manganese-ore deposit to have been formed at the surface by replacement, either of the clays or of the rocks of which they are the alteration products, by manganese oxides deposited from percolating waters. I must say that Mr. Ahlers had already come to this conclusion before I visited the place, and that we agree in a general way as to the origin of these manganese-ore deposits The evidence of the two other deposits that have been opened up, namely Sannasil Haruvu and Rámandrug No. 4, point to the same general conclusions as to the origin of the ores.

Evidence supporting the superficial replacement theory.
The Naráyandevarkerra Ghát Sections.

We can now consider this theory in more detail. Many interesting sections are to be seen in the road-cuttings on the ghát road leading down from Rámandrug to Naráyandevarkerra, a village in the plains to the west of the Sandur synclinal. At many places on the way down are to be seen sections showing nodules of manganese-ore in the altered phyllitic rocks. They are usually of ovoid or flat lenticular shape, a few inches long, with their length parallel to the cleavage and bedding—which are usually coincident—of the rock. From these nodules small stringers of manganese-oxide are seen to ramify out into the phyllitic rock, their direction tending to follow the lamination. In one place a section is exposed showing the altered clayey rocks traversed by a network of quartz veins. In this section there are also numerous nodules and veinlets of manganese oxide. These not only cut the clayey rock irregularly as regards the bedding or lamination, but they also cut the quartz veins, showing that they have been formed after the quartz veins, and therefore after the phyllitic rocks that the quartz veins have pierced. This is supported by microscopic examination, which shows that these nodules have been formed by replacement of the phyllitic rocks, remains of which they almost invariably contain. Other sections on this ghát road show small thicknesses of massive quartzites. These also have been in places impregnated with manganese oxide so as to be quite black, though still containing a large percentage of quartz; whilst in other places nodules of manganese-ore have been formed in them, this ore being sometimes good hard metallic psilomelane, though never present in sufficient quantity to be worth extraction. Any one examining these sections would, I think, agree with me, that in every case the manganese-ore is subsequent in time of deposition to the containing clayey rock. Moreover he would agree that this clayey rock, which is often a variegated lithomarge, has been formed by the alteration of the phyllites seen fresh in some places. He would further agree that there was some connection between the alteration of the phyllites and the presence of manganese-ore.

Rámandrug Main Bed sections.

Let us now turn to Rámandrug Main Bed. There, at the N. W. end of the main bench, is a good exposure, beside the tramway line to the ropeway at Prospect Point, of some of the rocks forming the 'country' on the foot-wall side of the deposit. The fresh form of the rock is a fairly hard greyish rock of rather dark grey colour with a greenish to brownish tinge. This rock dips into the hill-side conformably with the ore-deposit and is finely laminated parallel to the dip. It would probably be best described as a laminated siliceous magnetite-slate, tending to be flaggy. Under the microscope it shows a fine grained mixture of magnetite and quartz, with limonite and a micaceous mineral. The rock is fairly heavy, and small chips of it are easily picked up by a magnet. It also gives a fairly strong reaction for manganese, showing that this element is present in appreciable amount. It is not, of course, possible to be sure that this manganese is an original constituent and was not introduced by percolating solutions; especially when there is such an abundance of manganese-ore close at hand. But the rock seems to be fresh. It is only a portion of the rock in this exposure that has the characters given above. The remainder has suffered a partial alteration of a very interesting character. The altered rock, which is illustrated in the accompanying figure (77), appears variegated in patches of red, white, and black. The black part is almost invariably separated from the white by a zone of red colour, as indicated in the figure. A careful study of the rock *in situ*



b = black;
r = red;
w = white.

Fig. 77.—Piece of altered magnetite-slate.

has suggested that the probable explanation of the phenomenon is that under the influence of solutions saturating the rock the iron and manganese have started to segregate. The manganese has segregated faster and retreated into the thin black zones marked 'b' in the figure. [Occasionally the very centre of the black band is occupied by a thin veinlet of psilomelane, marking the final stage of concentration.] The iron has retreated less rapidly than the manganese, forming red zones (r) on either side of the manganese bands. In so doing the iron, which was partly in the protoxide form in the fresh rock (as magnetite), suffered peroxidation with the formation of the red colour. The white part represents the rock bleached of its manganese and a part of its iron; for it has not lost all its iron and gives a slightly reddish streak, due to the fact that the portion of the iron that has not retreated into the red zones has been peroxidized in the same way as that which has retreated. In one place the beginning of the change is seen in the appearance of a small red area in the midst of the otherwise fresh rock. Doubtless this patch would have continued to grow with the retreat towards its edge of the manganese, and later, as the patch became larger, a white spot would have appeared in its middle, and this, with the retreat of the iron after the manganese, would have increased in size until the retreat of iron and manganese could go on no further, on account of being stopped by manganese and iron retreating from another white patch. What this occurrence seems to me to teach is that firstly there are still rocks near the manganese-ore deposits containing original manganese, and, secondly, that there is a great tendency for changes to be set up in such rocks with the segregation of the manganese and iron, not only from the other constituents of the rock, but from each other. The foregoing deductions are more or less confirmed by the fact that the black zones react for manganese rather strongly, probably more strongly than the original rock, though it would need a quantitative test to confirm this; whilst the red zones and white zones do not yield any appreciable quantity of manganese although, it will be remembered, the fresh rock contains it.

Further along the tramway line to the ropeway a second somewhat similar section is to be seen. Dark irregular drawn-out patches are thickly scattered through a light ground. The light parts represent what now look like soft white shales, whilst the darker parts are yellow ochre in colour and are almost invariably separated from the white portions by a thin zone or layer ($\frac{1}{8}''$ to $\frac{3}{16}''$ thick) of hard limonite. This, then, is another example of segregation, the segregating material being in this case iron alone. Either the original phyllite or slate did not contain any appreciable quantity of manganese, or the manganese it contained was removed during the changes by which the iron was made to segregate. Considering the large amount of iron present, it is possible that some of it has been introduced by the waters causing the segregation

The Rámandrug lithomarges.

Underlying the deposits at both Rámandrug Main Bed and No. 4 there is a large amount of variegated and banded lithomargic rock. This rock at No. 4 contains numerous black patches of wad and occasional segregations of harder ore (psilomelane). Moreover, the manganese-ore deposit at No. 4 is seen to send down 'roots' or projections of manganese-ore into this lithomargic rock, as shown diagrammatically in figure 78. At Rámandrug Main Bed, as already noticed on page 1007, a tunnel driven into the working face has shown that the manganese-ore does not continue down on its dip for any depth, but gives way to these lithomargic rocks.

Summary of origin.

On page 1016, in noticing the manganese minerals found in these deposits, I have described how the psilomelane and wad have been derived by replacement from phyllitic rocks. What I think all the foregoing evidence, taken in conjunction with this, points to is that where these manganese-ore deposits now are there were originally phyllites, containing both magnetite and a small quantity of manganese. Waters then percolated through the masses of rock and took the manganese and iron into solution, leaving the leached rock behind in the form of a lithomargic mass of variegated colour. The solutions containing manganese and iron may not have deposited their burden exactly in the same place as where they obtained it. They had the whole length of the Sandur Hills in which to operate. Where, however, conditions were favourable the manganese and iron in solution, doubtless as carbonates, were oxidized and deposited, though not usually in the same places. Once a certain quantity of one element had been deposited, segregative tendencies would probably come into play and cause the selective deposition of further quantities of the same substance at the same place—the other constituent being carried further on and deposited elsewhere, in some cases close by, and in others at a considerable distance. Wherever the deposition took place, solution of the phyllitic rock, in some cases fresh and previously unaltered, and in other cases already altered during the leaching out of its iron and manganese, had to take place to make room for the substance being deposited. Thus it is that the deposits seem to have been formed by metasomatic replacement. From the fact that the manganese-ores so often contain magnetite, it looks either as if the magnetite were less soluble than the manganese in the phyllite, or as if in a very large number of cases the rock replaced by the manganese-ore were fairly fresh. As regards the disposition of the material taken into solution when the manganese was deposited, the same difficulty arises as in the Central Provinces. In some cases, perhaps, the masses of lithomarge associated with the manganese-ore deposits represent the aluminous material taken into solution. But, considering the banding and remains of original structures of phyllitic rocks these lithomarges show, this does not seem very probable. Hence it seems necessary to suppose that the aluminous and siliceous material of the replaced rocks was usually completely carried away in solution.

Depths to which deposits extend.

At Rámandrug Main Bed, as will be seen from Fig. 76, the manganese-ore extends 50 feet, or a little more, inward from the original outcrop along the bedding planes of the replaced rock. The depth at Rámandrug No. 4 is about the same; whilst the indications at Sannasil Haruvu are that the bottom of the manganese-ore will be reached at a similar depth. It is perhaps hardly fair to judge from these three deposits situated in one part of the State as to the depth to which the deposits in other parts will be found to continue. In the Kamátaru area, where no work has been done on the ore except to break up a few surface boulders, the ores seen in the outcrops display all the mineralogical and structural peculiarities of the Rámandrug ores. Hence we can fairly suppose that, like those of Rámandrug, the Kamátaru ores have been formed by superficial replacement, although one would never have supposed it had the Rámandrug deposits not been opened up. At Kamátaru, however, it is probable that the ores sometimes continue to a greater depth than at Rámandrug. In the first place, the tendency with deposits formed by superficial replacement is for the ores to be best in quality at the surface, and to become poorer, owing to the presence of a larger residue of the original rock material, the greater is the depth from the surface. In discussing the minerals of the Sandur deposits I have mentioned that the ores at Kamátaru are generally of higher grade than those at Rámandrug. The meaning of this may be that the Rámandrug deposits have been eroded to a greater dehth from the surface than those of Kamátaru, or that the replacement at Kamátaru has been more complete. In either case we should expect the Kamátaru deposits to extend to a greater depth from the surface than those of Rámandrug. That this is probably the case in at least one or two cases is indicated by the outcrops. Thus at Durgámma Kolla there is a very fine cliff-like outcrop a little below the edge of the plateau (see Plate 46). It is 48 feet high at its highest point, and one may conclude from this that the manganese-ore may continue in depth for a greater distance than 50 feet from the top of the outcrop along the direction of bedding of the replaced rock. Nevertheless, it is not probable that any of these deposits, except perhaps with rare exceptions, continue inwards for greater depths than 100 feet.

Possibility of original beds or lenses of manganese-ore.

I have assumed, on account of the similarity of ores, that all the deposits are of the same origin as those of Rámandrug. Considering, however, that only three deposits have yet been opened up, it is necessary to recognize the possibility that some of the outcrops may represent original manganese-ores deposited contemporaneously with the enclosing rocks, and therefore, like them, possibly extending to considerable depths. But if any deposits of manganese oxide were laid down during the period of sedimentation of the Dhárwárs, it is more probable that the deposits were of lenticular shape, than that they were continuous beds like the sandy and clayey sediments. And in this case such an original deposit would thin out lenticularly in depth, although it might be taken up again by other lenses deeper down along the dip of the rocks.

Width of the deposits.

We can now turn to the question of the width of these deposits. At Rámandrug Main Bed the full width, across the strike of the Dhárwár rocks, to which the rocks have been replaced with the formation of the marketable manganese-ores, has not been exposed. As shown in the figure 76 on page 1006, it is at least 90 feet. At Rámandrug No. 4 the width of the manganese-ore deposit across the strike of the rocks is about 90 paces as paced on the top of the plateau above. If the interpretation of the structure of this deposit given in figure 78 be correct, however, this 90 paces must be greater than the true thicknes, owing to the rolling of the replaced beds. About 100 feet would probably be about the true thickness of the rock replaced by manganese-ore. Nevertheless, the effective width of the deposit itself is the 90 paces, if the depth of the deposit is only to be reckoned as 50 feet. At Sannasi Haruvu it is about 245 feet across the strike of the manganese-ore deposit, of which an actual thickness of 110 feet may be considered as the maximum for the manganese-ore, the remainder being iron-ore (see page 1021). Many of the Kamátaru deposits have outcrops of considerable width. Thus the Alada-marada Banda deposit is 46 paces across, the Durgámma Kolla outcrop 133 feet wide, the southern outcrop of Hunase-marada Kativi 84 feet across, and the northern outcrop of the same deposit 200 feet across.

Length of the deposits.

The length of many of these deposits is considerable. Sannasil Haruvu I measured as 408 feet; the Rámandrug Main Bed is probably at least 700 feet long, although it would be difficult to give an accurate figure without a careful survey; Alada-marada Banda is 112 paces long; Durgámma Kolla is 423 feet long (according to Mr. Ghose); the southern outcrop of Hunase-marada Kativi is 357 feet, and the northern about 500 feet long. Many of the deposits show, of course, outcrops of less length and breadth than the figures given above.

Quantities of ore.

We can now make a rough guess at the amount of ore available in the Sandur Hills. Mr. Ghose thinks that if we take the 40 largest deposits the average length can be taken as 400 feet, and the average width 50 feet. If we assume that the average depth to which each deposit extends is only 50 feet, then the number of cubic feet of ore is $400 \times 50 \times 50 \times 40 = 40{,}000{,}000$, which, taking an average specific gravity for the ore of only 3·5, =

$$\frac{40{,}000{,}000 \times 62{\cdot}5 \times 3{\cdot}5}{2240} = 3{,}900{,}000 \text{ tons approximately.}$$

If the average depth to which the deposits extend be taken as 80 feet instead of 50, then the amount of ore works out as $6\frac{1}{4}$ million tons. Mr. Ghose regards even the latter as a conservative estimate. These figures have to be reduced, however, to allow for interbanded iron-ores; nevertheless considering the fact that on opening up a deposit the length and width are often found to be greater than indicated by the outcrop, I am inclined to agree that they do not overstep the mark. Probably if we allow for the other 50 deposits, and for deposits in other parts of the State not yet explored, it will not be exaggerating to say that there are probably 10,000,000 tons of manganese-ore to be extracted in this State. A considerable proportion of this 10 million tons will, however, be fairly ferruginous, and have to be sold as ferruginous manganese-ore, rather than as manganese-ore proper. Nevertheless, making all deductions there can be no doubt that there are large quantities of manganese-ore in the Sandur Hills. The figure given above can only be regarded as a guess. It is, of course, possible that it not only does not overshoot, but that it is very much below, the mark. This can only be shown in years to come as the deposits are further opened up.

Are the quantities of ore too large to have been formed by superficial replacement.

Considering the enormous quantities of manganese-ore that must be allowed to be present in these hills even on the most conservative estimate, one cannot help wondering if the mode of formation ascribed to them above is adequate to account for their accumulation. It must be remembered that even if we allow—simply for the sake of argument, and probably much overstepping the mark—that the manganese-ore deposits of this State contain in all 100,000,000 tons of ore, and that the average manganese contents of the ore is 50 per cent., which also oversteps the mark, so that we allow 50,000,000 tons of manganese to be present, yet this forms a very small proportion of the whole of the mass of rock composing these hills. Thus, one cubic mile of rock alone, of specific gravity 2·7, would weigh 11,090,000,000 tons; so that, even if all the manganese had been derived from a cubic mile of rock only, it would correspond to 0·45% only of manganese in the original rock. Now the average amount of manganese in the earth's crust is usually taken as about 0·08. If the whole of the 50,000,000 tons of manganese had been derived from 6 cubic miles of rock only, it would correspond to only 0·075% manganese in this rock But there are many times this amount of rock in the Sandur Hills; and even though the solutions producing the surface replacements did not, in all probability, draw on nearly the whole of this rock for their manganese, yet it will be seen that the amount of manganese in the fresh rocks must have been amply sufficient to give rise, by the process of secondary replacement, to the manganese-ore deposits we now find. It is further to be remembered that the rocks with which the manganese-ores are associated were probably more or less contemporaneous in time of formation with the manganese-bearing rocks of the Central Provinces. And it may easily have happened that at the same time as there was a great precipitation of manganese oxides taking place in the Central Provinces and Central India, the deposits being formed in other Dhárwár areas, although not sufficiently manganiferous, except perhaps in rare cases, to be called manganese-ores, were yet often more highly manganiferous than usual. So that if it be considered that an average amount of 0·08 per cent. of manganese in the rocks of Sandur would not have been sufficient, considering the amount of rock that is likely to have been drawn upon, to provide all the manganese now concentrated in the deposits at the surface, it would not be unreasonable to suppose that the average amount of manganese in the Dhárwárs of Sandur, and for the matter of that in other Dhárwar areas of India, was considerably higher than 0·08 per cent.

The manganese minerals present.

The principal minerals in the manganese-ore deposits of the Sandur Hills are psilomelane and wad, with subordinate amounts of pyrolusite, of altered manganite ('pseudo-manganite'), and of a hard grey crystalline mineral. The typical ore is an irregular mixture of psilomelane and wad, in which both minerals often contain minute scattered octahedral crystals of a very magnetic mineral that is in all probability magnetite. It might possibly be mangan-magnetite; but this it is not possible to test, because it would be impossible to be quite sure that any grains of it when isolated were free from attached or included manganese-ore. These magnetite grains are identical in shape and size with those to be found in all the phyllites and slates of these hills. Further the ores often contain fragments of altered rock of slaty aspect, usually with a reddish streak; these, which also contain the tiny magnetite octahedra, must be regarded as altered phyllite or slate, often impregnated with or partly replaced by iron oxide. An examination of specimens containing such fragments shows that this altered phyllite or slate passes gradually into wad, the streak changing from reddish through chestnut to blackish brown, probably as the percentage of manganese increases. The wad retains both the slaty structure and the magnetite grains of the phyllitic rock. Further, in the specimens in which it is mixed with psilomelane, it looks as if the wad finally passes into psilomelane, probably by the accession of more manganese. The psilomelane itself, although it does not show the slaty structure of the wad and altered phyllite, yet often does show a roughly laminated structure, parallel to the bedding of the phyllites and wad. From this it seems inevitably to follow that the psilomelane is the final product in the passage of phyllite into manganese-ore by the process of metasomatic replacement: the first stage of the alteration is a soft slaty rock usually of ferruginous character, the iron itself being probably a secondary

Psilomelane and wad formed by replacement of phyllite introduction; the second stage is the production of wad from the altered phyllite, and sometimes direct from fresh phyllite by the introduction of manganese in solution, the wad retaining the original magnetite grains, lamination, and slaty cleavage, of the phyllite; the third stage is the conversion of this wad into psilomelane, the latter retaining the magnetite grains and often the original lamination planes of the phyllite, but not its cleavage. Some of the psilomelane looses even this lamination. The tell-tale to this process is the magnetite, which seems to be the only mineral of the original phyllite that has been able to resist solution and replacement, and consequently to remain in the finished psilomelane. This psilomelane is the compact dull grey variety, with little sparkle about it, except when it contains the glistening points of magnetite. It does not all contain admixed wad. Thus in the Kamátaru deposits the tendency is for the psilomelane to predominate, and the ores from this area are consequently of higher grade than those of the Rámandrug area, where the wad is much commoner.

Pseudo-manganite and pyrolusite in cavities.

As might be imagined, the ore produced by this process is often cavernous. Sometimes these cavities have been filled with various minerals. One of the commonest of these is the radiate fibrous mineral that I once described under the name of 'manganite'[1]. As I have noticed on page 84 the analysis of this mineral since made by Mr. Fawcitt shows that it has suffered partial alteration into pyrolusite. I have consequently made use of name 'pseudo-manganite' to express the fact that although it often has the physical properties of manganite to a large extent, yet it has usually been partly altered so as to be intermediate in composition between this mineral and pyrolusite. When in this intermediate condition it commonly shows a bronze tarnish. But it has frequently been still further altered with the production of radiate pseudomorphs of pyrolusite needles of rich black colour. Both these minerals may occur as radiations projecting freely into the interior of the cavities; or they may occur as radiations in the mass of psilomelane or wad without there being any open spaces. In these cavities botryoidal, or even stalactitic, linings of psilo-

Botryoidal and lead-like psilomelane.

[1] *Rec. G. S. I.*, XXXIII, pp. 229-232, (1906).

melane are sometimes present, instead of the pseudo-manganite or pyrolusite radiations; sometimes these linings of psilomelane form the basis on which the radiations rest. Traversing the ores in veinlets there is sometimes the lead-like variety of psilomelane. Not infrequently there are patches and veinlets of a bright grey metallic-looking mineral that has not yet been satisfactorily identified. It suggests hollandite in appearance. But it fails to give a satisfactory reaction for barium, whilst it contains a certain amount of silica. It is slightly magnetic, and fairly hard. Hence for the present it can be regarded as probably braunite; but this is not certain and needs confirmation by complete analysis, for it is not typical of braunite. It is also not certain that all the bright mineral is of one species. There may be some examples of hollandite.

Braunite? and hollandite?

I have very few data as to the chemical composition of the manganese-ores of the Sandur Hills. Though the ores often look as if they should contain sufficient manganese to be classed as first-grade, those mined at Rámandrug are partly of second and partly of third grade; and, generally speaking, it can be said that no first-grade ores have yet been mined in any quantity. The reason for this is that these ores usually contain a considerable amount of iron taking the place of a portion of the manganese that one would otherwise expect to be present from the appearance of the ores. But it is possible that when some of the Kamátaru deposits are opened up it may be found possible to obtain considerable quantities of ore running over 50% manganese. The following are some analyses supplied by Mr. Ghose of bulk samples of the ores of Rámandrug Main Bed. They were carried out by V. Spiera of Kámthi:—

Chemical composition of the ores.

	Average sample, foot of main outcrop, October 1905.	Average samples of stacks, January 1906.		
Manganese	48·60	43·69	40·26	47·65
Iron	12·74	12·89	12·54	11·17
Silica	0·70	0·80	1·15	0·90
Phosphorus	0·009	0·009	0·015	0·012

The following are some analyses, supplied by Mr. Aubert, of hand-specimens of ores from the Rámandrug deposit. They were picked to illustrate various types of ore. The analysts were Messrs. W. H. Pearson of London :—

	1	2.	3.	4.	5	6.
Manganese . .	54·39	53·54	50·05	41·21	39·47	47·84
Iron . . .	5·38	5·55	11·45	19·40	16·90	10·
Silica . . .	0·59	0·50	0·50	0·65	1·	0·3
Phosphorus . .	0·016	0·03	0·026	0·033	0·023	0·5

The means of the foregoing figures are the following :—

	Mean of 4 analyses of samples.	Mean of 6 analyses of hand-specimens.
Manganese	45·05	47·75
Iron	12·33	11·45
Silica	0·89	0·61
Phosphorus	0·011	0·030

From these it may be concluded that the average figure for the Rámandrug ores is—

Manganese	45
Iron	12
Silica	1
Phosphorus	0·02

But I believe that in actual practice the ore is found to be of lower grade than this.

The chief characteristics of the Rámandrug ores are thus seen to be the high iron, and very low silica and phosphorus. Besides ores corresponding to the foregoing analyses, large quantities of ores of much lower grades are also mined. They are characterized by lower manganese and correspondingly higher iron, but except occasionally are not at present made use of. Every grade of ore ranging from manganese-ores of the above composition through manganese-ores very high in iron and manganiferous iron-ores, to iron-ores very low in manganese, could be obtained, were there a demand for them.

I have no analyses of the Kamátaru ores. Mr. Aubert tells me, however, that several analyses of ores from this area range between the following limits :—

Manganese	44 to 56
Iron	13 to 4
Silica	1 to 0·50
Phophorus	0·01 to 0·03

Descriptions of Deposits.

My visit to the deposits of the Sandur Hills was so hurried and brief that I had to confine myself to a general survey of a few of them, in order to work out their origin and mode of occurrence, and was not able to give that attention to details, such as dimensions, dips, and variations in composition from one part to another of a deposit, as would have enabled me to give a connected account of each. To do this would be the work of some months. Hence I propose to supplement what has been written in the foregoing pages merely by a few notes on some of the deposits visited.

On page 1003 will be found a list of deposits divided into groups according to the area in which they occur.

Group I.—The Rámandrug Deposits.

In addition to the deposits listed on page 1002, which all occur on the edge of, or on top of, the Rámandrug plateau, there are several occurrences of manganese-ores of no commercial importance, but considerable scientific interest, to be seen in the sections on the ghát road down to Naráyandevarkerra. These have already been noticed on page 1007, and also by Foote. According to him [1] :—

'The schist beds in which the manganese-ore occurs in the form of compact earthy-textured, dark grey or black concretionary nodules, lie rather more than half-way down the ghat road which leads to Narayan Devar Kerra. The schists are drab in colour, and the nodules show up distinctly'.

A 'fair specimen' of this ore was analysed by Mr. Philip Lake, with the following result :—

Insoluble matter and SiO_2	38·96
$Fe_2O_3 + Al_2O_3$	12·82
MnO_2	42·90
CaO	0·78
Combined water	3·16
Moisture	0·67
	99·29

[1] *Mem. G. S. I.*, XXV, p. 194, (1895).

This corresponds to 27·12 % manganese. Foote suggests that the ore is braunite or hausmannite. The available oxygen is stated to be 7·33 %; accepting this, the 27·12 % manganese should have been returned as 39·86 % MnO_2 and 2·48 % MnO, instead of as 42·90 % MnO_2, the analysis then totalling up to 98·73 only. A simple calculation shows that 27·12 % Mn require only 10·52 % oxygen for hausmannite and 11·27 % for braunite, whilst 15·22 (42·34—27·12) is available. The analysis indicates, in fact, that the mineral is psilomelane, as indeed is shown by the physical characters of the specimen preserved in the Museum of the Geological Survey of India.

1. Sannasil Haruvu (Rámandrug No. 2).

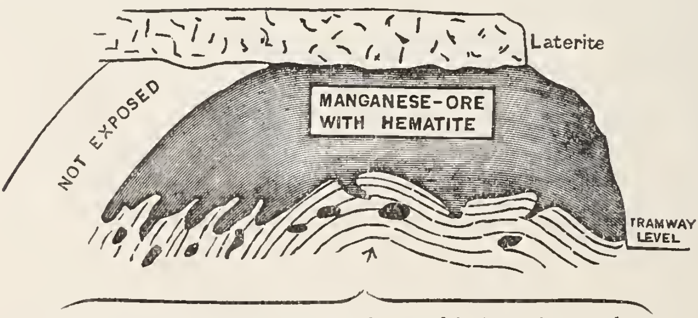
This is the most northerly of the Rámandrug deposits. It is situated $2\frac{5}{12}$ miles N. N. W. of the Rámanamallai G. T. S., 3,256 feet, on the top of a spur of the ridge, and must be about the same height above the plains as the other Rámandrug deposits, namely, about 1,200 feet. The length of the deposit, from the last outcrop seen at the N. N. W. end of the deposit, to the point where it begins to disappear down the slope at the S. S. E. end and is either covered up by débris or dies out, I paced as about 136 paces. The width measured by Mr. Ahlers across the strike at the point where the deposit is being worked is 245 feet. From the outcrop alone it is difficult to say what proportion of the total thickness consists of manganese-ore and what of iron-ore. The cuttings or workings on the north-east side of the spur on which the deposit lies show that there is a thickness of about 40 paces of iron-ore separating the manganese-ore into two bands. Hence it can be taken that one half the full thickness is manganese-ore and the remainder iron-ore. On the western edge of this cross section of the deposit the rocks are seen to be vertical, whilst on the eastern edge they dip at angles varying from 55° to 65° to the N. N. E., *i.e.*, towards the interior of the incline. I think 65° may be taken as the average dip across the whole section. Hence of the 120 feet that may be manganese-ore, the true thickness works out as $120 \times \sin 65° = 108·7$, or, at a maximum, 110 feet.

The ores in this deposit consist of the psilomelane-wad mixtures. These are often cavernous, then frequently containing abundance of good crystallizations of pseudo-manganite, or of the pyrolusitic pseudomorphs. There is often a little of a yellowish and whitish mineral in minute crystals. It has not yet been identified. The iron-ores are mainly soft earthy hematite, which has evidently been formed by the replacement of shaly rocks, probably representing original phyllites or slates. There is also some limonite. The manganese-ores show plenty of evidence of their formation by metasomatic replacement, both of the decomposed phyllitic rocks, and also of the some of the earthy hematites or hematitic 'shales'. The workings had not been carried sufficiently deep to show the downward passage into the decomposed phyllites.

A ropeway was being constructed, with its brake-gear not many feet below the edge of the ridge, in order to carry the ore down to the plains below, a vertical distance of some 1,000 feet.

3. Rámandrug No. 4.

This deposit is situated on the N. W. side of the spur from the Rámandrug Plateau known as Prospect Point and about a mile S. S. E. of Sannasil Haruvu. The top of the plateau is laterite, of which there must be a thickness of some 30 feet. Hence the top of the manganese-ore deposit must be this distance below the level of the plateau. There was originally a large cave in the manganese-ore in the nearly vertical scarp where it cropped out just under Prospect Point. This was still left at the time of my visit, and showed very rugged vesicular surfaces of manganese-ore exactly like laterite in appearance. In Figure 78 I have given a rough sketch of what seems to me to be the correct inter-



Shaly lithomarges largely altered to wad in irregular patches.
Scale:—1″=about 120 feet.
Fig. 78.—Rough cross-section of Rámandrug No. 4 deposit.

pretation of the structure of this deposit. The portion indicated therein as the manganese-ore deposit looks as if it forms a thick rolling bed, the inward termination of which gives way to lithomargic rocks as shown. This bed-like mass rests upon lithomargic rocks, which are laminated conformably with the 'bedding' of the manganese-ore, and into which roots or processes of manganese-ore seem to have grown down from the main mass of manganese-ore. The lithomarges themselves are so largely replaced by and impregnated with manganese oxide, mostly in the form of wad, that they are coloured with white patches in brownish black. The beds overlying the manganese-ore 'bed' had not been exposed by the quarrying operations, and were obscured on the hill-side by tumbled blocks of laterite, soil, and vegetation. The portion that is indicated as the manganese-ore deposit in the figure contains a considerable amount of iron-ore, associated with the manganese-ores in no very regular fashion. The iron-ores consist of hematite, varying from soft red to hard blue-black, with a considerable amount of limonite and some yellow ochre. In one place there is a veinlet of hematite and limonite about one inch thick traversing the manganese-ore, and pointing in this particular example to the deposition of some iron-ore subsequent to that of the manganese-ore. The manganese-ores consist of the same ores as at the Main Bed deposit.

Prospect Point ropeway.

At the corner of the Prospect Point spur some 200 feet below the top of the plateau is the loading station and brake-gear of an aërial ropeway, which carries the ore, both of this deposit and of Rámandrug Main Bed, just round the other side of Prospect Point. This ropeway has, according to Mr. Ahlers, a vertical drop of 750 feet, and a length of supporting rope of 2,400 feet from brake-gear to unloading station at the bottom of the hill. These ropes, of 1 inch diameter, are carried on 7 trestles. The hauling rope is an endless one of ½ inch diameter. The capacity of each bucket is 0·6 tons. When there is a full supply of ore 50 trips a day, equivalent to 30 tons of ore, can be made with a working day of 10 hours. At the bottom of the ropeway there are two shoots, one for each bucket, through which the ore is tipped into 1-ton trucks standing on 2-foot gauge rails. These trucks are run out on to an elevated platform between the metre-gauge rails of the Southern Mahratta Railway siding from Mariyamanhalli, and the ore tipped sideways into the railway wagons.

4. Rámandrug Main Bed.

(*See Plates 44 and 45.*)

This deposit is situated about a mile W. N. W. of Rámanamallai G. T. S., 3,256 feet, in the bay of the plateau immediately to the south of the Prospect Point spur. It possibly joins on to the No. 4 deposit on the N. W. side of the Point underneath the laterite. There is the usual lateritic capping on the plateau here, and the top of the deposit is a few feet below the top and about 150 feet above the top of the Prospect Point ropeway. It is the biggest of the Rámandrug deposits and the one that was first opened up. The deposit has the usual N. N. W. strike of all the Rámandrug deposits, with a steep dip, which can be taken as averaging 65° across the middle section of the deposit, into the interior of the syncline, *i.e.*, to the E. N. E. The length of the deposit, from Prospect Point to where it disappears on the edge of the hill to the S. S. E., may be about 700 feet.

The deposit is at present being worked by two benches parallel to the strike of the ore-body. One of these—the main bench—is about 140 feet below the top of the plateau, and the other some 50 to 60 feet lower. The upper one is that shown in figure 76, and is some few feet below the base of the ore-body as seen on the working face. The tunnel driven into the working face for 66 feet, and the information it gives, have been noticed on page 1006. The ore is extracted by drilling and blasting, and stacked on this bench, where it is cleaned. Then it is lowered to the lower platform by one of two contrivances. One of these is a rough gravity incline with a double pair of 2-foot rails. The other, a more ambitious structure, was not finished at the time of my visit. It was 103 feet long at an angle of nearly 30°. The loaded ore-trolly is run on to rails on a carriage, which is then lowered bodily, hauling up an empty trolly on a similar carriage with rails. At the bottom of the incline the trolly is run off the carriage and run out to the loading station of the ropeway at Prospect Point, to which there is a double track of rails. The waste from the southern part of the deposit is run out to the south on tram lines and tipped down a slope into the valley below. For the disposal of the waste from the north part it is intended to carry an elevated shoot from the main bench over the lower bench, so as to tip the waste down the

Photographed by L. L. Fermor.

Bemrose, Collo., Derby

GENERAL VIEW OF WORKINGS AT RÁMANDRUG MAIN BED, SANDUR HILLS.

hill-slope below. Plate 44 gives a general view of the deposit, and Plate 45 a clear view of the ore-body.

It is along the cuttings made for the rails to Prospect Point that the sections noticed on pages 1008—10 and illustrated in figure 77 are to be seen.

The typical ore is the blotched or mottled mixture of wad and psilomelane, but is sometimes psilomelane alone or wad alone; it sometimes shows the cavities lined with pseudo-manganite, and pyrolusite; also lead-like psilomelane, and scattered patches and spots of the hard crystalline mineral. There is perhaps less iron-ore mixed with the manganese-ores than at the other Rámandrug deposits. There is also some of the grey to yellowish mineral in minute crystals seen at Sannasil Haruvu.

Output.

The output from the Rámandrug deposits from 1905 to 1907 is shown below:—

Year.	Long tons.
1905	1,200
1906	447
1907	15,455

These are figures of ore despatched rather than of ore actually quarried.

6. Rámandrug Barracks Deposit (or 'Mánganese Cave').

A little below the edge of the cliff by the barracks of the Rámandrug Cantonment there is another outcrop of manganese-ore, in which there is a large cave. The cave faces S. W., is 22 paces long from N. W. to S. E., and 13 feet in breadth. I forgot to measure the height. But it must be two or three times that of a man. In this cave one is practically surrounded by manganese-ore on all sides except that in which the opening is. The ore is the usual mixture of psilomelane and wad, the former tending to predominate. There is also a little pseudo-manganite. At the back of the cave, at the bottom, the rock looks like iron-ore, but when broken it shows poor manganese-ore inside. This deposit is not being worked at present. It is probably the reappearance, across the valley between Prospect Point spur and the Barracks spur, of the Rámandrug Main Bed. Either the manganese-ore that once joined the two was removed at the time of the erosion of this valley; or the valley was formed before the manganese-ore, in which case the manganese-bearing solutions have replaced two portions of the same beds of rock, although they were separated by an intervening break. The former alternative seems the more likely.

Group II.—The Kannevihalli Deposits.

The second locality noticed by Foote[1] :—

'occurs 2 miles south of Kannevihalli on the western flank of a small spur extending northward from the south western apex of the curve of the Kumaraswami section of the Sandur hills. The ore which is much blacker in colour and of richer quality than that occurring on the Narayan Devar Kerra ghat, is imbedded as nodules in a greyish soft argillite which is greatly weathered on the surface. The nodules are of all sizes, from that of a small nut up to a child's head. They occur in large numbers, and could easily be quarried along the bare side of the hill and shot down to the foot of the spur........'

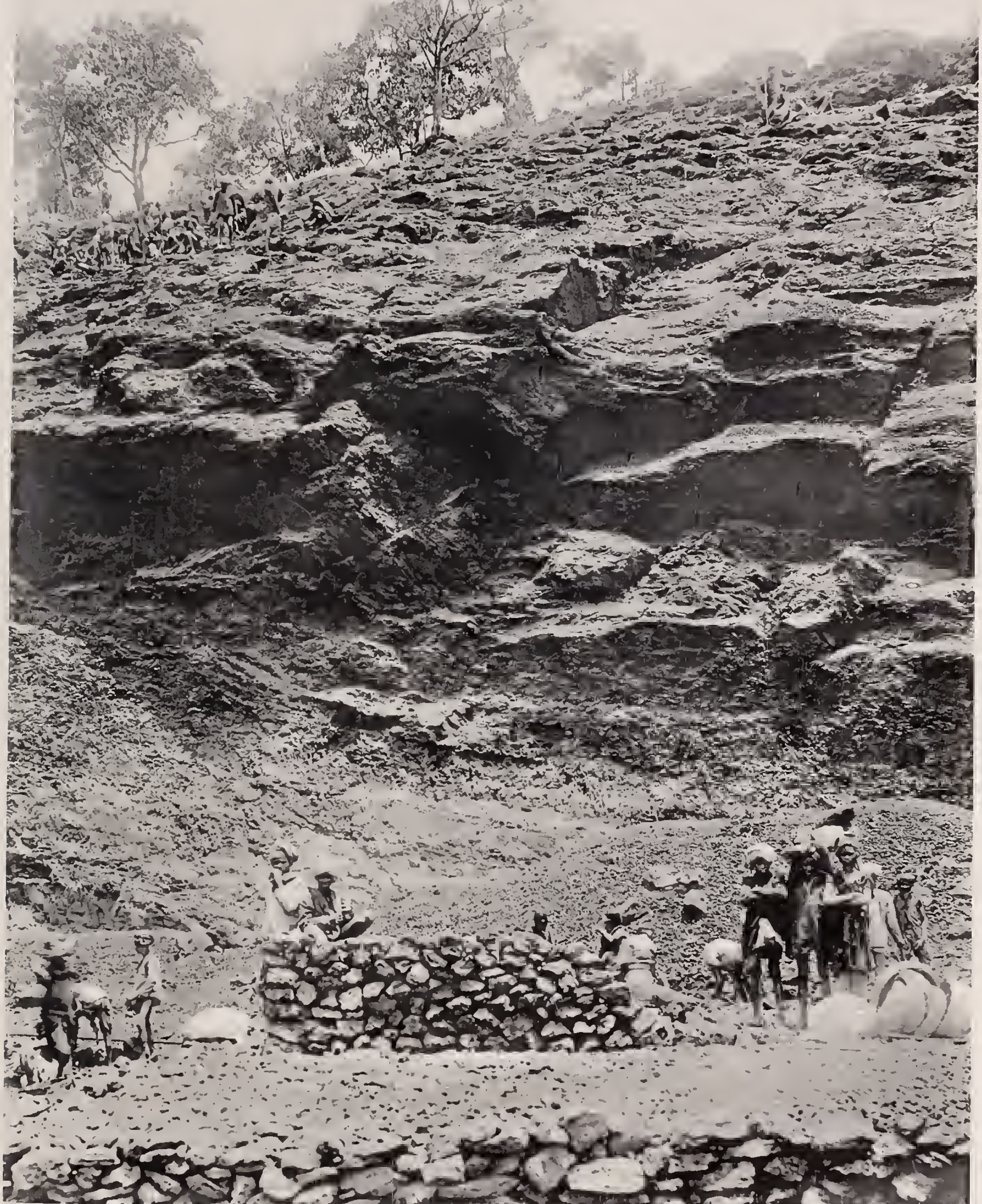
This is probably not one of the deposits mapped by Mr. Ghose, for it is doubtful if anyone would consider such nodule deposits worth working under present conditions. It must be somewhere near the Iruku Kolla deposit in the Kumáraswámi group.

I did not visit any of the Kannevihalli deposits myself, except for a few outcrops I crossed on the way from Rámandrug to the mouth of the Narihalla. The occurrences I crossed were none of them of any value and were exposures of phyllites and fine-grained sandstone-like quartzites impregnated and partly replaced by manganese oxide.

The Narihalla.

In the bed of the Narihalla leading through the Oblagandi gorge to Sandur there are to be seen many good exposures of rock ; but, as far as I noticed, none were of manganese-ore. In the bed of the stream, a considerable proportion of the pebbles and boulders of every description of rock were coated with a shiny black glaze, which, at least in the one specimen I tested, seems to be due to manganese oxide. Many of the fragments when broken open were found to be manganese-impregnated and replaced rocks of various descriptions. Some of these specimens were very interesting, showing every stage in the metasomatic replacement of phyllites, slates, and fine-grained quartzites, by manganese oxide. Several of the partly-replaced specimens were beautifully variegated in various shades of white, brown, red, purplish, and black, due to different combinations of iron and manganese with the original colours of the rocks.

[1] *Loc cit.*, p. 195.



Photographed by L. L. Fermor. Bemrose, Collo., Derby.

MANGANESE-ORE BODY WITH LITHOMARGE BELOW; RÁMANDRUG MAIN BED, SANDUR HILLS.

During 1906 a start was made to open up a deposit of detrital ore lying on the low ground at the foot of the hills. Now, however, preparations are being made to work the deposits *in situ* from which this ore was derived. It is proposed to bring the ore down by a ropeway.

The output from Kannevihalli in 1906 and 1907 is as follows:—

Year.	Long tons.
1906	2,762
1907	7,595

Group III.—The Kumáraswámi Deposits.

Beyond the list of deposits given on page 1003 I have nothing to say about these deposits, because I was not able to visit any of them.

Group IV.—The Kamátaru (Kammátharuvu) Deposits.

The deposits to which Foote refers on page 195 of his Bellary Memoir are probably ones situated on low ground to the south of the Kumáraswámi and Kamátaru areas in the Tonashagiri and Tumraguddi Reserved Forests in the Kudligi taluk of the Bellary district (see page 993).

In two days spent round Kamátaru I was shown some ten of the deposits of this group by Mr. Ghose. The astonishing feature about them is that they should have remained undiscovered so long. On the plateau itself, which is given up to cultivation in parts and fairly bare in the other parts, there are some ten deposits all within a radius of a mile from Kamátaru village. They mostly take the form of long low outcrops showing faint signs of dip, are fairly bare, except for lichens in places, and are usually black. They do not as a rule rise more than five to ten feet above the level of the plateau. But there are also outcrops both of laterite and of iron-ore; and, further, there is a great similarity between the outcrops of the manganese-ores and iron-ores, and often a similarity of these with the laterite outcrops. And the only way in which it would be possible for a geologist or prospector crossing the plateau to miss the manganese-ores, would be for him to be deceived by their similarity to iron-ore or laterite, to break the rocks in only a few places, and happen to strike on the ferruginous rocks in every case. These remarks do not apply to most of the other deposits in the State, for they occur in parts well covered with jungle and grass, which I am told gets as high as a man during the cold weather. I was fortunate to be in the area during the monsoon before the grass had grown very long again after being burnt down in the previous hot weather.

Starting from No. 40 (Pám-kollatha Tattu), situated about $\frac{1}{4}$ mile N. W. of Kamátaru village, a line of deposits runs for about $1\frac{1}{2}$ miles across the Kamátaru plateau to No. 52 (Alada-marada Banda), situated at the apex of a triangle or bay of low ground that projects up from the south into the southern edge of the Sandur Hills. At this point the line of deposits branches. One branch continues the previous line for $1\frac{3}{4}$ miles further—along the S. W. edge of the S. E. spur of the Sandur Hills, which forms the N. E. side of the triangle—as far as deposit No. 59 (Jánál Haruvu).

The total length of the N.W.-S.E.-running line of deposits is therefore a little over three miles, and it is possible that several of the deposits along this line represent one band of replaced rock and will be found to be continuous beneath the soil or laterite when they are opened up. However, they cannot all represent one band of replaced rock; because in more than one place there are two or even three parallel outcrops. which have been entered up as separate deposits. But probably the replacement of three bands of rock would explain the occurrence of the whole of the deposits.

The other line of deposits branches off at right angles and runs S. W. along the S. E. edge of the Kamátaru plateau, starting with No. 66 (Jogannáditha Kolla), and ending up with No. 60 (Hanumánthana Kativi) situated about $1\frac{1}{2}$ miles S. W. of the branching point.

Nearly all the Kamátaru outcrops, when broken open, show the hard compact psilomelane, frequently with the included magnetite grains, and with usually only a comparatively small amount of associated wad. The ores of this area will therefore probably turn out to be of higher average grade than those of the Rámandrug area. These ores, also, sometimes show pseudo-manganite, pyrolusite, and the hard grey crystalline mineral.

Because the Kamátaru deposits had not been opened up and show a remarkable similarity to one another as far as outcrops go, and because I was able to examine them only very cursorily, I shall notice the more striking only of the ones I visited.

45. Yelakála Gadda.

This deposit is situated about ¼ mile S. 20° W. of Kamátaru village. The manganese-ore exposure is small. But the interesting feature is the way in which the manganese-ore deposit is being converted into laterite by the growth of limonitic patches and processes, which gradually take the place of the manganese-ore and break it up into isolated patches, leaving pieces of the ore in the laterite. The final stage of the process is the complete disappearance of the manganese-ore with the formation of typical laterite, with all the characteristic vesicular and tubular structures. Nearly all the manganese-ore seems to disappear entirely; but a certain proportion of it separates out in the laterite in pyrolusitic patches, and sometimes the limonite forming the edge of the tubes is replaced by psilomelane. Associated with the manganese-ore is hematite, which is suffering the same conversion into limonitic laterite. The laterite in both cases often contains abundance of yellow ochre.

47. Badapatti Banda.

This deposit can be taken as typical of those on top of the plateau. The outcrop is flat, not sticking up much above the surface of the ground. It is also much corroded, so as to look very much like laterite. Consequently the true strike is difficult to see, but it is probably about E. 35° S. The outcrop is 11 paces wide with hematite cropping out on either side. After going 40 paces N. E. over hematite and laterite there is another band of manganese-ore 7 paces wide, mixed with hematite and much obscured by laterite. About 100 yards further N. E. there is another low outcrop, but it is reckoned as another deposit under the name of Kare-marada Banda. The typical ore of the Badapatti Banda deposit is dark grey psilomelane with veinlets of a bright crystalline mineral. There are also wad, magnetite specks, and a light grey radiate mineral, in the ores.

52. Alada-marada Banda.

This is the deposit situated at the head of the apex of the triangle at the point where the line of manganese-ore deposits branches into two. The outcrop is on top of the plateau, but also goes partly down the N. N. W. slope of the valley. It is 112 paces long, and 46 across. The strike is N. W. with a doubtful dip to the N. E. at 32°. The strike of the outcrop is, however, N. N. W. To the S. E. the outcrop ends in a small cliff overlooking the valley, and approaches the Durgámma Kolla deposit. From this end of the outcrop a fine view is obtainable over very hilly country in which rugged granite hills predominate, the nearer portions being in Bellary and the farther in Mysore. The ore is partly the hard grey psilomelane without any admixture of wad, and is partly the mixture of these two minerals typical of Rámandrug. On top of the outcrop there are little patches of laterite. There are also small isolated tubes of laterite going down into the manganese-ore, though probably only for a small distance.

53. Durgámma Kolla.

(See Plate 46.)

This is probably the finest of the Kamátaru deposits. It lies immediately to the S. E. of Alada-marada Banda. There are here three parallel bands of ore of which the lowest lies outside Sandur, in the Tonashagiri Reserved Forest of the Bellary District. This is treated as a separate deposit under the name of Pilál-marada Gundu. The first band forms a bold outcrop on the edge of the S. E. end of the Kamátaru plateau along the N. E. side of the triangle of low land. According to the measurements of Mr. Ghose the length of the outcrop on the top of the plateau is 423 feet, and the breadth 133 feet. This outcrop seems to be composed nearly entirely of the hard grey psilomelane, with occasional hematite, and a few lateritic patches. The ores, however, also show some of the radiate mineral and some wad and pyrolusite. Below the manganese-ore 'bed' occupying the crest of the ridge there is a thickness of iron-ore (hematite altering to limonite), and below this the second band of manganese-ore. This gives rise to an overhanging cliff 48 feet high at the highest point, and 75 paces long. The surface of the cliff is very irregular, corroded, and iron-stained, so that it is brown, and looks like iron-ore at first sight. Wherever broken into, it shows manganese-ore—the hard grey psilomelane with some soft oxide. In one place the face of the cliff is covered with pebbles of hematite, manganese-ore, and limonite, in a lateritic cement. This coating was perhaps deposited in a fissure in the manganese-ore; the manganese-ore on the S. W. side of the fissure then broke off and rolled down the hill-side, leaving a portion of the filling adhering to the present cliff of manganese-ore. This cliff is illustrated in Plate 46. A little below the

Photographed by L. L. Fermor. Bemrose, Collo, Derby

CLIFF OF MANGANESE-ORE AT DURGÁMMA KOLLA, SANDUR HILLS.

manganese-ore outcrop there is a spring issuing from the rock. It is iron-charged and is depositing its iron in the form of a limonitic slime as a coating on the masses of manganese- and iron-ore lying in the nálá. Mr. Ghose tells me that lower down, at the foot of a hill called Kálhatti-marada Tattu, the water of this spring has deposited soft black manganese oxide on the rocks exposed in the nálá. It seems probable, as far as one can judge from an outcrop, that the Durgámma Kolla bands contain a large quantity of good-quality ore.

55. Pilál-marada Gundu.

As already explained this is really the third and lowest band of Durgámma Kolla, but it lies outside the limits of Sandur, being in the Reserved Forest of Tonashagiri, in the Bellary district. It also forms a sort of cliff. The ores are similar to those in the Durgámma Kolla bands.

56. Karada Badasála Kativi.

This is really a S. E. continuation of one of the Durgámma Kolla bands. The ores are the same except for one variety. This is an oolitic ore composed of oolites of lead-like psilomelane $\frac{1}{16}$ to $\frac{1}{8}$ inch in diameter, very thickly crowded in a soft matrix giving a deep brown streak. This is the only occurrence of oolitic ores I saw in Sandur; but Mr. Ghose says similar ores occur at several other localities. The ore is exactly like some of the oolitic ores of Mysore.

63. Hunáse-marada Kativi.

This is one of the most south-westerly of the deposits on the line running S. W. from Alada-marada Banda, and is about 2 miles south of Kámataru village. The deposit crops out along the edge of the plateau and is mostly very flat. The strike seen was E. 5° S. with a moderate dip to the north side. The length of the outcrop seen by me was 357 feet and the width 84 feet. According to Mr. Ghose, however, there is another outcrop to the north of this, that is 500 feet long and up to 200 feet wide. In one place there is a band of laterite apparently interbedded with the manganese-ore; in reality it probably fills a cleft in the manganese-ore. There are also smaller patches and veinlets of laterite in the manganese-ore; and interbedded hematites. The ores are similar to those of the other Kamátaru deposits.

CHAPTER XXXIX.

DESCRIPTIONS OF DEPOSITS—*continued.*

Madras Presidency—*continued.*

Chengalpat District.

Coimbatore District.

Ganjám District—Boiráni—Gudhiári—Nautan-Barampur—Mathura—Kálikot—Rambhá.

Kadapáh District.

Karnul District.

Madura District.

Nilgiri Hills.

Nellore District.

Pudukottai State.

Chengalpat District.

A specimen of 'Purple Clay Ironstone, containing a vein of Manganese '[1] was sent to the Madras Exhibition of 1855 from the Red Hills, while at the 1857 Exhibition 'Brown wad and brown fibrous manganese have been exhibited from the Red Hills, Bangalore and Cuddapah '.[2] The Red Hills are composed of laterite.

Coimbatore District.

Mr. F. A. Nicholson[3] says that 'manganese was detected in the black sand from Vírapaneli in Coimbatore taluk'.

Gánjam District.

The manganese of this district was first discovered in June 1902 at Boiráni, by Mr. T. Chaudry, who also found signs of manganese-ore at Mathura and Nautan-Barampur, and in all three places conducted a certain amount of excavation to examine the various deposits.

A brief visit to this neighbourhood in December 1904 showed me that manganese is present as stains, impregnations, and coatings,

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1 Jury Reports, p. 6, (1856).
2 Ditto , p. 2, (1857).
3 Coimbatore District Manual, p. 23, (1887).

on many of the rocks adjoining the road from Rambha to Boiráni, a distance of about 30 miles; and since manganese-bearing rocks were found *in situ* at these localities, it seems possible that careful prospecting over the whole of this estate might lead to the discovery of payable manganese-ore, especially as manganese-garnet and rhodonite, so often associated with the manganese-ore deposits of the Central Provinces and Vizagapatam, are amongst the minerals found here. But up to the present no commercially valuable manganese ore deposit has been found. All the occurrences are in the Kallikota and Atagada Estates.

The rocks of this neighbourhood consist of various—usually very garnetiferous—gneisses and gneissose granites, the latter often showing banding or streaking due to the drawing out, while still plastic, of white felspar-quartz schlieren into cylindrical bodies, which usually show a dip of 20°-45° to the W. 10°-30° S. There are also hypersthene-granulite intrusions. The garnetiferous gneisses—containing graphite in one case and probably belonging to the khondalite series—often give rise to well-wooded, rounded hills, while the gneissose granites usually form very jugged, rocky and bold, tors and hills, much less thickly jungle-clad.

In the valley between these hill ranges in which Kálikot and Boiráni are situated, besides the above rocks, low mounds and hills of quartzites—often garnetiferous—are found, and it is on this low ground also that the manganese localities at present known are situated; it must be remarked that the rocks of the valleys are often obscured by alluvial deposits devoted mainly to the cultivation of rice. The strike of these rocks seems to range between E. and N. E. with the dips in either direction.

The manganese localities visited will be noticed as follows:-

Atagada Táluk:—

1. Boiráni.
2. Gudhiári.

Kálikot Táluk:—

3. Nautan-Barampur.
4. Mathura.
5. Kálikot.
6. Rambha.

1. Boiráni.

This deposit is situated perhaps ½ mile S. 40° E. from Boiráni village in some very slightly elevated ground, nearly barren of vegetation and surrounded by rice fields on the lower ground. It was discovered by Mr. T. Chaudry in June 1902, the surface indications being abundance of small granules and nodules of psilomelane lying on the ground, as well as black stains and impregnations in some garnet-felspar-rock cropping out there.

The source of all the manganese here is probably the manganese-garnet of a band of the rock I have called *kodurite* (see page 255), which when fresh consists of manganese-garnet, orthoclase, and apatite. The garnet is a manganiferous one intermediate in composition between grossularite and andradite, and has been called *grandite*, (see page 165). The felspar is white and the garnet occurs in abundance as small scattered and aggregated crystals of yellow and orange colour. Somewhat extensive excavations in the form of irregular pits have shown that this rock has a strike varying between E. 30° N. and N. 30° E. and that it is at least 21 feet wide, having a dip to the N. W. side of 35° to 50°. Almost everywhere the kodurite is greatly altered, the change taking the form of the replacement of the felspar by chalcedony and opal of various shades of white, black, brown and green, while the garnet may also be completely removed, or may remain as fresh crystals set in an opal-chalcedony matrix (see fig. 2, Plate 8). In other places the rock has yielded a soft bright yellow-green material. For an analysis of the Boiráni kodurite see page 257. The rock immediately underlying the kodurite band seems to have been originally felspar-rock, with quartzite beneath this. The felspar-rock has been very largely replaced by manganese in the form of psilomelane, so as to form in one place an ore-bed of 4½ feet thickness. This bed was followed to a depth of 35 feet by means of a drive on the dip, and, judging from information supplied by Mr. Chaudry, the section must have been somewhat as follows :—

Above :—Silicified and decomposed kodurite.

6″ Decomposed felspar-rock with nodules and strings of psilomelane.

2′ Cavernous psilomelane, with the cavities filled with a siliceous limonite, probably representing the remains of original felspar-rock or gneiss, and still retaining some felspar.

1′ Psilomelane in which the limonitic material is small in extent.

6″ Psilomelane, mostly nodular or botryoidal and containing but a small amount of limonite.

6″ Psilomelane gradually passing downwards into:—

Soft limonitic rock of unknown thickness, spotted and patched with soft black manganese oxide.

To judge from specimens collected there can be no doubt whatever that the ore is the result of the replacement of felspar-rock or of felspar-quartz-rock by manganese oxide, and that the underlying limonitic rock is the result of replacement of quartzite by iron oxide. It seems a fair deduction to suppose that the replacing manganese has come from the overlying kodurite, which at some time or other has been subjected to the action of waters that brought silica in solution and removed, in some places completely, all the original constituents of the rock.

The ore itself is psilomelane, very seldom free from felspathic or limonitic patches. It is either nodular, cellular, or botryoidal in shape. About 20 tons of ore had been collected, and a sample of this was analysed by Messrs. J. and H. S. Pattinson with the following result:—

Sample No. A. 19.

Manganese peroxide	41·65
Manganese protoxide	2·72
Ferric oxide	28·14
Baryta	0·05
Silica (combined)	6·75
Silica (free)	3·50
Phosphoric oxide	1·635
Arsenic oxide	0·050
Water (combined)	6·50
Moisture at 100° C.	2·55

This is equivalent to:—

Manganese	28·44
Iron	19·70
Silica	10·25
Phosphorus	0·712

It will be seen from the above that the ore is quite unmarketable further, considering its origin, it is not probable that the ore continues to any great depth, while the thickness of the ore-layer is 3½ feet as a maximum, and in other places not more than six inches; hence the profitable working of the deposit would be quite out of the question, even if the ore were of first rate quality, and even if the deposit were not 30 miles from the railway.

The various workings have exposed the ore-bed for about 200 yds. in a N. E. direction. About 100 yds. to the N. of the deposit occurs streaked gneissose granite, the relations of which to the ore-deposit are not apparent.

Manganese-laterite.

About half a mile S. 10°E. from the above deposit a pit in a rice field had exposed 4 feet or so of a loose gravel of granules of manganese-ore averaging $\frac{1}{4}$ to $\frac{1}{2}$ inch in diameter, mixed with granules of quartz and limonite, and resting below on decomposed whitish felspar-quartz-rock, often traversed by manganiferous veins, or pseudomorphed into chalcedony. About 50 yards S. S. W. of the above pit some manganese-laterite has been found extending for some yards and occurring to a depth of $2\frac{1}{2}$ feet or so, resting below, according to Mr. Chaudry, on débris of felspar, quartz, and limonite, fragments of which can also be seen included in the laterite in places. This laterite consists in the main of granules of wad and psilomelane set in a ferruginous clay and is apparently the same material as the above-mentioned loose granules, here cemented together. The source of the manganese was not to be seen, but this occurrence may perhaps be indicative of another band of manganese-garnet-bearing rock below the surface.

2. Gudhiári.

About 50 or 100 yards W. of N. from the E. end of the range of gneissose granite hills occurring to the S. W. of Gudhiári village, the usual manganese-ore granules are to be seen scattered about through a yellow-brown sandy soil.

3. Nautan-Barampur.

Ninety paces N. 20°E. from the road from Kálikot to Boiráni, at about the mile-stone $\frac{6}{I}$, a pit, 6 feet deep, shows large boulders and fragments of garnet-rhodonite-rock, often with a little quartz, and exactly like the similar rock found so frequently in the Nágpur district of the Central Provinces, except that in this case there are often little strings and patches of a light blue-green mineral (apatite) and occasional felspar ? The garnet is a manganiferous variety, but whether it is spessartite, spandite, or manganese-grandite, has not been determined. Some pieces of rock are entirely garnet, and both these and the pieces of garnet-rhodonite-rock are blackened in patches ; but not a single piece of good manganese-ore did I see. The rock is probably *in situ* just below the bottom of the pit, and but for the absence of any fragments or pebbles of good manganese-ore, it might be worth while to open up the deposit on the chance of finding a parallel band of good manganese-ore. This pit was in the middle of a field, and nowhere else were any signs of similar rock seen ; but, to judge from some hillocks of khondalite near by, the strike of the manganiferous rock is perhaps about N. E. 26 yards S. 10°W. of this pit there is another showing banded khondalite, often manganese-stained and impregnated.

4. Mathura.

On the south side of the Rambha-Kálikot road, at a point about 300 to 400 yards S. 30°W. from the Nautan-Barampur rhodonite-garnet pit, another pit had been dug on the top of a low mound. This pit showed 8 feet of khondalite in layers 1 to 6 inches thick, with a very gentle dip, possibly to E. 10° N. The khondalite is banded and very rich in both garnet and sillimanite. It is partly stained brown by iron oxide and partly blackened by secondary manganese oxide. Under the microscope some black patches are seen of a black and apparently original mineral. This is probably graphite rather than manganese oxide, which, as far as is known, occurs in khondalite as a secondary constituent only.

5. Kálikot.

A cutting along the base of the hill at the back of the new bungalow being built for the manager of the estates showed a débris of boulders of a soft decomposed khondalite, often showing little scales of graphite, and derived from the hill above. Little psilomelane veins and soft black patches and stains were visible in many of these boulders and also in similar material extracted in the course of sinking a well in front of the bungalow ; also veins of porcellanic lithomarge.

6. Rambha.

The road from Kálikot to Rambha passes through a very fine avenue of banyan trees on approaching Rambha and just before crossing the railway. To the right of the road in this avenue was an excavation, probably for murram, showing 3 to 4 feet of a red-coated débris of fragments and grains of limonite, decomposed quartzite, and a little manganese-ore, resting upon similar material, coated black externally with manganese oxide, so that there was a horizontal line of junction between the red- and the black-coated material. This is probably due to deposition of manganese oxide from water filling the excavation during the rains, and taken in conjunction with the common occurrence of small amounts of manganese as veins and impregnations in the rocks of this neighbourhood, indicates that the meteoric waters must often contain manganese in solution; this points to a wide distribution of rocks containing manganese minerals, and suggests that it may be worth while prospecting the portions of these estates lying more remote from the main road.

Kadapah District.

According to Dr Balfour, peroxide of manganese occurs in this district [1], but no further information is available as to the character of the deposit.

Karnul District.

At the 1857 Madras exhibition the following specimens from this district are said to have been exhibited :—

(a) impure braunite [2];
(b) magnesian limestone with dendritic manganese [3];
(c) peroxide of manganese from Roodrar in the Koil Kuntla táluk [4];
(d) slightly magnetic steel-grey iron sand [5];

According to Mr. N. G. Chetty[6] 'manganese is to be found in Nandavaram, Banganapalle, Nágireddipalli in Sirvel Taluk and several places in Koilkuntla'.

[1] *Cyclopædia of India*, 1st Edit., p. 1183, (1857).
[2] *Jury Reports*, 1857, p. 2.
[3] *Ibid.*, p. 4
[4] *Ibid.*, p. 2,.
[5] *Ibid.*, p. 3.
[6] Karnoo District Manual, p. 99, (1886)

Madura District.

According to the Rev. C. F. Muzzy, whose collections are fully described by Mr. J. H. Nelson [1] 'manganese abounds on the hills [2],' while a specimen from Puda-kudi of 'wood-opal striped with oxide of iron or manganese' is mentioned[3]. Various other minerals containing manganese are also enumerated, *viz.* :—aplome, carpholite, jeffersonite, and arfvedsonite, but it is not stated how or by whom these minerals were identified. A less complete list of these collections was given earlier by Dr. E. Balfour. [4]

Nilgiri Hills.

Newbold [5] says that manganese-ore 'has been discovered by Colonel Cullen and Dr. Benza on the Neilgherries', and later [6] that it has also been found 'in the iron ore near the lake at Ootacamund, and in the Kaiti valley'; while the 'Gazetteer of Southern India' [7] states that 'the black oxide of manganese is found about the hills in many places, existing in small veins and retiform deposits'.

Whilst staying at Ootacamund in October and November 1907 I was able to confirm the last statement. The characteristic rocks of the Nilgiri Hills are various members of the charnockite series. These rocks have been to a very large extent altered at the surface with the production of soft variegated lithomarges and other clays. This alteration goes down to some depth, in many cases certainly 50 feet and probably considerably deeper in places. The alteration is, however, very irregular, so that in many places masses of the charnockite rocks crop out at the surface, whilst isolated residual boulders of these rocks are often found in the clays. At many spots round Ootacamund one finds, especially in the cuttings by the roads and foot-paths, and on the foot-paths themselves, black veinlets of a soft black manganese oxide, best designated wad, traversing the lithomarges, in which they often form a perfect network. These veins range in

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1 'The Madura Country', pp. 4-16 and 23-42, (1868).
2 *Ibid.*, p. 30.
3 P. 15.
4 Catalogue of the Government Central Museum, Madras, 1855.
5 *Mad. Jour. Lit. Sci.*, XI, p. 45, (1840).
6 *Jour. Roy. As. Soc.*, VII, p. 214, (1843); also see *Jour. Roy. As. Soc.*, VIII, p. 234, (1846).
7 Pharoah and Co., Madras, p. 470, (1855).

thickness from that of a piece of paper to ½ inch and over. In some places the manganese oxide forms irregular patches, with remains of the charnockite scattered in it. In one place, namely, in a new cutting where the Ootacamund railway cuts through the line of hills joining Cairn Hill to Elk Hill, I found one of these patches of wad over a foot in diameter. The manganese in all these cases must have been derived from the rocks of the charnockite series during their alteration into lithomarges. For doubtless the rocks of the series contain a small proportion of manganese—probably in the ferro-magnesian constituents, such as hypersthene, augite, and garnet—although the analyses given in Dr. Holland's Memoir on this series do not return this constituent, probably because it was not looked for.

Amongst the spots where this manganese oxide occurs the following may be specified :—

1. On the path leading along the ridge from Snowdon to Dodabetta.
2. In the new railway cuttings at the western end of Ootacamund Lake.
3. In the other railway cutting mentioned above.
4. At several points on the road to Governor's Shola.
5. By the side of the De Winton Road a little before reaching the path to Monte Rosa, as one goes from Sylk's Hotel, and in the path leading up from this point through the plantation on the hill behind.

In places there is a small capping of lateritic rock on the lithomarge, and in one of these occurrences of laterite I found a little dark brown wad. This was near the road-metal quarries close to the 3rd milestone on the New Pykara Road.

Nellore District.

Dr. Alex. Hunter[1] gives the following minerals as having been sent from Nellore by Mr. F. N. Crozier to the Madras Exhibition :—'jet black sand containing iron and manganese' and 'garnet aplome spar'. On page 70[2] aplome garnet from Kaligiri used as emery is mentioned.

[1] Letter No. 347, dated 1st November 1856, to Chief Secretary to Government. Quoted in Boswell's Nellore District Manual, p. 7, (1873).

[2] *Loc. cit.*

Pudukottai State.

In the 'Review of Mineral Production in India for 1897', page 48, it is said that manganese-ore is reported to occur in this State; but I have been unable to obtain any confirmation of this supposed occurrence.

CHAPTER XL.

DESCRIPTIONS OF DEPOSITS—*continued.*

Madras Presidency—Vizagapatam District.

History—Output and labour—Physical characters of the district—Geology—List of deposits—Nature and quality of the ores—Communications and transport.

The Kodur Mines—Output—Garividi—Kodur—Duvvám—Deváda—Sandanandapuram—Sivarám—Perapi—Itakerlapilli—Mulagám—Govindapuram—Garbhám—Kotakarra—Gadasám—Ávagudem—Aitemvalsa—Gotnandi—Bondapillì—Garraráju Chipurupalli (Garuja)—Perumáli—Rámabhadrapuram—Táduru—Chintclavalsa—Thonaum—Other localities.

History.

In addition to being the district in which manganese-ore was first mined for export, its ores were amongst the earliest known in India. Specimens of manganese-ores from Vizianagram and Bimlipatam were sent to Dr. A. J. Scott of Edinburgh by Dr. Alexander Hunter, who, according to Scott, had given a description of the former ore in several of the Madras journals. In a paper published in 1852[1], Scott gives the following analyses :—

	Vizianagram.	Bimlipatam.
Silicic acid	8·300	9·09
Peroxide of iron	12·910	11·72
Lime	..	1·244
Magnesia	2·339	0·668
Water	0·539	0·432
Red oxide of manganese	73·786	76·177
Oxygen	1·864	0·655
Total .	99·738	99·986
Metallic manganese	53·428	54·929

[1] *Edin. New Phil. Jour.*, LIII, pp. 277-9, (1852); the Vizianagram analysis is erroneously given as totalling to 99·735.

Scott remarks that the analysis of the Vizianagram ore agrees most nearly with that of marcellin from St. Marcel in Piedmont, investigated by Damour, who considered the mineral to be a mixture of braunite and silicate of MnO; but Rammelsberg remarked that if it possess a distinct crystalline form, as it appears to do, it cannot be a mixture; and he suggests that the crystals may be braunite and that the analysis has been made with a specimen containing impurities. Combined silica is, however, now considered to form an essential part of the formula of braunite, and the above analyses conform very roughly to the formula $7Mn_2O_3 . 2Mn_2SiO_3$.

In 1855, E. Balfour published a letter that had been sent to him in 1850 by Mr. F. H. Crozier.[1]

Mr. Crozier forwarded with this letter a black mineral that he supposed was antimony-ore, as the natives said it was *surmá.* It was to be found in some quantity a few miles to the south of Cheepooroopully (Chipurupalli).[2] He says :—

'When at Bimlipatam some months since I met an encampment of Mundoolawanloo or itinerent sellers of medicines on route from the northward to Madras. On examining the articles they had for sale in the prepared and original state, I found some of the ore correspond in appearance with that we had obtained from Cheepooroopully, and they confessed that they always made a detour from the direct road to that place for the express purpose of procuring it.'

Further :—

'I sent for one of the soorma merchants in the bazar, and on my showing him several pieces of that by me, he at once said it was soorma of inferior description and worth about 2 annas a lb., in the crude state: he further said that he had been in the habit of purchasing the same ore from the Mundoolawanloo caste I have referred to'.

Balfour says that :—

'the ore, first mentioned by Mr Crozier, which the people consider an inferior description of the sulphuret of antimony, *soormah,* so largely used in medicine and for the toilet in this country, has been carefully analysed by Dr. A. Scott, who has reported it to contain 53 and 54 per cent. of metallic manganese, and oxygen about 22·558'.

According to the Reports by the Juries, Madras Exhibition, 1855, page 3, the manganese-ores from Vizianagram and Bimlipatam :—

'occur in huge veins from 3 to 5 feet in thickness amongst primitive granites.'

[1] On the Iron Ores; the Manufacture of Iron and Steel; and the Coals of the Madras Presidency, Madras, 1855, pp. 238-240.

[2] Doubtless in the area now known as the Kodur Mines.

According to the same Reports, page 6, peroxide of manganese was also obtained from the same area. According to the Gazetteer for Southern India, page 29, published by Pharoah and Co. in 1855 :—

> 'manganese-ore of great purity has recently been discovered to a very considerable extent in the Coomaram Tannah'

of which Chipurupalli was the chief station.

Mr. D. E. Carmichael says [1] 'that *manganese* (súdda) is to be had on the rock at Bimlipatam and is delivered in the town at two annas a maund'.

Dr. King in 1886 [2] described the use of psilomelane as road-metal on the road to Pálkonda at a point about 6 miles to the northward of Vizianagram. He also says [3] that :—

> 'traces of a similar development of crystallime limestone and associated manganese-ore occur near Ramachandrapuram [4] in the Salur zamindari; the high road, when it bifurcates to Bobbilli on the one side and Salur on the other, being also metalled for some distance with débris of the ore'.

The known workable deposits of manganese-ore of this district nearly all lie in the Vizianagram Zamindari, and the above-mentioned ores from Bimlipatam and Vizianagram were, in all probability, not actually extracted at these towns but in the adjoining country.

A syndicate was formed in 1891 to work these deposits, and there was a small initial export of 674 tons in 1892 (not reported in the official statistics), with an export of 3,130 tons in 1893. In 1895, the syndicate was converted into a company under the title of the Vizianagram Mining Company, Ld., with the sole rights to work manganese-ore in the Zamindari of that name. A brief account of the work up to 1896 has been given by Mr. H. G. Turner [5], one of the directors of the above-mentioned company, and formerly Collector of the Vizagapatam district.

The success of the Vizianagram Mining Co. gave rise to active prospecting by other people and concessions were obtained by Messrs. Gordon Woodroffe & Co. of Coconada, Messrs. A. S. N. & Co. of Nellore, and by Mr. H. G. Turner. But all the best deposits had apparently been secured by the V. M. Co., and very little ore has yet been extracted from any of the other deposits except Avagudem.[6]

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[1] Vizagapatam District Manual, p. 155, (1869).
[2] *Rec. G. S. I.*, XIX, p. 155, (1886).
[3] Page 156.
[4] ?Rámabhadrapuram.
[5] *Jour. Iron Steel Inst.*, 1896, No. II, pp. 155-1[illegible]0
[6] Since transferred to the V. M. Co.

During 1905 and 1906 the Madras Manganese Company—since converted into the Bobbili Mining Co., Ld.—started work on several small deposits situated within reach of Chipurupalli and Garividi stations.

Output and labour.

The importance of the industry that has developed to work the Vizagapatam deposits can be seen from the following table giving figures of both output and average daily number of workers :—

YEAR.	Output in long tons.	Average daily number of workers.
1892	674	(a)
1893	3,130	(a)
1894	11,410	(a)
1895	15,816	600 to 1,100
1896	56,869	1,200
1897	74,467	2,750
1898	62,980	3,530
1899	84,652	4,780
1900	92,008	4,242
1901	76,473	2,770
1902	68,171	3,966
1903	63,074	2,939
1904	53,602	1,980
1905	63,789	2,508
1906	111,501	5,848
1907	159,219	8,417

(a) Figures not available.

Physical characters of the district.

Topographically the Vizagapatam district is composed of two belts. One consists of low-lying plains adjoining the sea-coast and stretching inwards to distances of 30 to 50 miles from the coast ; whilst the other, lying to the north-west of the coastal belt, is composed of the wild hills known as the Eastern Ghâts, which rise to elevations of 3,000 and 4,000 feet. These plains and the eastern portions of the ghâts are drained by a number of comparatively short rivers and streams flowing on the average in a south-easterly direction to the sea. The largest of these, for which no name is given on the map (Atlas Sheet 108), flows by Pâlkonda and Chicacole The manganese-ore deposits of this district are all situated, as far as is known, in the coastal plains, but three occurrences of manganese-silicate-rocks (Nos. 21, 22, and 23, on Plate 56) have been located in the eastern fringe of the ghâts, and a close search in these densely wooded hill tracts might lead to the discovery of economically valuable deposits of manganese.

Geology.

Geologically the Eastern Ghâts, the eastern fringe of which is shown on the map (Plate 56), are composed, in this part of their course, of alternating bands of gneissose granite, the charnockite series, and the khondalite series, with an average strike of N. N. E. The rocks in the plains to the east are largely obscured by alluvium given up to cultivation; but wherever they appear at the surface either in isolated hills or mounds, or as obscure outcrops in the fields and stream-beds, they are found to be composed of rocks of the same three groups as in the Ghâts. These plains have not, however, been geologically mapped into these three divisions. The manganese-ore deposits mostly occur as low mounds and hillocks protruding from the alluvium, but in places the presence of manganese-ore beneath the surface is indicated by pebbles of ore at the surface. As has been earlier more fully explained (Chapter XIII), these deposits are regarded as having been formed by the chemical alteration of apatite-spandite-felspar-rock (kodurite), spandite-rock, pyroxene-spandite-rock, and other varieties of the kodurite series, with consequent concentration of manganese oxide into workable deposits of psilomelane, pyrolusite, and braunite. These manganese-silicate-rocks are supposed to be basic segregations from a magma that was considerably more acid (approaching a granite), and the whole mass of acid and basic rocks is held to have been intruded in the molten condition into the pre-existing rocks. The junction between manganese-intrusives and the older rocks is but rarely seen, but, judging from the relative proximity of rocks of the three series above mentioned, it seems as if the manganese rocks have always intruded themselves into the rocks of the khondalite series. The khondalite series of T. L. Walker consist chiefly of khondalite (sillimanite-garnet-graphite-quartz-schists), and granular crystalline calcareous rocks composed of some or all of the following minerals:—diopside, wollastonite, scapolite, felspar, garnet, and calcite; and the manganese-intrusives seem to be more intimately associated with the latter rocks than with the typical khondalites.

List of deposits.

The following is a list of the manganese-ore deposits I have visited, or concerning which I have been able to obtain definite information:—

1. Garividi.
2. Kodur.
3. Duvvám.
4. Deváda.
5. Sandanandapuram.

(Nos. 1–5: The Kodur Mines.)

6. Sivarám.
7. Perapi.
8. Itakerlapilli.
9. Mulagám.
10. Govindapuram.
11. Garbhám.
12. Kotakarra (I and II).
13. Gadasám.
14. Àvagudem.
15. Aitemvalsa.
16. Gotnandi.
17. Bondapilli.
18. Garraráju Chipurupalli (Garuja).
19. Perumáli.
20. Rámábhadrapuram.
21. Táduru (Tadiyur).
22. Chintelavalsa.
23. Thonaum.
24. Other localities.

These will be described later in order of number. Where I know from a personal visit or from definite information the situation of a deposit I have indicated it on the map (Plate 56) by a cross (+), but where I do not know the situation of the deposit relative to the village within the limits of which the deposit is situated I have simply underlined the name of the village on the map. The district is divided into a large number of taluks, some of these corresponding to zamindaris. The deposit given in the above list are situated in the following taluks:—

Chipurupalli taluk:—Nos. 1, 2, 3, 4, 6. 7, 8, 9, 10, 14, 15, 16, 17.
Vizianagram taluk:—No. 5.
Gajapatinagram taluk:—Nos. 11, 12, 13.
Pálkonda taluk:—18.
Bobbili taluk:—No. 19, part of 20 (Bankuruvalsa).
Sálur taluk:—Part of 20 (Sonpuram and Mámidipilli).

Since the foregoing list was drawn up the Madras Manganese Co. has, during 1906, started work at the following additional localities, about which I have practically no information (for output from them see pages 435 and 463):—

Gadabavalsa, Lakshmipuram, Nimmalavalsa, Sarveswarapuram, Viziarampuram, Batuva, Viswanadhapuram, Challapuram, and Rávivalsa; and, in 1907, at the following additional localities:—

Baidapilli, Chinna Ranyám, Kothavalsa, Chokkarapalem, Gotnandi, Vedullavalsa, Gumadám, Mukkunarasannapeta, Regati, Dannanapeta, Gunpam, Palavalsa, Duggivalsa, Kondapalem, Sivandhoravalsa, Butharayavalsa.

In addition to the localities given in the list on page 1047, the output of which will be found given under the headings of the respective deposits, the Vizianagram Mining Co. have raised ore at the following localities during 1907:—

Deposit.	Manganese-ores.	Ferruginous manganese-ores.	Total.
Bajuvalsa	16	286	302
Batuva	103	312	415
Boddam	1,694	684	2,378
Chinna Palavalsa . .	8	19	27
Chipurupalli . . .	..	834	834
Dannanapeta . . .	842	..	842
Devarapilli . . .	..	419	419
Gadabavalsa . . .	59	357	416
Jada	685	205	890
Kottapeta . . .	54	141	195
Lingalavalsa . . .	2100	8	2,108
Naiduvalsa . . .	54	..	54
Nellimarla . . .	3,033	909	3,942
Vedullavalsa . . .	172	731	903

The nature and quality of the ores.

The principal ore is *psilomelane*, often very cavernous, and frequently containing scattered granules of *braunite*; these pass in places into big plates of this mineral, which is sometimes, as at Garividi, the predominant mineral. Kidney-shaped and stalactitic varieties of psilomelane have been found at Garbhám, and the lead-like variety at Ávagudem. *Pyrolusite* is also of fairly frequent occurrence, especially at Kodur and Sandanandapuram; whilst *vredenburgite* (at Garividi) and *manganmagnetite* (at Kodur, Garbhám, and elsewhere) have also been found.

Since 1906 the Vizianagram Mining Co. has divided its output into *manganese-ores* and *manganiferous iron-ores*, all ores with 43% Mn and over being classed as manganese-ores, and all ores with 35—43% Mn and not less than 15% of iron being classed as manganiferous iron-ores. As already explained (see page 498) I consider this latter term inappropriate as applied to ores with more manganese than iron; I have therefore designated such ores *ferruginous manganese-ores*, instead of 'manganiferous iron-ores'.

The samples taken by me from deposits Nos. 1, 2, 4, 5, 7, 11, 12, 14, and 20, were analysed at the Imperial Institute. The results are inserted later in the descriptions of the respective deposits; but the limits and mean of these 12 analyses are shown in the following table :—

	Limits.	Mean.
Manganese	32·21 to 49·05	42·96
Iron	4·80 to 15·70	11·22
Silica	1·10 to 10·30	4·29
Phosphorus	0·13 to 0·48	0·27
Moisture	0·50 to 1·85	0·90

These can be compared with the analyses of Kodur and Garbhám ores given by Mr. Turner in the *Jour. Iron Steel Inst.*, No. II of 1896, page 160 :—

	I.	II.	III.	IV.	V.
Manganese	48·65	46·15	50·35	45·08	47·09
Iron	7·10	10·35	6·38	13·23	10·80
Silica	2·23	3·20	3·21	4·60	2·45
Phosphorus	0·12	0·21	0·24	0·27	0·26
Moisture	1·10	1·30	1·65	1·80	1·48

Note.—I and II, Kodur ore; III and IV, Garbhám ore; V, Garbhám ore (cargo test).

and with the following summary of figures representing the average quality of the ores mined by the Vizianagram Mining Co. They are based on figures—scattered through the text under the headings of their respective deposits—kindly supplied by Mr. T. Caplen in 1906:—

	Manganese-ores (8 analyses).		Ferruginous manganese-ores [1] (7 analyses).	
	Limits.	Mean.	Limits.	Mean.
Manganese . .	41·45 to 49·69	44·34	35·43 to 38·51	36·75
Iron . . .	2·35 to 1·290	9·08	12·87 to 19·32	15·20
Silica . . .	3·05 to 5·70	4·15	4·93 to 6·90	5·72
Phosphorus . .	0·26 to 0·45	0·32$^{7}_{7}$	0·20 to 0·455	0·335

Communications and transport.

As regards railway communications, a glance at the map will show that the East Coast Section of the Bengal-Nágpur Railway passes right through the manganese area, the stations of Sigram, Chipurupalli, and Garividi, being most convenient. The output of Garbhám, the Kodur mines, and Perapi is despatched from Garividi, from which the distance to the port of Vizagapatam is 56 miles. The projected railway from Raipur in the Central Provinces to Vizianagram will further improve the communications, especially for the Rámabhadrapuram deposits. The ores are at present carted from all the deposits to the railway, and the example of the Central Provinces in the construction of mining tramways has not been followed.

The Kodur Mines.

(See Plates 47 to 50.)

The following deposits:—

1. Garividi,
2. Kodur,
3. Duvvám,
4. Deváda,
5. Sandanandapuram,

[1] Termed 'manganiferous iron-ores' by the Vizianagram Mining Co.

given in the list on page 1047 are usually known as the Kodur Mines and are all being worked by the Vizianagram Mining Co., Ld. Kodur was the first to be worked seriously, not only in this district, but in the whole of India.

These quarries (for they are open-cast workings rather than mines are situated along a line about 3 miles long, running S. E. from Garividi to Kodur and then S. 40° E. from Kodur to Deváda and S. 30° E. from Deváda to Sandanandapuram. The chief of these mines is that known as Kodur (more correctly Koduru), which is partly within the

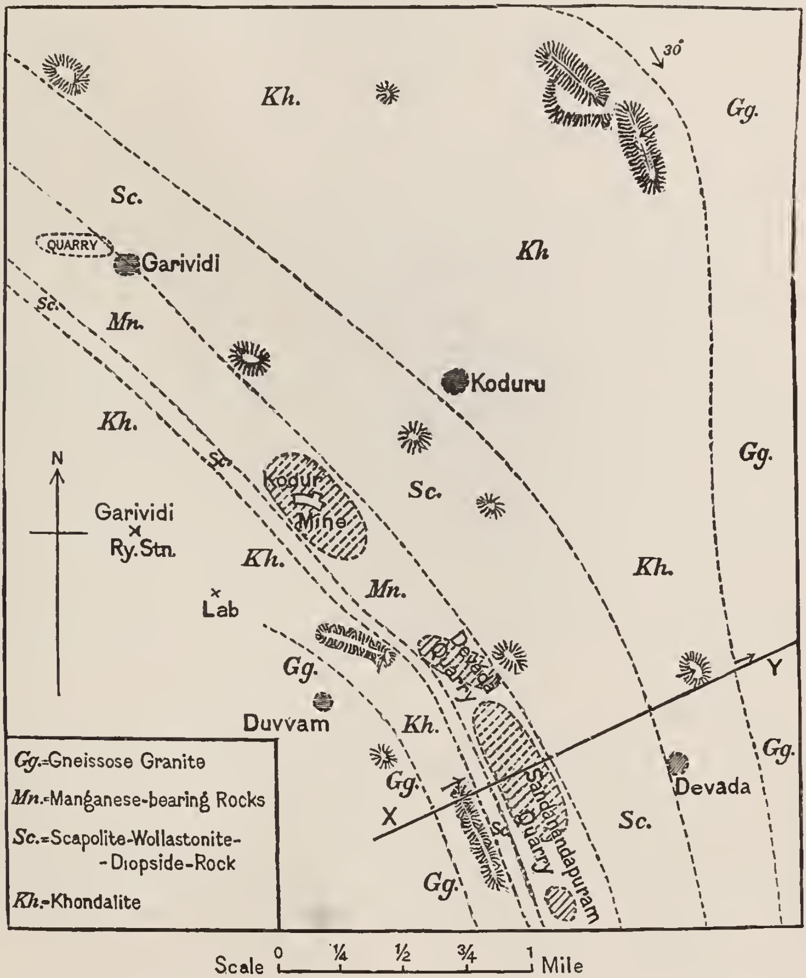

Fig. 79.—Geological sketch map of the Kodur Mines, Vizagapatam district.

limits of Kondakoduru (or Kondapálem) and partly in Duvvám, none of the excavations being within Koduru village limits.

As is shown in the map (Fig. 79) of this area, parallel bands of rock showing a similar change of strike lie on either side of the manganiferous belt. On the N. E. side of the ore belt occurs a belt of wollastonite-scapolite-gneiss (composed of wollastonite, scapolite, green pyroxene, brown garnet, with subordinate calcite, felspar—both orthoclastic and plagioclastic—, quartz, and sphene), which crops out in a series of small hills and tors of barren blackish aspect (one of these hills is shown in Plate 50, fig. 2). These gneisses are so folded and vary so in dip that it is extremely difficult to say if they dip under or over the ore-belt. Forming another curve outside the gneisses is a belt of khondalite (graphite-garnet-sillimanite-quartz-schist) marked by the three hills shown on the map at a distance of 1 to 1½ miles from the ore-belt. In these hills also the dip is variable, being to the E. N. E. in the most southern one and to the S. W. and S. S. W. in the middle and northern ones respectively. Further to the east of this khondalite belt gneissose granite comes in

On the S. W. side of the manganiferous belt there is a repetition of the rocks seen to the N. E. of the belt. The scapolitic gneisses are exposed on the low ground to the west of the Deváda and Sandanandapuram quarries and presumably continue to the N. W. where, however, the ground is obscured by alluvium. Although the rocks are much disturbed, still it is evident that the general dip of this belt is towards the ore-belt. To the S. W. of the gneiss-belt is another of khondalite dipping under scapolitic gneisses and marked by the ridges to the west of the Deváda and Sandanandapuram quarries. To the S. W. again of the khondalite is gneissose granite.

Hence a section along the line XY of Fig. 79 might be as in Fig. 80, in which the ore-zone is composed of very felspathic rocks carrying bodies of manganese minerals and intruded along the bedding planes of the scapolitic gneisses. The repetition of similar rocks on either side of the ore-belt may, however, indicate an overturned synclinal, through the base of which the felspathic and manganiferous rocks have burst, as shown in Figure 81.

Fig. 80.

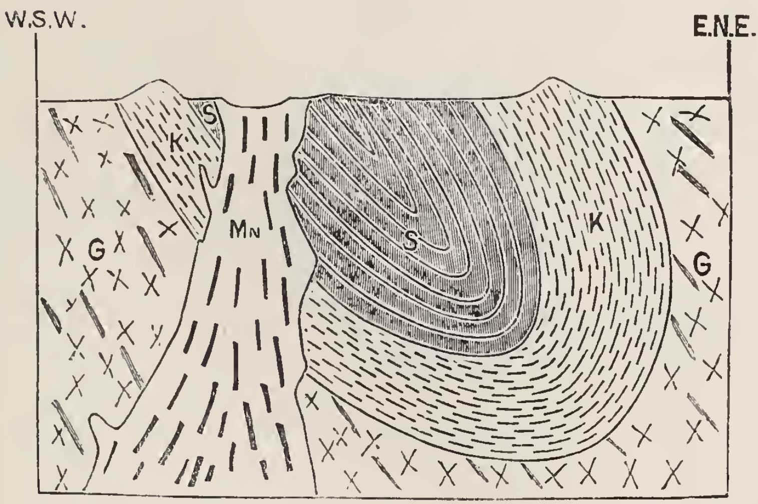

Fig. 81.

G = Gneissose granite; K = Khondalite;
S = Scapolite-wollastonite-diopside-gneiss:
Mn = Manganese-intrusives.
Scale :—About 2″ = 1 mile.

Heights of hills exaggerated.

Figs. 80 and 81.—Alternative interpretations of structure along the line of section XY in Fig. 79.

It has already been explained on page 1046 that the ore-belt is regarded as composed of decomposed and chemically altered rocks of igneous origin, to the fresh form of which the name *kodurite series* has been applied—after the Kodur mine. These intrusives consisted chiefly of acid rocks such as quartz-felspar-rock and felspar-rock (the felspar being orthoclastic), with segregations of more basic rocks, such as apatite-spandite-orthoclase rocks (kodurite), apatite-pyroxene-spandite-orthoclase-rock (pyroxene-kodurite), pyroxene-rock, spandite-rock, and pyroxene-spandite-rock, arranged as patches and streaks in the non-manganiferous intrusives. Subsequently the whole of this mass of intrusives has been subjected to intense chemical action, so that the felspar has been converted into lithomarge, and the manganiferous rocks into manganese-ores. In the description of the various deposits the various pieces of evidence will be given from which the conclusions as to origin given in Chapter XII have been drawn.

Output.

From 1892 to 1907 the Kodur mines have produced 276,364 tons of manganese-ore, giving an average of 17,273 tons a year, the details being as follows :—

Years.	Long tons.
1892	674
1893	3,130
1894	11,410
1895	15,816
1896	26,869
1897	23,947
1898	27,800
1899	29,312
1900	28,163
1901	18,210
1902	14,748
1903	15,985
1904	12,065
1905	14,752
1906	16,048
1907	17,435
TOTAL	276,364

During 1906 and 1907, the Kodur ores have been separated into two classes, as follows :—

	Manganese-ores.	Ferruginous manganese-ores.	Total.
1906	16,010	38	16,048
1907	16,943	492	17,435

1. Garivldi.

No ore-body *in situ* has been located within the limits of this village, the excavations—which lie to the W. and N. W. of the village and about a mile N. of Garividi Railway Station—being entirely for detrital ore in the alluvium. At the time of my visit (January 1905) extensive abandoned excavations were to be seen, nearly filled with water, and showing round the sides a gravel composed of granules of manganese-ore and quartz. In this gravel were scattered pebbles of manganese-ore and quartz ; but the percentage of the ore pebbles was evidently too small for this part of the gravel to be worth working. Immediately to the N. W. of the village, however, a small amount of quarrying was being carried on, and here pebbles and boulders of manganese-ore up to a foot in diameter were being extracted from the clayey gravel in which they were embedded. And in view of the size of some of these boulders it seemed that ore *in situ* could not be very far below. The gravel consisted of round granules or pisolites of ore, $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter, loosely cemented by a sparse reddish clayey matrix. The pebbles and boulders of ore were broken open to ascertain the quality, and then, if sufficiently good, carted to Garividi Railway Station. The owner of the land to the north of the old excavations had some men employed in digging shallow pits in his rice-fields, extracting the ore-pebbles from their matrix of brown clay, and then filling up the pits again. He sold the ore to the Vizianagram Mining Co., Ld., at Rs. 2 per ton.

Output.

These gravel deposits have been worked for several years, but as the figures for the Kodur mines are usually grouped together, I do not know how much ore has been won at Garividi. The figures for the two years for which I have been able to obtain separate figures are as follows:—

Year.	Long tons.
1899	1,974
1900	1,978

Nature and quality of the ores.

The best braunite in the Vizagapatam district comes from Garividi. Some specimens can be obtained in which single cleavage faces of the mineral are 3 inches across.

One piece of this braunite (A. 345) was analysed completely by Messrs. J. & H. S. Pattinson with the result given in full on page 68, where it is shown that the analysis corresponds to the formula $15Mn_2O_3.\ 4MnSiO_3$ for this particular piece of braunite. The constituents of commercial importance are as follows:—

Specimen No. A. 345.

Manganese	51·88
Iron	9·90
Silica (total)	8·25
Phosphorus	0·031
Moisture	·25

Another picked piece of ore composed of fairly coarse granular braunite with a specific gravity of 4·67 (and therefore probably containing a little admixed psilomelane) was also subjected to complete analysis by the same analysts:—

Specimen No. A. 348.

Manganese peroxide (MnO_2)	38·62
Manganese protoxide (MnO)	34·48
Ferric oxide (Fe_2O_2)	14·43
Alumina (Al_2O_3)	1·24
Baryta (BaO)	0·07
Lime (CaO)	0·82
Magnesia (MgO)	0·51
Potash (K_2O)	0·25
Soda (Na_2O)	0·23
Combined silica (SiO_2)	8·05
Free silica (SiO_2)	0·10
Sulphur (S)	0·037
Phosphoric oxide (P_2O_5)	0·055
Arsenic oxide (As_2O_5)	*nil*
Cobaltous oxide (CoO)	0·05
Nickelous oxide (NiO)	0·05
Cupric oxide (CuO)	0·05
Lead oxide (PbO)	*nil*
Zinc oxide ($Zn O$)	0·15
Titanic oxide (TiO_2)	0·07
Chlorine (Cl)	trace
Fluorine (F)	*nil*
Combined water (H_2O)	0·60
Moisture at 100°C.	0·25
Carbonic oxide (CO_2)	*nil*
	100·112

Manganese	51·13
Iron	10·10
Silica (total)	8·15
Phosphorus	0·024

This analysis also corresponds closely—but not so exactly as A. 345, probably owing to a little admixed psilomelane—to the formula $15Mn_2O_3.\ 4MnSiO_3$.

A third picked specimen submitted to complete analysis was supposed to be a variety of braunite. Analysis, however, showed it to be a new mineral of the formula $3Mn_3O_4 . 2Fe_2O_3$; to this I have given the name *vredenburgite* (see page 49). It is distinguished from braunite by its duller lustre, bronze tint, and highly magnetic character. The full analysis is given on page 44; the following shows the constituents of commercial importance:—

Specimen No. A. 346.

Manganese	45·62
Iron	21·90
Silica (total)	0·20
Phosphorus	0·012
Moisture	0·20

There were 185 cart-loads of Garividi ore containing about 140 tons of ore lying at Garividi station ready for despatch. A sample (A. 28) taken from these consisted largely of medium to coarsely facetted braunite; with a certain proportion of the grey psilomelane, with cavities filled partly with black powder and partly with braunite, that is so characteristic of Kodur. This sample was analysed by Messrs. J. & H. S. Pattinson with the following result:—

Sample No. A. 28.

Manganese peroxide	54·62
Manganese protoxide	16·02
Ferric oxide	14·00
Baryta	1·94
Silica (combined)	4·45
Silica (free)	0·25
Phosphoric oxide	0·31
Arsenic oxide	0·005
Water (combined)	3·80
Moisture at 100°C	0·75

This indicates the presence of about 45% of braunite and 55% of psilomelane, and is equivalent to:—

Manganese	46·93
Iron	9·80
Silica (total)	4·70
Phosphorus	0·134

I am indebted to Mr. Caplen, manager of the Vizianagram Mining Co., Ld., for the following figures representing ores actually mined at Garividi:—

	Range of analysis.	Average analysis, 1906.
Manganese	40 to 47	43·02
Iron	5 to 13	10·02
Silica	3 to 6	5·03
Phosphorus	0·07 to 0·30	0·259

2. Kodur.

(*Plates 47 to 50.*)

The group of pits known as the Kodur Mines is situated a little over ½ a mile due east of Garividi Railway Station; work was begun on this deposit in 1892. The first account of it was given by Mr. H. G. Turner in the discussion on Mr. J. Head's paper on the 'Manganese-ore deposits of Northern Spain' [1].

The character of this deposit when first discovered can be judged from the following extract from Mr. Turner's account:—

'The first mound discovered was within a few hundred yards of the railway. Unaware of its nature and value, the railway contractors were breaking up the boulders of manganese rock for ballast. This mound consisted of about 60 acres of black manganese rock and boulders intermixed with an alluvium of decomposed gneiss'.

Since 1892 work has progressed continuously on this deposit, the yearly production of manganese-ore increasing to a maximum in 1899. Of the total production of manganese-ore from all the Kodur mines from 1892 to 1907 given in the table on page 1054, probably ⅘ has come from the Kodur mine.

The main pit of the Kodur mine is about 180 to 190 yards long in a S. of E. direction, and is of irregular shape. Fig. 82 gives a rough sketch-plan of it as it was at the time of my visit in January 1905,

[1] *Jour. Iron Steel Inst.*, No. II, for 1896, p. 156.

while Plate 47 gives a good idea of the nature of this excavation. The depth approaches 100 feet at the deepest parts.

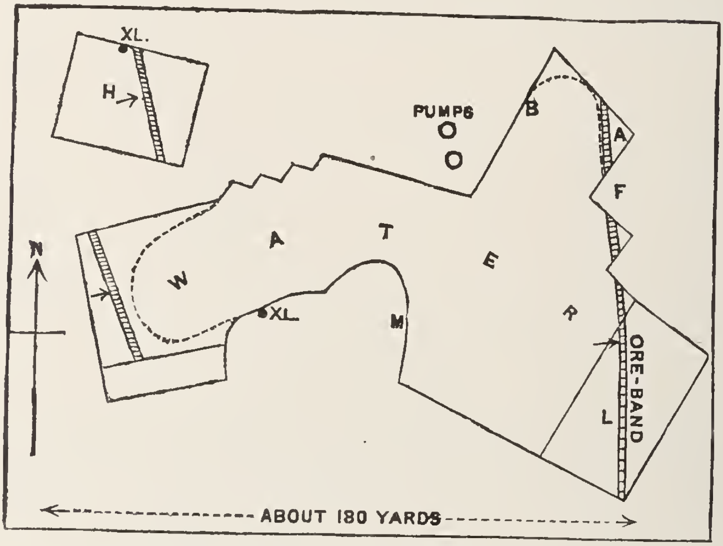

Fig. 82.—Rough sketch-plan of the Kodur Quarry (Jan. 1905.)

The lithomarges.

The smoke from the pumping engines had sooted over all the walls of the quarry except those recently cut, so that it was by no means easy to examine the pits thoroughly. The soft rocks in which the ore-bodies lie consist largely of lithomargic clays of white, yellow, red, and pink, colours, often almost porcellanic in structure, together with abundant wad of dark brown and black colours, occurring as streaks, patches, and spots, in the above. Ochres also occur. When white the lithomarges are almost pure kaolin, and might perhaps be sorted out during the quarrying and sent to pottery works. A specimen of this kaolin was analysed by Mr. J. C. Brown of the Geological Survey of India with the following result:—

Dried at 100° C.

Combined water	13·08
Silica	49·84
Alumina	36·96
Lime	Traces
	99·88
Moisture	1·18

Photographed by L. L. Fermor.

Bemrose, Collo., Derby.

GENERAL VIEW OF THE MANGANESE-QUARRY AT KODUR, VIZAGAPATAM DISTRICT MADRAS.

This indicates kaolin containing only 6·33 per cent. of free quartz, the presence of which is rendered evident by a gritty feeling on powdering up the rock. The coloured lithomarges owe their colouration to oxides of iron, and often contain a small quantity of quartz, not usually visible to the eye, but easily separable by powdering and washing.

Yellow ochre.

The yellow ochre found in some places consists partly of limonite rendered impure by lithomarge and quartz, which are left behind on treating the powdered ochre with hydrochloric acid.

Wad.

The wads, also, often consist of lithomarge impregnated with oxides of iron and manganese, so as to impart a brownish black to black colour; when treated with hydrochloric acid they leave a residue of white lithomarge and quartz. One specimen of black wad was subjected to complete analysis by Messrs. J. & H. S. Pattinson with the result given on page 119. As there shown, the analysis indicates the wad to be an admixture of oxides of manganese and iron with over 6% of kaolin. The constituents of commercial significance are shown below :—

Specimen No. A. 338.

Manganese	41·59
Iron	4·10
Silica	3·40
Phosphorus	0·114
Moisture	4·35

These lithomarges, wads, ochres, etc., were no doubt formed during the chemical changes by which the manganese-ores were produced from the manganese silicates, such as spandite and manganese-pyroxene. The rocks from which they were derived were no doubt mainly felspar- and quartz-felspar rocks; but any or all of the other rocks noticed below may have contributed to their formation. Such extensive chemical changes naturally led to great changes in volume, and many small slips must have taken place in the lithomarges before equilibrium was set up. In many cases the wad has been formed by the impregnation of lithomarge with manganese oxide, and this impregnation has often taken place up to some crack and stopped abruptly at it, so that there are often very sharp changes from black or yellow, to white, red, or purple. In some cases actual fissures must have been formed down which fragments of the various soft rocks fell, producing a sort of fault breccia seen in various parts of the pit. One such case is described on page 1064. The small slips in these lithomarges, etc., have frequently slickensided them along the cracks.

Before describing the ore-bodies, it will be well to consider briefly the rocks to be found in various parts of the mine. These are nearly all in an advanced state of chemical decomposition, the lithomarges and wads being some of the products; and it was only a close examination of the lithomarges that led to the discovery of patches of less altered rock here and there.

Quartz-felspar-rock.

In the extreme S.W. corner of the pit is some coarse-grained kaolinized quartz-felspar-rock containing patches and streaks of pyrolusite and passing above into lithomarge and psilomelane with some pyrolusite. The original rock was evidently a quartz-felspar-rock. Another variety, now mainly kaolin, contained tiny scattered quartz grains and abundant limonitic specks, possibly representing remains of garnet, so that the original rock here was possibly garnet-quartz-felspar-rock. At another point along the south wall in this corner of the mine a coarse-grained quartz-felspar-rock was found, with the felspar sufficiently fresh to give a potassium flame-reaction. In the S. E. corner of L (Fig. 49) kaolinized fine-grained quartz-felspar-rock was also found.

Felspar-rock.

Amongst the lithomarges, wads, and ochres, being removed at L in order to get at the underlying manganese-ore, and well shewn in Plate 49, is a rock, now all lithomarge, that was probably once all felspar; and many similar examples are to be found in other parts of the quarry.

Vein-quartz (rose).

A cutting on top of the bank on the south side of the quarry between XL and M shows a patch of vein-quartz about 4 paces long that seems to be surrounded by wad with some lithomarge and to be an isolated mass. The quartz varies in colour from pale reddish to pale violet. Vein quartz also occur in patches in the lithomarges and wads at M.

In the N. E. corner of the mine (shown in Fig. 1, Plate 50) many interesting rocks are seen in the decomposed walls. On descending at

A the soft steps were found to be composed largely of a moderately fine-grained rock, which was apparently once a pyroxene-spandite-felspar-rock (with apatite-pyroxene-kodurite), the pyroxene being now represented by manganese-oxide pseudomorphs. The walls along B were also composed largely of similar rocks, which in one place were sufficiently fresh to permit of the preparation of a microscope slide. This showed that the pyroxene was entirely converted into manganese oxide, and the felspar probably orthoclase; the pyroxene being moulded on to the idiomorphic garnet, and the felspar interstitial with regard to both.

Pyroxene-spandite-felspar-rock.

Along B is also found a rock composed almost entirely of spandite. The rock is a friable granular rock of medium grain, and dark chocolate-brown colour, and sometimes shows little patches of the lavender manganapatite to be noticed below. The garnet (spandite) is deep orange-red to blood-red where transparent; and the microscope shows, scattered through the rock, a small amount of apatite which is allotriomorphic with regard to the garnet. Along the wall A B there is a large quantity of this spandite-rock extending for 20 paces along the path. The rock contains thin yellowish clayey bands. The garnets are often elongated so that the rock shows a sort of parallel structure, the long axes of which dip to W. S. W., and are hence roughly at right angles to the dip of the rocks (to E. N. E.).

Spandite-rock and apatite-spandite rock.

In this rock there is a veinlet, varying from a fraction of an inch to 4 inches thick and traceable for 4 feet horizontally, of a lavender-coloured variety of mangan-fluor-apatite. It is possible that this is a segregation veinlet formed during the cooling of the magma from which the spandite-rock crystallized out.

Mangan-fluor-apatite.

Another rock found along B is a black altered rock that looks as if it is pseudomorphous in manganese oxide after an original coarse-grained pyroxene-rock. That this is the case is supported by the fact that on the path leading down to the water's edge at M there is an exposure of a similar rock, in some

Pyroxene-rock.

cases free from garnets and in others containing an abundance of the usual orange-red manganese-garnet (spandite). On breaking up this rock it was found to pass inside into an exceedingly tough rock composed of plates of a dark greenish to greyish black mineral, which, under the microscope, is seen to be a pyroxene of yellow-green to brownish green colour, practically non-pleochroic, and showing both prismatic and pinacoidal cleavages. The extinction angles in sections parallel to the vertical axis range up to 45°. There is also a certain amount of a colourless pyroxene (? rhodonite). The pyroxene is seen to be altering very largely to manganese-ore, which traverses it as a network, extends along cleavage cracks, and unites into patches. In some cases the pyroxene individuals are as much as an inch across. In sections showing both spandite and pyroxene it is seen that the two minerals have crystallized at about the same time, the spandite having perhaps started before the pyroxene. This spandite-pyroxene-rock rests on a layer, 6 inches thick, of a coarsely crystalline limestone, which is underlain by similar rock. The limestone is probably a small xenolith like the much larger once to be noticed below, and contains scattered granules of both the garnet and pyroxene. Fresh granules of both the pyroxene and garnet extracted from the limestone gave decided reactions for manganese. At the junction, the calcite of the limestone interlocks with the large plates of the pyroxenic rock and a few interstitial plates of calcite also occur in the latter.

Pyroxene-spandite-rock.

Along the wall B at its northern end the rock is very variegated and consists apparently of masses of more or less blackened pyroxene-spandite-rock (probably original segregations) in a matrix of lighter coloured spandite-felspar rock. Near B irregular patches of spandite-rock, altered pyroxene-rock, crumbly fragments of white felspathic rock, and rounded pieces of pyroxene-spandite-felspar-rock are set in a matrix composed of little grains of kaolinized felspar and spandite in a soft or kaolinic clay-coloured basis; and the whole rock is probably to be regarded as a detrital infilling of a fissure, opened out in these soft rocks on account of some change in volume produced by the chemical changes that have affected the whole of this mass of rocks. One of these included masses is composed of pyroxene(?)-spandite-rock and is a yard across.

A fissure-rock.

At F is to be found a crumbly and partly altered rock of fairly fine grain, composed of orange-red spandite, very pale greyish apatite and a little white felspar giving a potassium flame colouration. The rock is partly altered with formation of wad and a pale yellowish clay, but was evidently once an apatite-felspar-spandite-rock (kodurite), the last-named mineral forming perhaps ⅔ of the rock.

Apatite-felspar-spandite-rock (kodurite).

In two different parts of the excavation, isolated masses of crystalline limestone are found that are almost certainly of the nature of xenoliths torn up from below by the mass of intrusive rocks composing the manganese-ore belt of rocks. These limestones may once have formed part of the scapolitic gneisses (see page 243), and may either have been derived from a variety of those rocks containing a greater quantity of calcite than usual, or they may have been formed from the typical diopside-garnet-scapolite-wollastonite-rock by the absorption of materials from the intrusives that carried them up. One of these xenoliths is exposed at the surface on top of the southern bank of the mine (XL on Fig. 82), with rounded surfaces and curved hollows, such as are made by a stream on a limestone bed. Some very jagged quartzose strings and patches were weathered out from the mass. It is 13 paces long in a N. E. direction and 12 paces across. The rock is a very coarsely crystalline limestone, contains green coccolite,— in some place pale green and in others greenish black,— wollastonite, sometimes in porphyritic crystals an inch long, sphene, scapolite, and some quartz, and beautiful, pale blue, rounded prisms of apatite up to ¼ inch long.

Xenoliths of crystalline limestone.

The limestone shows a certain parallel arrangement of its constituent minerals and has a dip of 55° to N. 20° W.; resting on it at the edge of the excavation is a medium-grained rock composed of microcline, and green pyroxene, with sphene, quartz, and ilmenite.

The second locality for these xenoliths is at XL (Fig. 82) in the separate pit (H) to the north of the west end of the main pit. At the time of my visit the quarrying operations were uncovering surface débris from two rounded masses of crystalline limestone 2 or 3 yards apart. One of these masses contained a patch of wollastonite-rock. The limestone contained blue apatite.

A third xenolith of crystalline limestone in pyroxenic rock has already been mentioned (page 1064). In this place the limestone has evidently absorbed manganese from the pyroxenic rock, so that manganese-garnets and -pyroxenes have been developed in it. It is possible that the blue apatite in the large xenoliths of crystalline limestone was absorbed from the manganiferous intrusives.

Chert.

At the western end of the quarry along its southern edge near the water level were many huge blocks of brown chert in the lithomarges and decomposed quartz-felspar-rocks. During the chemical changes that have led to the formation of the manganese-ores large quantities of silica must have passed into solution. Such silica must to a large extent have been redeposited as these masses of chert. This chert contains ramifying chalcedony veins and small vein-like cavities, which are often found to contain water when newly fractured.

Mangan-magnetite.

Dr. Holland has described (see page 38) a specimen from Kodur of magnetite containing 2·16% Mn and 2·52% Al_2O_3. At Kodur I found this mineral only in the ores at A (page 1069); but what is probably also mangan-magnetite, containing perhaps a larger per cent. of Mn, is very common at Garbhám and Ávagudem.

The ore-bodies.

It is in the soft lithomargic and other rocks noticed above that the manganese-ore bodies are embedded. At the time of my visit the bottom of the pit was filled with a depth of about 8 feet of water, as shown on Plates 47 and 50. This water was due to unusually heavy rains in the previous monsoon (July to September) and was being slowly reduced by pumping. Two bands of ore were visible: one at the west end not more than 5 feet thick and dipping steeply to E. 20° N.; and another at the east end of similar thickness and dipping steeply to E. 10° N. The pit is thus cut at right angles to the strike of these ore-bands and the excavation between the west and east end of the pit would appear to have been made in practically barren lithomarge. But Mr. Tom Caplen, the manager of the Vizianagram Mining Co, Ld., tells me that ore occupies the whole bottom of the pit.

Mr. W. H. Clark, who was formerly at Kodur, and is now manager of the Central Provinces Prospecting Syndicate, tells me that large

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Photographed by L. L. Fermor.

Bemrose, Collo., Derby.

SECTION AT KODUR SHOWING LITHOMARGE, WAD AND MANGANESE-ORE

lenticular masses of ore were extracted in excavating this pit, and that they seemed to run together below and form a mass having the general shape of the pit.

The ore-body at the western end is not really a continuous band of ore, but consists of lenticular and boulder-like masses of manganese-ore in wad and lithomarge; there are also often small pebble-like masses of ore in the patches of wad, usually towards their centre. A careful examination of this and similar occurrences of wad at other parts of the deposit makes it evident that these boulder-like masses of ore are the result of the replacement of the lithomarge by oxides of manganese, wad being the first product, passing on the accession of more manganese oxide into manganese-ore. Plate 48 illustrates a section seen at this end of the quarry, the black patches (O) being manganese-ore, the white lithomarge, and the half tones wad.

The pit H, separated from the main quarry, was not deep, and exposed an ore-band striking N.15°W., not more than 3-5 feet wide, and, as far as could be seen, also composed of isolated masses. This strike brings it to the west end of the main pit at a point some 30 yards east of the ore-band noticed in the previous paragraph, so that it is probably another ore-band.

The ore-band at the east end of the quarry is best studied in the N. E. corner B A (Fig. 82) of the quarry. This is the portion illustrated in Plate 50, Fig. 1, where coolies are seen actively engaged in quarrying the ore. On the way down the zig-zag path the soft rocks are seen to be composed of the various decomposed rocks originally composed of apatite, manganese-pyroxene, spandite, and felspar, and already noticed on pages 1062 to 1064.

The rock of immediate interest is the mass of spandite-rock seen in the wall A B (see page 1063). In places the spandite-rock is altered to pyrolusite and psilomelane, and at the S. E. end of the cutting this alteration is more frequent. Here there is an apparent dip at 45° to S. E. and some bands of spandite-rock have been changed to shiny psilomelane at the centre.

There is also another band of brecciation due to the filling in of a fissure by spandite, clay, ore, and kaolinized felspar-rock. In the corner at A (Fig. 82) a mass of manganese-ore was being worked. A large part of this mass consisted of crumbly spandite-rock; every stage in the passage of this into manganese-ore was to be found, the final product being a vesicular psilomelane with numerous vesicles averaging about $\frac{1}{16}$ to $\frac{1}{8}$ inch in diameter. Some of these vesicles are empty and then are found to contain water when freshly broken open; some contain a brownish black powder and some shining black braunite, usually traversed by thin veinlets of psilomelane.

The quantity of ore visible in this part of the pit was not very large. As shown in Fig. 82 this band of ore continues right across the eastern end of the mine; it was also being worked at L as shown in Plate 49, which is a photograph of this part of the mine.

Besides the ore-bands mentioned above there were obscure exposures of manganese ore at several points round the sides of the pit, while little bands and nodules of ore were of frequent occurrence throughout the soft rocks.

In addition to the main pit there are several excavations to the north, but as none of these were being worked and time was limited, I did not examine them; but they had evidently been excavated in similar soft lithomargic rocks.

Nature and quality of the ores.

In the process of formation of manganese-ore from spandite-rock the first variety of marketable value formed is composed of hard grey vesicular psilomelane with a large quantity of a soft brownish black powder, and often a few scattered specks of braunite. This variety passes into that most characteristic of Kodur (A. 334), namely, a vesicular hard grey psilomelane with some of the vesicles empty, some filled with brownish black powder, and some with braunite. These patches of braunite seem to be able to grow at the expense of the psilomelane, so that patches up to 1 to 3 inches across are sometimes formed in the psilomelane. Another variety, not found in any quantity, is composed largely of black facetted braunite with a little interstitial psilomelane.

Two specimens of ore were selected for complete analysis. A.334 is the typical ore mentioned above. A.336 is a porous dirty ore,

Photographed by L. L. Fermor.

Bemrose, Collo., Derby.

THE EAST END OF THE KODUR QUARRY.

composed of a very magnetic mineral (probably mangan-magnetite), psilomelane, and soft brownish black oxide.

	Specimen No. A. 334.	Specimen No. A. 336.
MnO_2	71·10	44·68
MnO	9·84	24·85
Fe_2O_3	6·57	13·14
Al_2O_3	1·38	6·84
BaO	0·65	0·53
CaO	0·66	0·86
MgO	0·32	0·50
K_2O	3·75	1·01
Na_2O	0·21	0·21
SiO_2 (combined)	2·00	4·50
SiO_2 (free)	*nil*	0·20
Sulphur	0·025	0·030
P_2O_5	0·492	0·261
As_2O_5	*nil*	*nil*
CoO	0·05	0·08
NiO	0·05	0·07
CuO	0·04	0·07
PbO	*nil*	*nil*
ZnO	0·10	0·10
TiO_2	0·06	0·11
Chlorine	Trace	Trace
Fluorine	*nil*	*nil*
H_2O (combined) water	2·60	1·90
Moisture at 100°C.	0·30	0·20
CO_2	*nil*	*nil*
	100·197	100·141
These are equivalent to :—		
Manganese	52·58	47·50
Iron	4·60	9·20
Silica (total)	2·00	4·70
Phosphorus	0·215	0·114

On the assumption that the braunite has a composition corresponding to the formula $7Mn_2O_3 . 2MnSiO_3$, the analysis A.334 can be expressed in terms of the mineralogical composition as follows :—

Specimen No. A. 334.

Apatite		1·132
Braunite (including 6·57 Fe_2O_3)		22·75
Psilomelane :—		
$Al_4(MnO_5)_3$	3·47	
Ba_2MnO_5	0·87	
Ca_2MnO_5	0·04	
Mg_2MnO_5	0·73	
K_4MnO_5	5·80	
Na_4MnO_5	0·38	
Co_2MnO_5	0·08	
Ni_2MnO_5	0·03	
Cu_2MnO_5	0·07	
Zn_2MnO_5	0·16	
H_4MnO_5	10·03	
Mn_2MnO_5	53·20	
	74·91	74·91
Sulphur		0·025
TiO_2		0·06
Moisture at 100°. C.		0·30
		99·177
Surplus oxygen		1·02
		100·197

The oxygen error is rather large; but may be due either to the presence of some $Mn_4(MnO_5)_3$, or to other constituents in the specimen, such as spots of soft black oxide.

The foregoing ores seem to have been formed by the alteration *in situ*, with accession of further supplies of manganese oxide from other parts of the rock-mass, of masses of spandite-rock; but frequently ores are formed in the midst either of rocks containing no manganese, such as the quartz-felspar-rocks and their resultant lithomarges, or in rocks, such as apatite-spandite-felspar-rock, in which the percentage of original manganese is small. In such cases the resultant ore formed by replacement of the pre-existing rock, whatever it may have been, is pyrolusite or compact psilomelane. A specimen of such pyrolusite taken from a stack of such material and composed of compact pyrolusite, with cavities lined with mammillated pyrolusite, was subjected to complete analysis by Messrs. J. & H. S. Pattinson with the result given on page 82 of Part I. The analysis there given is equivalent to :—

Specimen No. A.197.

Manganese	59·78
Iron	0·05
Silica (total)	0·50
Phosphorus	0·417

It will be seen from the above that this is very high grade ore, characterized by very low iron, and high manganese and manganese peroxide; it should be suitable for glass manufacture and chemical purposes.

From some 90 tons of Kodur ore lying at Garividi Railway Station ready for despatch I took sample A.27. This consisted of the various varieties of cavernous psilomelane with scattered specks of braunite and a few braunite patches. It was partially analysed by Messrs. J. and H. S. Pattinson with the following result :—

Sample No. A. 27.

Manganese peroxide	57·19
Manganese protoxide	14·15
Ferric oxide	13·85
Baryta	2·20
Silica (combined)	2·95
Silica (free)	0·20
Phosphoric oxide	0·438
Arsenic oxide	0·005
Water (combined)	3·30
Moisture at 100° C.	0·65

This is equivalent to :—

Manganese	47·11
Iron	9·70
Silica (total)	3·15
Phosphorus	0·191

and indicates the presence of nearly 30 % of braunite.

In the following table the first two analyses were given by Mr. H. G. Turner in *Jour. Iron Steel Inst.*, No. II, for 1896, page 160, whilst the figures in the 3rd and 4th columns were kindly supplied by Mr. T. Caplen, manager of the Vizianagram Mining Company, Limited.

Analyses of merchantable Kodur ores.

	Manganese-ore, 1896.	Manganese-ore, 1896.	Range of analysis of manganese-ores, 1906.	Average analysis of manganese-ores, 1906.
Manganese . .	48·65	46·15	45 to 55	49·69
Iron . . .	7·10	10·35	5 to 10	7·41
Silica . . .	2·23	3·20	2 to 5	3·20
Phosphorus . .	0·12	0·21	0·20 to 0·30	0·297
Moisture . .	1·10	1·30	..	..
Insoluble . .	..	..	..	3·52

The working of the deposit.

Partly on account of the irregular nature of the scattered ore-bodies and partly because of the structural weakness of the enclosing rocks, it has been found necessary to excavate the whole of the mass of rock. Since big falls of side would occur from time to time were the sides of the pit kept vertical, the pit has been excavated in a series of steps some 6 to 10 feet high (see Plates 47 to 50). At the eastern end of the quarry an attempt was once made to follow the manganese-ore into the lithomargic 'country' by means of galleries, the object being to obviate the necessity of removing the large overburden of lithomarges, etc., covering this part of the deposit. The attempt failed on account of the structural weakness of the rocks and presumably insufficient timbering and the galleries fell in; so that it has been found necessary to remove the overburden and work down to the manganese-ore, as shown in Plate 49, where the old galleries are still visible.

No attempt has been made to introduce any labour-saving appliances for removing the ore and waste from the quarry; but instead these products are carried out of the pit on the heads of men, women and children, as can be seen in Plates 49 and 50. The ore is hand-dressed on the bank of the mine and stacked, and, after analysis, is hand-trammed to Garividi Railway Station. During the rains (July to September) work is stopped because the pit becomes partly filled with water. Before work can be resumed it is necessary to remove a large part of this

FIG. 1.—N. E. CORNER OF KODUR MANGANESE-QUARRY.

Photographed by L. L. Fermor. *Bemrose, Collo., Derby.*

FIG. 2.—UNLOADING MANGANESE-ORE AT GARIVIDI RY. STA., EAST COAST RY.

water, for which purpose a couple of pulsometer pumps are employed worked by the vertical engines seen in Plate 47. The ore in the bottom of the pit cannot be touched until well on into the cold weather when the whole of the water has been removed by continuous pumping; after this has been accomplished pumping is still necessary to control the constant influx of subterranean water.

3. Duvvám.

Part of the main Kodur pit already described is within the limits of this village. Between the Kodur pit and the Deváda quarries shown in Fig. 79, there are several other pits lying in Duvvám limits. As, however, they were not being worked, I did not examine them. But it was evident from the sides that they had been excavated in similar soft rocks to the Kodur pit.

In the only year, namely, 1899, for which the output figures of Duvvám have been separated from those of Kodur, the output was 571 tons.

The following figures showing the range of analysis of Duvvám ores, now no longer worked, were supplied by Mr. Caplen:—

Manganese	43 to 48
Iron	4·5 to 16
Silica	2 to 4

4. Deváda.

The rocks.

There is here a series of shallow excavations showing similar kaolin, lithomarge and wad to Kodur, often with patches of pyrolusite scattered through these soft rocks. In places quartz-felspar-rock was seen. In one of the pits soft altered rather fine-grained quartz-apatite-spandite-felspar-rock (quartz-kodurite) was found, the apatite being light sea-green in colour and up to ¼ inch or more in diameter, while the felspar reacted as usual for potassium, and the spandite was pale sherry-coloured.

Apatite.

A little to the S. W. of this pit I was shown a spot from which some eight years previously some hundred-weights of large crystals of apatite had been obtained. The excavation then made had become silted up with clay, but round the edges I found abundance of the soft rather fine-grained apatite-felspar-rock with a certain proportion of spandite; hence it seems probable that the apatite crystals were obtained from a pegmatitic variety of the apatite-spandite-felspar-rock (kodurite). Mr. W. H. Clark kindly showed me a heap of this apatite lying on the surface of the ground near the Kodur quarry, whither it had been taken. The crystals are hexagonal prisms, a few of them showing pyramidal terminations. They are much corroded by tunnels and cavities; but whether these are an original feature, or were formed while the crystals were lying on the ground, I do not know, although I suspect the former to be the case. One piece indicated a prism 5 inches in diameter. The colour on fresh fractures is a beautiful deep sea-green, and the mineral is mangan-fluor-apatite. I saw, also at the apatite locality, some of the crumbly brown spandite-rock so abundant at Kodur.

'Country.'

One of the pits had been partly cut into the diopside-scapolite-wollastonite-rock forming the band to the west of the ore-belt, thus showing that this rock undoubtedly forms the western wall of these intrusives. That this rock also forms the north-eastern wall of the ore-belt is indicated by the small tor of these rocks shown on the map (Fig. 79) a little to the east of the Deváda pits. The rocks in this tor are extremely contorted and are traversed at the northern end by a granitic intrusive.

Nature and quality of the ores.

I saw very little ore exposed in any of the Deváda pits, but some 50 tons of ore were lying at Garividi Railway Station, from which I took sample A. 30. This ore consisted of pyrolusite, and psilomelane (both dull and shiny), with scattered facets of braunite in some of the psilomelane and pyrolusite. There was also some dull facetted ore suggesting psilomelane pseudomorphous after pyroxene. The sample was analysed by Messrs. J. and H. S. Pattinson with the following result:—

Sample No. A. 30.

Manganese peroxide	66·26
Manganese protoxide	6·76
Ferric oxide	10·14
Baryta	7·92
Silica (combined)	1·10
Silica (free)	*nil*
Phosphoric oxide	0·41
Water (combined)	3·60
Moisture at 100°C.	1·00

This indicates the presence of some 11% of braunite and is equivalent to :—

Manganese	47·08
Iron	7·10
Silica (total)	1·10
Phosphorus	0·179

In the only year, namely, 1899, for which I have been able to obtain the output figures of Deváda separated from those of Kodur, the output was 2,167 tons.

Mr. Caplen sends me the following figures shewing the range of analysis of Deváda ores, which, however, are no longer (in 1906) being extracted :—

Manganese	42·5	to	50·0
Iron	3·5	to	11·0
Silica	1·5	to	4·5

5. Sandanandapuram.

Detrital accumulations.

The succession of shallow pits lying within the limits of this village forms the southern end of the manganiferous belt, as far as it has been traced. Most of the pits disclose only detrital accumulations of pebbles and boulders of manganese-ore and khondalite, in a matrix composed of pisolitic granules of manganese-ore, hematite, limonite and quartz, set in a red clay. In one of these excavations, situated at the northern end of Sandanandapuram, at a point a little to the N.E. of the north end of khondalite range of hills lying to the west of the Sandanandapuram quarries, a considerable quantity of loose pieces and crystals of quartz was being removed. Some of these were water-clear, free from flaws, and often pale rose or amethystine in colour. One piece showing pyramidal and prismatic faces is 9 inches across. Another doubly terminated crystal is smoky quartz. In the most southern pit (known as the Dimidi pit) the detrital accumulations rest on brown chert, which here occurs in considerable quantity and is veined and patched with psilomelane. In an ore stack here the ore was traversed by a network of cavities lined with chalcedony, some of which was pale rose-coloured, the ore being both psilomelane and pyrolusite.

Amethystine quartz.

Chert.

Lithomarges.

Towards the north end of Sandanandapuram there is a large pit containing a considerable depth of water. Along the east wall are exposed fine-grained banded gritty lithomarges of various colours and in some places a granular quartz-rock with a subordinate kaolinic matrix. A large quantity of ore is said to have been obtained from this pit, and, to judge from heaps of small granules lying on the banks, this ore was chiefly pyrolusite occurring as segregations scattered through the lithomargic clays, from which the ore is said to have been separated by washing and sieving.

Scapolitic gneisses.

On the low ground immediately to the west of these pits there are numerous outcrops of the diopside-scapolite-wollastonite-rock, often containing garnets and in places intruded by quartz-felspar-rock. These rocks are much twisted, with very irregular dips to the east side of the strike, which averages N. N. W.

Nature and quality of the ores.

Practically all the ore seen in the ground was in detrital accumulations, although much pyrolusite was apparently once obtained as segregrations in lithomarge. From the stacks, containing about 100 tons of ore, I took sample A.29, which was chiefly pyrolusite, usually slightly cavernous, some pieces being very fine-grained and some showing stellate crystalline groups up to $\frac{1}{8}$ inch in diameter.

There were also a few pieces of psilomelane and of compact fine-grained wad, while one or two pieces looked like blackened pyroxene. The sample was analysed by Messrs. J. and H. S. Pattinson with the following result:—

Sample No. A. 29.

Manganese peroxide	72·03
Manganese protoxide	4·50
Ferric oxide	6·85
Baryta	6·96
Silica (combined)	1·80
Silica (free)	0·10
Phosphoric oxide	0·36
Water (combined)	3·80
Moisture at 100°C.	0·75

This is equivalent to :—

Manganese	49·65
Iron	4·80
Silica (total)	1·90
Phosphorus	0·157

In the only year (1899) for which the figures for Sandanandapuram have been separated from those of Kodur the output was 2,690 tons.

The following analytical figures were supplied by Mr. Caplen :—

	Range of analysis of manganese-ores.	Average analysis of manganese-ores, 1906.
Manganese	45 to 50	48·14
Iron	2 to 5	2·35
Silica	1·5 to 5	3·05
Phosphorus	0·18 to 0·30	0·262
Insoluble		4·10

6. Sivarám.

The rights to work this property, lying some 3 miles east of Kodur, were acquired by the A. S. N. & Co., who quarried and carted a certain quantity of ore to Chipurupalli Railway Station. I did not visit the deposit, but the ore stacked at Chipurupalli Railway Station consisted of pyrolusite and psilomelane.

7. Perapi.

There are a large number of shallow excavations arranged over a distance of at least ½ a mile along a line stretching N. 20° W. to S. 20° E. The most northern excavation is about 300 yards S. 40° E. of Perapi village. These pits were, at the time of my visit, separated into two groups, the northern and the southern, by about a ¼ mile of unopened ground. Dips, when seen, were usually fairly steep towards the east side.

Ore is found both in detrital deposits overlying the rocks *in situ*, and also *in situ*, either as replacement patches in the quartz-felspar- and felspar-rocks, or as combined alteration and replacement products of masses of spandite-felspar-rock and spandite-pyroxene-rock. Thus the most northern pit shows 3 to 7 feet of detritus composed of fragments of ore with a small amount of interstitial gravel, while in one of the southern pits the detrital accumulations are as much as 10 feet thick in places. Of ore *in situ* the largest body seen was a mass of very impure character (ochreous and cherty), 20 to 30 feet wide but the thickest definite ore-band seen was in the most northern pit where the section given in Fig. 83 was seen, the ore-band varying in thickness from 1 to 3 feet. The felspar usually shows a pearly schiller is a potash variety, and is often kaolinized. The ore-band consist

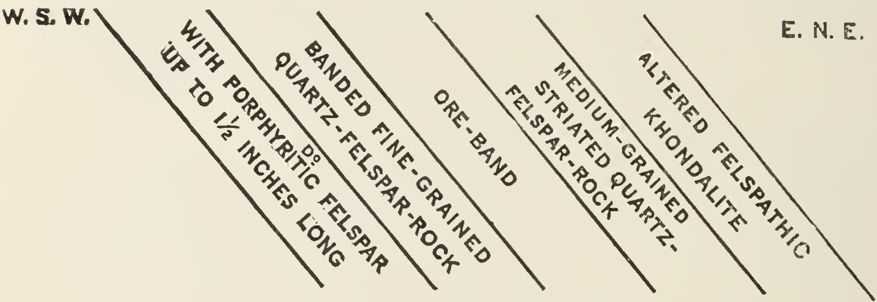


Fig. 83.—Section seen in a pit at Perapi.

of psilomelane associated with yellow ochre and studded with orange-red manganese-garnets up to $\frac{1}{16}$ inch diameter ; it has probably been produced by the replacement of the felspar of a band of spandite-felspar-rock, by manganese oxide introduced in solution, the garnets being left unaltered. Hence the rocks here were probably once banded quartz-felspar-rocks of different degrees of coarseness, with a narrow band, say 2 feet thick, of spandite-felspar-rock. In most of the pits similar quartz-felspar-rock or felspar-rock is seen, usually much fresher than in the Kodur group of mines. In one of the southern pits there is a large quantity of ore formed by the replacement of otherwise fresh felspar-rock. Under the microscope a section of the partly replaced felspar shows fresh microcline traversed by a network of psilomelane veins, joining together in places to form continuous patches of psilomelane.

Spandite-felspar-rocks.

Replaced microcline-rock.

Besides spandite-felspar-rock, usually partly converted into manganese-ore, which is seen in two or three places, several pits show *in situ* tough compact spandite-pyroxene-rock, the latter mineral

Spandite-pyroxene-rock (rhodonite).

usually predominating, and the rock having a dark greenish black colour Under the microscope the pyroxene is seen to be composed partly of a colourless variety, possibly rhodonite, and partly of the yellow-brown variety found at Kodur.

This rock is usually more or less altered to manganese-ore.

Chert and flint.

In some of the pits, especially in the southern ones, chert is extremely abundant, being grey, brown, or black, in colour. In the latter case it looks exactly like flint, having also the white outer coating characteristic of that variety of silica. Cavernous reticulated psilomelane, with the cavities filled with yellow ochre, is usually associated with this chert.

Scapolitic gneisses.

The rocks on either side of the ore-belt here are probably, as at Kodur, scapolitic gneisses; for two outcrops of this rock were noticed, one 200—300 yards east of the line of pits, and one to the west of the north end of the line of pits.

Nature and quality of the ores.

The character of the ores can be best judged from the constitution of sample A.31, taken from some 185 tons of stacked ore quarried from the northern group of pits. The ore was mostly fairly compact psilomelane, a large proportion of the pieces containing small scattered crystals of manganese-garnet, while some pieces showed kaolinic specks.

The analysis carried out by Messrs. J. and H. S. Pattinson showed the following:—

Sample No. A. 31.

Manganese peroxide	58·51
Manganese protoxide	4·04
Ferric oxide	18·82
Baryta	1·81
Silica (combined)	3·50
Silica (free)	0·10
Phosphoric oxide	0·475
Arsenic oxide	0·030
Water (combined)	5·20
Moisture at 100°C.	1·00

This is equivalent to:—

Manganese	40·10
Iron	13·20
Silica (total)	3·60
Phosphorus	0·207

The combined silica is in this case due, not to braunite, but to garnet, kaolin, etc.

The ores seen in the mine are often cherty and limonitic.

The following figures supplied by Mr. Caplen show the quality of the ores quarried by the Vizianagram Mining Co. at Perapi :—

	Range of analysis.	Average analysis at present day.	Ferruginous manganese-ore.
Manganese . . .	40 to 47	41·63	36·17
Iron . . .	7 to 13	11·52	15·69
Silica . . .	3 to 6	4·30	5·40
Phosphorus . . .	0·20 to 0·30	0·286	0·204
Insoluble . . .	..	6·50	8·20

Output.

The annual output from this deposit from 1900 to 1907 is shown below :—

Year.	Long tons.
1900	3,800
1901	3,100
1902	4,563
1903	1,779
1904	*Nil*
1905	4,715
1906	19,226
1907	9,160

For the years 1906 and 1907 the following amounts included in the above have been ferruginous manganese-ores (manganiferous iron-ores) :—

	Long tons.
1906	17,818
1907	8,466

8. Itakerlapilli.

Beyond the fact that the Vizianagram Mining Co. have located and worked a little manganese-ore somewhere within the limits of this village about 2 miles south of Perapi, I have no information about this deposit.

Mr. Caplen has supplied the following figures as representing the average analysis of the ore being mined here in 1906 :—

Manganese	43·00
Iron	8·74
Silica	5·70

9. Mulagám.

The only information about manganese-ore found within the limits of this village, situated about a mile S. S. E. of Itakerlapilli and 6 to 7 miles S. E. of Garividi Railway Station as the crow flies, is that 120 tons of ore were quarried here by the Vizianagram Mining Co. in 1900.

10. Govindapuram.

This locality is situated about 7 miles south of Sigram Railway Station; manganese-ore was worked here by Messrs. Gordon, Woodroffe & Co., of Coconada, and Kovoori Basivireddy at some time during the years 1898 to 1900. During 1906 and 1907 work has been carried on by the Vizianagram Mining Co., with the following resultant output :—

	Manganese-ore.	Ferruginous Manganese-ore.
	Long tons.	Long tons.
1906	..	1,269
1907	11	776

11, Garbhám.

(*Plates 51 to 54.*

This deposit was mentioned by Mr. H. G. Turner in the correspondence on Mr. J. Head's paper on 'The Manganese Ore Deposits of Northern Spain,' *Jour. Iron and Steel Inst.*, No. II, for 1896, pp. 157—160. Mr. Turner gives some analyses of Garbhám ore (see page 1094) and mentions the interesting fact that the ores of this district were 'known and worked by the native smelters, as vestiges of the furnaces were still to be seen close to the Garbham Hill.' In a recent paper by W. Venator in *Stahl und Eisen*[1] there are four photographs of the Garbhám workings.

Work was commenced on this deposit, which is probably the largest yet discovered in India, in February 1896, and since then an average

[1] Vol. XXVI, pp. 142 to 145, (1906).

of about 46,000 tons of manganese-ore per annum has been extracted from this deposit, making a total of 553,140 tons to the end of 1907, which is equivalent to over $\frac{1}{4}$ of the total quantity of manganese-ore extracted from the Indian deposits since the commencement of the industry in 1892, and is about $\frac{3}{5}$ of the total amount of ore extracted in this district. The accompanying rough sketch map (Fig. 84) shews the situation of the Garbhám deposit with respect to

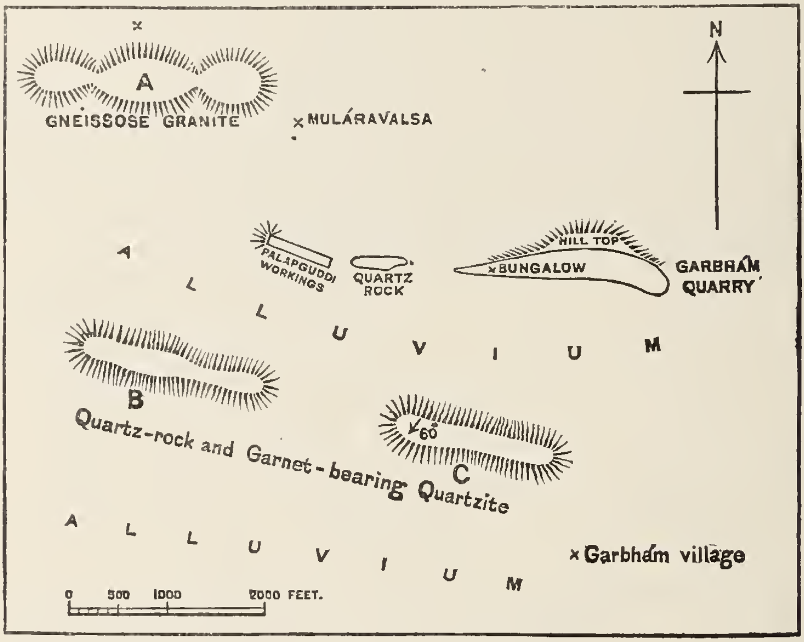


Fig 84.—Sketch plan of Garbhám.

surrounding hills. Most of the flat ground surrounding the deposit is soil or alluvium, but on approaching the foot of the hills A outcrops of gneissose granite are seen.

Situation of the deposit.

The hills A consist of three-dome-shaped masses of the typical gneissose garnetiferous biotite-granite of the district. The granite is streaked in a W. 15° to 20° N. direction. The hill C is composed of quartz-rock, garnet-quartz-rock and quartz-felspar-garnet-rock, these rocks being possibly members of the khondalite series. Hill B is apparently a continuation of the same. No true khondalites or scapolitic gneisses were, however, found close to the Garbhám deposit.

The deposit, before work was commenced, appeared at the surface as a long low ridge reaching a height of 70 to 80 feet above the plains at the part known as 'Hilltop.' The total length of the workings, as measured by Mr. H. B. Geeson, present manager of this deposit, is 1,600 feet in a S. of E. direction, while outcrops continue for another 200 yards to the west, giving a total length of 2,200 feet. Still further west, after a E.-W.-running mound of white vein-quartz or very coarse-grained quartzite, some 200 yards long, is a series of workings, some 250 yards long, stretching in a W.20°N. direction. They are known as the Palapguddi workings, although they are within Garbhám village limits (see page 1095); if the Garbhám deposit be assumed to be continuous below the surface right to their western end, then the total length of the deposit is about 4,500 feet.

Length of the deposit.

The width of the ore-body, judging from a section (Fig. 87 below) across the middle of the deposit, is 260 feet measured horizontally; or, taking an average dip of 40° to the south side, the actual thickness of the ore-body is 167 feet, of which 100 feet consists of ore, the remainder being lithomarges, wads, etc. In a section across the ore-body to the west of the middle the total horizontal width is about 350 feet, the greater width being due to an anticlinal fold. The actual thickness of ore is 81 feet in this section. In a section (Fig. 88 below) across the deposit to the east of this the total thickness of ore is much smaller still.

Width of the deposit.

The strike of the deposit is S. E. at the eastern end, changing to W. 10° S. at the western end of the mine, and this to W. 20° N. in the Palapguddi workings.

Strike of the deposit.

Except for the last paragraph (page 1095), all that follows deals only with the Garbhám deposit proper as exposed by the Vizianagram Mining Co.

The actual 'country' of the ore-deposit, as exposed in the workings, consists of various varieties of felspar and quartz-felspar-rock, sometimes showing gneissose banding and usually extremely kaolinized. The felspar, where fresh enough to be tested, is found to be a potash variety.

'Country.'

A close examination of the many sections seen in the Garbhám workings shows that the rock from which the ore originated was partly spandite-rock (in some places spandite-quartz-rock), and partly a quartz-ortho-

Origin of the deposit.

clase-rock containing abundance of spandite and pale greenish or greenish blue apatite (quartz-kodurite). These two rocks probably occurred as lenticular bands in the 'country' of felspar-or quartz-felspar-rock. The spandite-rock has, by alteration *in situ*, accompanied by addition of manganese brought in solution, yielded a large portion of the ore-body, especially where it is most massive. The apatite-spandite-quartz-felspar-rock (quartz-kodurite) has also yielded a fair proportion of ore, in which the apatite, quartz and felspar have been replaced by manganese oxide brought in solution, the manganese-garnets remaining unaltered and scattered through the manganese-ore (often compact psilomelane with scattered mangan-magnetite) thus produced. This rock, as well as the spandite-rock, has at other times given rise to manganiferous solutions, which have partly effected the replacement mentioned above, and have partly impregnated and replaced the bands of felspathic rock separating the original bands of spandite-bearing rock. Either previously to, or simultaneously with, this replacement by manganese, the felspar of the usually extremely felspathic 'country' has undergone extreme kaolinization.

If we imagine the ore-body to be divided longitudinally into two halves, we can say that the southern half of the ore-body consists more or less of solid ore, and probably corresponds roughly to the main mass of the original spandite-rock. The northern half of the deposit, on the other hand, was probably once composed partly of spandite-bearing rocks—the manganese of which partly collected into bands of manganese-ore during the subsequent alteration of the rock—and partly of non-manganiferous felspathic rocks, since converted into lithomarges, wads, etc. This half of the deposit now consists mainly of very soft lithomargic rocks, composed of white or variegated pink, brown, or yellow, lithomarge, spotted and streaked with black. In many places this decomposed rock is quite black and then looks like wad. The colouration of these lithomarges and wads is due to impregnation and often (in the latter case) partial replacement by oxides of iron and manganese; this impregnation has often taken place up to some small crack in the rock (on either side of which it is slickensided), so that there is a marked difference in the colour of the rock on the two sides of the crack. This is well shown in Plate 51. At the same

Constitution of the deposit.

Photographed by L. L. Fermor. *Bemrose, Collo., Derby.*

"COUNTRY" OF WAD AND LITHOMARGE AT GARBHÁM.

time there has frequently developed in this soft rock a number of parallel bands of psilomelane, often of the shining compact lead-like variety, found also at Ávagudem (of which an analysis is given on page 100). These bands follow the original dip of the rock. At other times the manganese has segregated to form irregular nodules and concretions of hard psilomelane and soft black manganese oxide (often pyrolusite); and these have been most certainly formed by replacement of the original felspathic rock. Fig. 2, Plate 54, shows a very good example of this replacement seen in an excavation at the western end of the deposit. In this photograph the white is kaolinized felspar-rock containing a certain amount of quartz. The dark part is partly wad and partly manganese-ore and was evidently slowly advancing its boundaries at the expense of the white. In the latter are isolated black patches of pyrolusite, one of which is seen just to the left of the head of the hammer. Fig. 85 shows an enlarged view of one of these masses of pyrolusite in process of formation. The outer zone or border of the patch, about ½ to 1 inch thick, consists of soft black ore, whilst in the interior of the patch the felspar grains

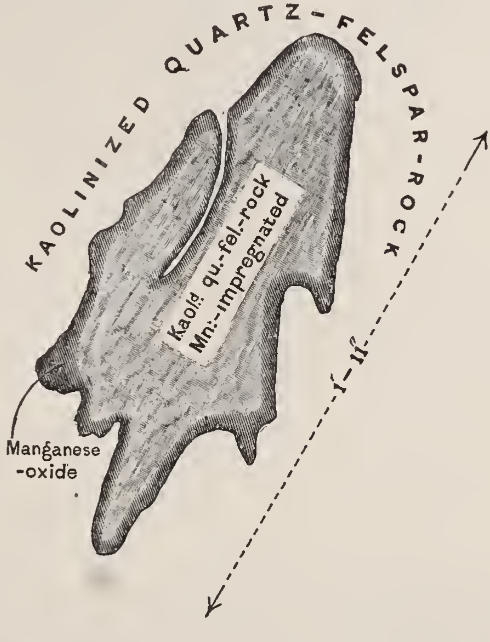


Fig. 85. - Quartz-felspar-rock undergoing replacement by manganese oxide.

still remain, but are kaolinized and separated by a black network of manganese oxide. Outside the black border the rock is quite unblackened. With the advent of further supplies of manganiferous solutions to this patch this outer border would gradually increase inwards in thickness, leaving a smaller and smaller central core of kaolinized rock, until the whole patch had been converted into ore (probably pyrolusite, but possibly psilomelane). On the opposite side of the same cutting as that illustrated in Fig. 2, Plate 54, and only 10 paces further along the strike (*i.e.*, towards the observer as one looks at the plate), the comparatively large area of white rock illustrated in Plate 54 is reduced to that shewn in Figure 86, in which kaolinized felspar-rock, with the felspar grains in an ochreous matrix, is surrounded on both sides by rock, composed of yellow ochre containing streaks and spots of soft black ore, the whole maintaining

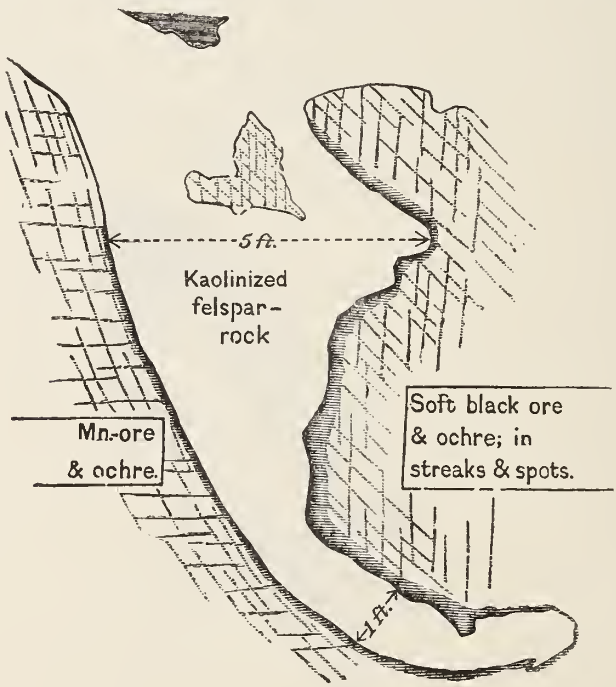


Fig. 86.—Felspar-rock undergoing replacement by manganese-ore and ochre.

the general southerly dip. The junction between the two rocks is as before marked by a 1-inch zone of soft black manganese-ore.

The kaolinized felspathic rocks interbanded with the manganese-ore and spandite-bearing rocks may be regarded as forming part of the ore-body; like these, the equally intensely kaolinized felspathic rocks lying to the north and south of the ore-body, and hence constituting the 'country,' have often been partly converted into wad, often in well-defined patches, as shown in Plate 51. In these black patches, as in those in the similar rocks forming part of the ore-body, a little manganese-ore has often developed, but rarely in sufficient quantity to be worth the cost of extraction, except where this 'country' has to be quarried as part of the dead-work.

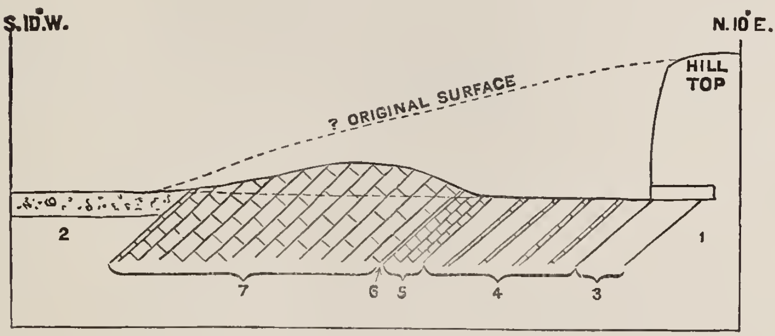
Manganese-ore in the 'country.'

Of the various rocks mentioned in the preceding paragraphs, both the apatite-quartz-spandite-felspar (quartz-kodurite) and the spandite-rock are to be found nearest their original condition in the northern parts of the deposit to the east of Hilltop.

Localities of spandite-bearing rocks.

In the middle section the ore-body seems to be dipping straight down to the S.10°W. at 40° as shown in Fig. 87. But the sections across the deposit

Sections across the deposit.

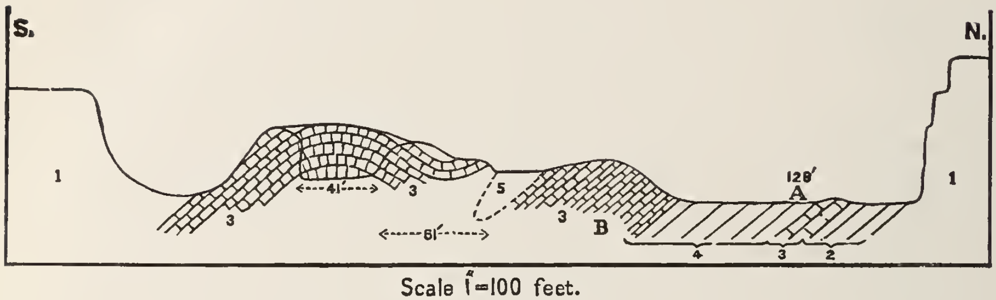


Scale :—1″=100 feet.

1. 'Country' of kaolinized quartz-felspar-rock with wad.
2. Not exposed, but probably same as 1.
3. Wad and lithomarge with psilomelane.
4. Wad and lithomarge with bands of psilomelane, usually the lead-like variety.
5. Manganese-ore (psilomelane with mangan-magnetite) containing patches of brown chert.
6. Kaolinized quartz-felspar-rock containing lenticular nodules of psilomelane 1-4 inches long.
7. Psilomelane with included mangan-magnetite, and in many places irregular patches and layers of yellow ochre, white lithomargic spots, and thin partings of kaolinized felspathic rock.

Fig. 87.—Section across the middle of the Garbhám manganese-ore deposit.

to the east (Fig. 88), and west (Fig. 89) of the middle section shew that the



1. 'Country' of kaolinized felspathic rocks with wad.
2. Wad and lithomarge with bands of lead-like psilomelane.
3. Manganese-ore:—Psilomelane often with mangan-magnetite, and ochreous and lithomargic patches.
4. Psilomelane, wad and lithomarge.
5. Decomposed granitic rock, exact relations to the manganese-ore being obscure.

Fig. 88.—Section across Garbhám manganese-ore deposit to east of middle.

ore-body is really stepped beneath the surface with a small anticlinal fold, as shown in fig. 89, (A), which is not strongly marked enough to appear

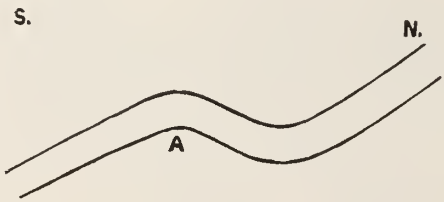
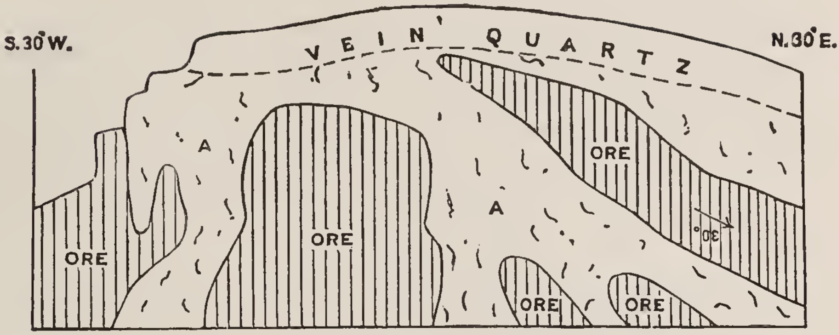


Fig. 89.—Diagram of anticlinal fold (A) affecting the Garbhám deposit west of the middle.

at the surface in the middle section, although it reaches the surface both to the east and west, apparently increasing the width of the ore-body. At the eastern end of the excavations the ore no longer forms a definite band, but has broken up into 5 separate masses separated by

Photographed by L. L. Fermor. Bemrose, Collo., Derby.

MANGANESE-QUARRY AT GÁRBHAM, VIZAGAPATAM DISTRICT MADRAS. FROM THE S.15° E.



Scale 1″ = 18 feet.

A.—Lithomargic clay with crystals of vein-quartz, patches of kaolinized quartz-felspar-rock and segregations of psilomelane.

Fig. 90.—Section seen at the eastern end of the Garbhám manganese-ore quarry.

kaolinized, and often manganese-impregnated, quartz-felspar- or felspar-rock, as shown in Fig. 90.

Pegmatite and quartz crystals.

The mass of rocks forming the ore-body has been, especially at the east end of the deposit, injected by pegmatite veins, which traverse it in all directions. This pegmatite is often a medium- to coarse-grained quartz-microcline-rock; but it is much more frequently composed almost entirely of crystalline quartz taking the form of hexagonal prisms terminated by pyramid faces at one end, which usually points into the centre of the vein, the other end being implanted. These crystals range in size from very small dimensions up to a length, in one case, of 19 inches with a diameter of eight. These veins were formed, in all probability, before the production by chemical action of the manganese-ores; for the manganese-bearing solutions have filled in any cracks and spaces between the crystals with psilomelane and have often gone further and partly replaced the quartz so as to produce a breccia of residual quartz in a matrix of psilomelane. In some places this supposed siliceous pegmatite apparently takes the form of a sill, as in Fig. 90 above. It has been found continuously all the way from Hilltop to the extreme east end of the mine.

Chert.

There often occurs in the midst of the ore-bodies abundance of brown chert, probably formed simultaneously with the ore, and thus representing, as at Kodur, Perapi, and other places, some of the silica removed from the felspar and manganese-garnet when they suffered alteration to kaolin and manganese-ore respectively. Some chert is also associated with the vein-quartz and seems to have then resulted from the solution and re-deposition of the latter during its replacement by manganese-ore, as described above.

Nature and quality of the ores.

The most common form of manganese-ore at Garbhám is psilomelane, of which almost every variety may be found, from stalactitic, mammillated, botryoidal, and kidney-shaped masses, to irregular cavernous ore, compact dull-grey ore, and the light shining lead-like variety found also at Ávagudem (which see for analysis). A complete analysis of a picked specimen of dull grey-ore (? a variety of psilomelane) with a few white specks (? kaolin) and numerous tiny octahedra (? mangan-magnetite) was made by Messrs. J. & H. S. Pattinson with the following result :—

Specimen No. A. 228.

MnO_2	65·73
MnO	2·66
Fe_2O_3	17·29
Al_2O_3	2·65
BaO	0·16
CaO	0·49
MgO	0·16
K_2O	1·62
Na_2O	0·32
SiO_2 (combined)	2·60
SiO_2 (free)	0·40
Sulphur	0·014
P_2O_5	0·698
As_2O_5	0·047
CoO	0·15
NiO	*Nil*
CuO	0·005
PbO	*Nil*
ZnO	*Nil*
TiO_2	0·03
Chlorine and fluorine	*Nil*
H_2O (combined)	4·40
Moisture at 100°C.	0·70
CO_2	*Nil*
	100·154

This is equivalent to :—

Manganese	43·61
Iron	12·10
Silica (total)	3·00
Phosphorus	0·305

This analysis can be re-arranged in terms of the mineral composition of the ore, as follows :—

Specimen No. A. 228.

Kaolin		5·57
Psilomelane :—		
$Fe_4(MnO_5)_3$	12·74	
$Al_4(MnO_5)_3$	1·13	
Ba_2MnO_5	0·21	
Ca_2MnO_5	0·94	
Mg_2MnO_5	0·36	
K_4MnO_5	2·50	
$NaMnO_5$	0·59	
Co_2MnO_5	0·25	
H_4MnO_5	14·00	
Mn_2MnO_5	49·49	
	82·21	82·21
Magnetite (mangan-)		10·45
Quartz		0·40
Sulphur		0·014
$P\ O_5$		0·698
As_2O_5		0·047
CuO		0·005
TiO_2		0·06
Moisture		0·70
		100·154

The magnetite is no doubt mangan-magnetite; given the amount of manganese in it, this could be taken from the psilomelane and an equivalent amount of iron put in its place. I have not converted the P_2O_5 into apatite, because there is not enough lime. The phosphorus is possibly present as oxide; but if as phosphate, the withdrawal of the requisite amount of bases would only have the effect of somewhat decreasing the amount of magnetite shown above.

The ore is, however, usually of the dull grey variety of psilomelane, in cavernous masses, the caverns of which may contain reddish clay, or black wad. The ore also often contains whitish lithomargic spots up to ½ inch diameter. A large proportion of the ore contains little specks and patches of a hard black shining mineral, which was assumed in the field to be braunite. In all the specimens except one, however, that I collected, I find that this mineral is extremely magnetic—braunite being only weakly so—and that it is an iron mineral giving a fairly strong manganese reaction. Hence it may be provisionally designated *mangan-magnetite*, as in the analysis above, and is probably similar to the mangan-magnetite from Kodur described by Dr. Holland (see page 38). This mineral also occurs abundantly in some places in the wad attached to psilomelane, and in pyrolusite. Its abundance probably accounts in part for the fact that the Garbhám ores contain on the average a considerably higher percentage of iron than those of Kodur. It tends to show octahedral outlines and ranges up to ¼ inch in diameter. The one exception mentioned above is a fine piece of braunite showing a crystal face 3 inches across and given to me by Mr. Geeson, who was not certain that the specimen came from this deposit. Pyrolusite is also fairly common and takes the form of fine-grained bluish-grey ore, although in places it occurs as tiny crystals in cavities. Various forms of wad are also, of course, very abundant, but they are not of much value as a rule. One form, looking like a dark brown mud, with little shiny grey-black areas, was completely analysed by Messrs. J. & H. S. Pattinson with the result given on page 119. It is there shown that this wad is probably to be regarded as an indefinite mixture of oxides of manganese, with oxide of iron and partly kaolinized felspar. The constituents of commercial importance are shown below:—

Specimen No. A. 221.

Manganese	39·95
Iron	5·45
Silica (total)	10·95
Phosphorus	0·086

A fair proportion of the ore stacked on this mine contains patches and crystals of residual manganese-garnet scattered through a psilomelanic matrix.

The ores from this mine are usually 3rd grade; fair quantities of second grade and small quantities of first grade ore have also been won; whilst in the last two years (1906-1907) ferruginous manganese-ores (termed manganiferous iron-ores) with less than 40% Mn have been sold. The highly phosphoric character of the ores is due, probably, to the large quantities of apatite in the rocks from which they have been derived.

Photographed by L. L. Fermor.

Bemrose, Collo., Derby.

CARBHÁM MANGANESE-QUARRY FROM W. 40° N.

I took 2 samples from the Garbhám ore-stacks. They were as follows:—

Sample A. 21.—2nd grade ore from the stacks on the south side of the mine. Some of the pieces were almost entirely psilomelane, of tabular, shiny, and dull, botryoidal and cavernous varieties. Others were almost entirely soft pyrolusite, and some a mixture of pyrolusite and psilomelane. Some of the psilomelane contained mangan-magnetite. Many of the pieces showed small patches of lithomargic or ochreous matter.

Sample A. 22.—From stacks of 3rd grade ore on south side of mine was similar in mineral constitution to A. 21, except that it contained a larger proportion of the various impurities, such as lithomarge and ochre. This could be best described as ferruginous manganese-ore.

The analyses carried out by Messrs. J. & H. S. Pattinson are shown below:—

	Sample No. A.21.	*Sample No. A.22.*
Manganese peroxide	67·75	52·76
Manganese protoxide	5·12	6·88
Ferric oxide	13·57	22·42
Baryta	0·53	0·36
Silica (combined)	2·45	4·15
Silica (free)	1·65	2·15
Phosphoric oxide	0·76	0·845
Arsenic oxide	0·021	..
Water (combined)	3·50	3·80
Moisture at 100° C.	0·50	0·50

These are equivalent to:—

Manganese	46·78	38·67
Iron	9·50	15·70
Silica (total)	4·10	6·30
Phosphorus	0·331	0·368

Sample A. 21 is therefore barely up to 2nd grade (47% Mn), whilst A. 22 is ferruginous manganese-ore.

In the following table, the first three analyses were given by Mr. H. G. Turner in 1896 (*Journ. Iron Steel Inst.*, No. II for 1896, p. 160), while the figures in the fourth, fifth and sixth columns were kindly supplied by Mr. T. Caplen, manager of the Vizianagram Mining Co.

Analyses of merchantable Garbhám ores.

—	Manganese-ore, 1896.	Manganese-ore, 1896.	Manganese-ore (cargo test), 1896.	Range of analysis of manganese-ore, 1906.	Average analysis of manganese-ore, 1906.	Ferruginous manganese-ore, 1906.
Manganese .	50·35	45·08	47·09	40 to 49	45·39	35·43
Iron . .	6·38	13·23	10·80	7 to 15	9·99	19·32
Silica . .	3·21	4·60	2·45	3 to 10	4·43	6·90
Phosphorus .	0·24	0·27	0·26	0·35 to 0·55	0·450	0·423
Moisture . .	1·65	1·80	1·48	..	..	..
Insoluble . .	..	..	..	..	6·08	8·45

The working of the deposit.

The deposit is, as usual, worked by open-cast quarrying, carried out almost entirely by manual labour. To break up the more solid masses of ore blasting has to be resorted to. Fig. 1, Plate 54, shows coolies at work drilling holes for blasting. The blasting is usually done during the middle of the day at the time when the coolies stop work for their midday meal. The ore and waste are carried out of the quarry on the heads of women and children. The ore after cleaning is mostly stacked on the south side of the mine, along which tram-lines have been laid. When the stacks have been sampled and assayed the ore is sent to Garividi Railway Station some 10 miles distant over a very poor road in country carts drawn by buffaloes and bullocks. The lowest part of the mine is in the S. E. corner, where there is a pit into which drains the comparatively small amount of water entering the workings ; from this the water is pumped to the surface and conducted to the rice-fields situated to the south of the mine. The floor of the workings at the S. E. end of the mine was, at the time of my visit, 120 feet below the top of the highest original outcrop on Hilltop, while the bottom of a big square pit just to S. W. of Hilltop was 101 feet (kindly measured by Mr. H. B. Geeson, by levelling) below the highest part of Hilltop. This means that manganese-ore has here been proved to exist at a depth of 100 feet below the surface. Plates 52 and 53 are views of the Garbhám workings. In Plate 52, A is Hilltop, now capped with a dump. The quarried face of Hilltop seen in the Plate is practically the north wall of the deposit. C is a mass of manganese-ore with quartz-veins and chert. The hill seen in the distance behind the quarry is probably a khondalite ridge. In Plate 53,

FIG. 1.—MANGANESE-ORE *IN SITU* AT GARBHÁM.

Photographed by L. L. Fermor. *Bemrose, Collo., Derby.*

FIG. 2.—MANGANESE-ORE (BLACK) FORMING BY REPLACEMENT OF QUARTZ-FELSPAR-ROCK (WHITE) AT GARBHÁM.

the irregular mass of rock seen in the foreground is manganese-ore. Further back are seen step-like excavations in the soft kaolinized quartz-felspar-rock, while behind this are tram-lines and bungalows, with flat alluvial country stretching away to some distant hills.

Output.

The output of manganese-ore from Garbhám since the beginning of work in 1896, up till 1907, is shown below :—

Years.	Long tons.
1896	30,000
1897	50,520
1898	34,691
1899	53,315
1900	56,195
1901	54,163
1902	47,544
1903	43,734
1904	41,487
1905	40,368
1906	44,861
1907	56,262
TOTAL .	553,140

The output of 1906 and 1907 is divided as follows :—

	Manganese-ores.	Ferruginous manganese-ores.[1]
1906	34,236	10,625
1907	41,296	14,966

The Palapguddi workings.

The Palapguddi excavations which (see fig. 84) extend for about 250 yards, in a W. 20° N. direction, were dug by Messrs. Gordon, Woodroffe & Co., and Kovoori Basivireddi. But they had to be abandoned at the instance of the Vizianagram Mining Co., because they lay within Garbhám village limits. These excavations show abundance of wad

[1] The Vizianagram Mining Co. terms these 'manganiferous iron-ores' and includes therein ores containing 35—43% Mn and not less than 15% Fe.

with fairly good psilomelane in places and a large amount of very cherty rock. At the western end there is a small mound showing a very cellular rock composed of chert and ore. The ore exposed in these workings is doubtless an extension of the Garbhám deposit.

12. Kotakarra.

There are two separate deposits within the limits of this village; they may be distinguished as I and II.

Kotakarra I.

W. 25° S. from the village, say ⅜ mile (incorrectly indicated on map, where deposit has been placed S. 25° W. of village instead of W. 25° S.), were some abandoned shallow pits dug during 1898-1900 by Messrs. A. S. N. & Co., who are said to have sent a little ore to Chipurupalli Railway Station. The general strike of the pits is about east and west. One of them shows beds of psilomelane containing spandite, and dipping at 30° to about S. Several other square pits showed psilomelane much mixed with limonite and often, in addition, brown chert.

From some 65 tons of ore stacked here I took sample A. 20 consisting of psilomelane, often very cavernous, stalactitic or botryoidal, and containing limonite in some of the cavities. Some pieces showed manganese-garnet included in the ore. The sample was analysed by Messrs. J. and H. S. Pattinson with the following result:—

Sample No A. 20.

Manganese peroxide	59·52
Manganese protoxide	3·89
Ferric oxide	19·57
Baryta	0·16
Silica (combined)	3·45
Silica (free)	0·25
Phosphoric oxide	0·31
Water (combined)	5·50
Moisture at 100°C.	1·85

This is equivalent to:—

Manganese	40·64
Iron	13·70
Silica (total)	3·70
Phosphorus	0·134

The ore is therefore low grade manganese-ore.

There is a considerable quantity of detrital ore resting on that *in situ*.

Kotakarra II.

These workings consist of a number of shallow excavations, not more than 20 feet deep, made by the Vizianagram Mining Co., and lie about 200 yards north of the village at the east base of a small hill of quartzites containing little black specks of an iron-ore altering to hematite. The dip of the quartzite is pretty steep to E. 10° S. and the hill strikes S. 10° W.

Opalized kodurite or apatite-spandite-felspar-rock.

In one pit there is a very interesting exposure. The strike of the rocks is E. 25° S. with a fairly steep dip to the south side, curling over to vertical. The following rocks are exposed in order from N. to S.:—

(1) dirty psilomelane banded with chert, and both containing abundant scattered manganese-garnets;

(2) banded rock of spandite and greenish blue apatite in a white siliceous matrix (probably opal). This rock was probably once apatite-spandite-orthoclase-rock (kodurite), of which the felspar has subsequently been replaced by opaline silica (see pages 256—261);

(3) psilomelane in layers 1 to 2 inches thick;

(4) kaolinized quartz-felspar-rock with some green clay;

(5) kaolinized quartz-felspar-rock with clayey and limonitic bands;

(6) soft manganese-ore with limonite and abundant residual patches of manganese-garnet.

I neglected to measure the thicknesses of the above rocks, but the total was probably not more than 5 feet. Rock 2 is, owing to the siliceous cement, quite hard and not friable and powders like the customary examples of apatite-spandite-felspar-rock, in which the felspar is kaolinized, seen elsewhere in this district. It is intruded by a coarse pegmatite of quartz and felspar. Overlying this exposure is a mixture of chert, altered pegmatite, and psilomelane with pyrolusite, all together forming a fairly solid rock, which was formed, possibly, by the chemical alteration of the underlying rocks.

Pyroxene-scapolite-quartz-rock.

In another pit I found a loose rounded block of fine-grained pyroxene (?diopside)-scapolite-quartz-rock containing also sphene, apatite, and occasional plagioclase. It is probably a variety of the scapolitic or calcareous gneisses.

At the time of my visit work was said to have ceased for three years at this locality, previous to which a few thousand tons of second-grade ore had been extracted and despatched. Very little ore *in situ* could be seen and this little was partly pyrolusite and partly psilomelane. No analyses are available.

13. Gadasám.

This deposit, lying some 4 miles S. W. of Garbhám, was worked at some time between 1898 and 1900 by Messrs. Gordon, Woodroffe and Co., of Coconada and Kovoori Basivireddi, and a considerable quantity of ore was carted to Chipurupalli Railway Station, where I saw it still lying in 1905. It was of very poor quality. The property has been recently acquired by the Vizianagram Mining Co., and Mr. Caplen has furnished me with the following analysis as typical of this locality :—

Manganese	46·87
Iron	4·20
Phosphorus	0·168
Silica	4·55

The following is the output of manganese-ore in 1906 and 1907 :—

Year.	Long tons.
1906	1,535
1907	459

14—Ávagudem.

This deposit is situated about 3 miles N. W. of Chipurupalli Railway Station and was worked between 1898 and 1900 by Messrs. Gordon, Woodroffe & Co. and Kovoori Basivireddi, by whom a large amount of excavation was done and a considerable quantity of ore—perhaps 2,000 or 3,000 tons—extracted, a little being sent to Chipurupalli Railway Station. It has recently been acquired by the Vizianagram Mining Co., who are now working it for export.

As I saw it in January 1905, the deposit had been exposed for about 750 paces in a W. 10° N. direction by a series of pits and trenches, and ore *in situ* was visible at intervals over nearly the whole of this length. The ore-band seemed to form a vertical reef, and ranged up to 55 feet in width. The 'country' where visible, consisted of quartz-felspar-rock and vein-quartz; but often it was not seen at all, owing to the large amount of detrital manganese-ore. In one place near the western end of the deposit some psilomelane containing abundant small crystals of manganese-garnet was found, indicating that the ores here have probably been derived from rocks similar to those found at Kodur and Garbhám.

These excavations are situated on the south side of a low ridge of white quartz and white garnetiferous quartzites, which runs E.10°S., and continues to the east into a high hill of khondalite containing abundance of bands and lenticles of white quartz, sometimes containing garnets and probably of later age than the khondalite.

Nature and quality of the ores.

A large proportion of the ore contains patches of chert, yellow ochre, and veinlets and cavities lined with quartz, and is consequently of little value. Magnetite is also found in several places scattered through the ore in granules up to $\frac{1}{4}$ inch across. These magnetite granules are usually traversed by tiny veinlets of psilomelane, so that it is very difficult to obtain chips of the pure mineral. A few tiny chips, apparently pure, gave a distinct reaction for manganese, so that this mineral is possibly a *mangan-magnetite*. There is also a fair quantity of ore comparatively free from the above-mentioned substances. The commonest variety is psilomelane of every variety, with some pyrolusite. Of the 2,000 or more tons of ore stacked by Messrs. Gordon, Woodroffe & Co. a large quantity contained too much quartz or ochre, but a considerable proportion was of fair quality.

Its quality could undoubtedly be considerably improved by careful cleaning. A sample taken from 450 tons of ore stacked at the western end of the deposit was analysed by Messrs. J. and H. S. Pattinson with the following result:—

Sample A. 32.

Manganese peroxide	58·43
Manganese protoxide	3·20
Ferric oxide	18·85
Baryta	1·05
Silica (combined)	4·43
Silica (free)	0·30
Phosphoric oxide	1·01
Water (combined)	4·70
Moisture at 100° C.	1·00

This is equivalent to:—

Manganese	39·41
Iron	13·30
Silica (total)	4·73
Phosphorus	0·440

and the ore can be classed as 'ferruginous manganese-ore'

Mr. Caplen has furnished me with the following figures :—

	Range of analysis.	Average analysis at present day.	Ferruginous manganese-ore.
Manganese . . .	40 to 50	42·41	35·75
Iron	7 to 15	12·90	16·89
Silica	4 to 6	3·85	5·95
Phosphorus . . .	0·3 to 0·5	0·375	0·439
Insoluble . . .	..	4·48	6·90

Lead-like psilomelane.

Amongst the varieties of psilomelane is one that has the colour and lustre of metallic lead. It is apparently homogeneous and breaks with a conchoidal fracture. It is similar to that found at Garbhám (see page 1085). A piece of this lead-like psilomelane was analysed by Messrs. J. & H. S. Pattinson with the result given in full on page 100. The constituents of commercial importance are shown below :—

Specimen No. A. 372.

Manganese	49·18
Iron	4·00
Silica (total)	0·45
Phosphorus	0·346
Moisture	2·05

The output from this deposit is given below :—

	Manganese-ores.	Ferruginous manganese-ores.	Total.
1899	2,025	..	2,025
1906	4,370	7,702	12,072
1907	1,528	6,401	7,929

15. Aitemvalsa (Itamavalsa).

This deposit I did not visit, but from what I was told it must lie about 4 miles N. of Chipurupalli Railway Station. It was once opened up by Messrs. Gordon, Woodroffe & Co., and Kovoori Basivireddi and a considerable quantity of ore was sent to Chipurupalli Railway Station.

The deposit has since been acquired by the Vizianagram Mining Co., Ld., and Mr. Caplen has furnished me with the following analysis of ferruginous manganese-ore quarried in 1906 at this locality :—

	Per cent.
Manganese	35·77
Iron	12·87
Insoluble	10·40
Phosphorus	0·222

The output from this deposit is as follows :—

	Manganese-ores.	Ferruginous manganese-ores.	Total.
1898	380	....	380
1906	1,230	735	1,956
1907	35	1,181	1,216

16. Gotnandi.

The only information I have relating to this deposit, which is held by the Vizianagram Mining Co., Ld., is that 109 tons of ore were extracted in 1898. I was informed that the deposit lies about a mile north of Bondapilli village.

17. Bondapilli.

In 1900, 200 tons of ore were extracted from this deposit, which is held by the Vizianagram Mining Co., Ld. Owing to the high prices prevailing in 1906 this deposit was re-opened and Mr. Caplen gives me the following analysis of ferruginous manganese-ores obtained from this deposit :—

Manganese	38·48
Iron	14·22
Silica	4·93
Phosphorus	0·332
Insoluble	5·83

The output figures for this deposit for 1906 and 1907 are probably included in those of Aitemvalsa.

18. Garraráju Chipurupalli (Garuja).

This deposit, usually known as Garuja, has been worked by the Vizianagram Mining Co., Ld., from 1900 to 1903 and then from 1905 onwards. From the table below it will be seen that 17,797 tons of ore have been extracted from this deposit up to 1906, giving an average of 2,542 tons per annum for the years during which it has been worked.

I was unfortunately unable to visit Garuja: but Mr. Caplen informs me that it is very similar to Perapi. He has furnished the following analyses of Garuja ores :—

	Range of analysis.	Average analysis at present day (1906).	Ferruginous manganese-ore (1906).
Manganese	40 to 47	41·45	38·51
Iron	7 to 13	11·70	13·20
Silica	3 to 6	3·63	5·50
Phosphorus . . .	0·25 to 0·35	0·298	0·269
Insoluble	——	5·05	8·40

The output figures for Garuja are shown below :—

Year.	Manganese-ores.	Ferruginous manganese-ores.	Total.
1900	3,500	..	3,500
1901	980	..	980
1902	1,176	..	1,176
1903	1,403	..	1,403
1904	..	..	..
1905	3,844	..	3,844
1906	3,630	388	4,018
1907	49	2,827	2,876
Total .	14,582	3,215	17,797

19, Perumáli.

The Vizianagram Mining Co., Ld., extracted 30 tons of ore from this deposit in 1900 and 10 tons in 1901. Work on this deposit was re-started in 1906 and Mr. Caplen supplies the following analysis of Perumáli ore :—

Manganese	40 to 46
Iron	8
Silica	5
Phosphorus	0·30

The output figures for this deposit are as follows :—

Year.	Manganese-ores.	Ferruginous manganese-ores.	Total.
1900	30	..	30
1901	10	..	10
1906	2,211	161	2,372
1907	1,470	1,239	2,709
Total .	3,721	1,400	5,121

20. Rámabhadrapuram.

The deposits grouped under this name are not actually within the limits of this village. There are three sets of excavations extended over a length of ⅔ mile in an E. 10° N. direction, along a very slightly raised grassy mound; they lie within the limits of the following villages :—

a. Sonpuram, known as West Mound,

b. Mámidipilli, known as Middle Mound,

c. Bankuruvasla, known as East Mound,

and are worked by Mr. H. G. Turner.

The most westerly excavations, those of Sonpuram, are about 2 miles east of the main Sálur-Vizianagram road where it passes through Rámabhadrapuram village. Sonpuram and Mámidipilli are in Sálur taluk, while Bankuruvalsa is in Bobbili taluk.

It is not certain that the ore seen in the Sonpuram pits is the same band as that seen in the other pits, so that there may be more than one band of ore. The maximum width of ore-band was 30 feet, in the main Bankuruvalsa pit, corresponding to an actual thickness of 15 feet, the dip being 30°. But the full width of the ore was not here exposed. The dip usually varies from 30° to very steep to the south side of the strike, which is usually E. 10°—25°S.

In the Sonpuram pits the main ore-band lies to the south of laminated quartzites, as also in most of the Mámidipilli pits; but in Bankuruvalsa and the most easterly of the Mámidipilli pits, the ore-bands exposed underlie (*i.e.*, are to the north of) the laminated quartzite.

The examination of these pits indicates that the original 'country' was quartzite, often felspathic or garnetiferous, along the bedding planes of which masses of apatite-spandite-felspar-rock (kodurite), of the same rock with quartz (quartz-kodurite), and of quartz-felspar-rock

Origin of the ores.

(usually with apatite), have been intruded, and that as usual the ores were subsequently formed at the expense of the manganese-garnet. Since the latter mineral is often seen in quite-fresh grains scattered through psilomelane otherwise of good quality, and since the kodurite is seen, when it undergoes decomposition, frequently to have its spandite changed to ochre, it seems that when the kodurite undergoes alteration the spandite of one portion is decomposed and the manganese removed, leaving the iron behind as ochreous spots, and that the manganiferous solutions so produced percolate to another part of the rock (often close by, sometimes in the same hand-specimen—see page 1109) and there replace felspar without affecting the spandite, so as finally to produce psilomelane studded with the unaltered spandite.

The intruded mass of rock, including all the felspathic rocks except the quartzite, must have been at least 60 feet wide, to judge from the abundant kaolin, ochre and wad now visible in the Sonpuram pits (see fig. 91, page 1107); probably if properly exposed by cross-cuts traversing the whole width of these rocks, the total width would be found to be at least 100 feet including partings of the original quartzites. As regards the age of these quartzites, they may be regarded as probably part of the khondalite series.

In the Sonpuram workings I saw but little spandite, so that the ore visible there was probably largely formed by replacement of rock that originally contained no spandite. In the Mámidipilli pits spandite is very abundant and the remarks in the preceding paragraphs apply especially to these. I did not examine the Bankuruvalsa pits carefully enough to state that spandite was absent there, but it was very noticeable that the sample (No. 26) taken from the Bankuruvalsa ore-stacks showed no spandite, whilst that (No. 25) from the Mámidipilli stacks exhibited abundance of it.

Nature and quality of the ores.

The ores are psilomelane and pyrolusite, the latter being most abundant at Bankuruvalsa; but in all three villages psilomelane is the predominant mineral. The character of the ores of each village can be best judged from the following samples:—

Sample A. 24. (Sonpuram) taken from some 350 tons of stacked ore. Composed mainly of psilomelane, both compact and cavernous often showing lithomargic impurities, and sometimes ull and soft black; with also a little deep bluish-black pyrolusite.

Sample A. 25. (Mámidipilli) taken from some 180 tons of stacked ore, consisted of various sorts of psilomelane, more or less compact, a good proportion of the pieces containing abundant orange-red spandite crystals. Several pieces contained ochreous clay and other impurities (lithomargic and quartzose).

Sample A. 26. (Bankuruvalsa) taken from some 70 tons of stacked ore. More than half the sample was compact fine-grained pyrolusite, often in concretionary forms and frequently streakily mixed with psilomelane. The remainder was psilomelane, both massive and concretionary. A smaller amount of lithomargic impurities than in the two preceding samples.

These three samples were analysed by Messrs. J. and H. S. Pattinson with the following results:—

	Sonpuram.	Mámidipilli.	Bankuruvalsa.
	Sample No. A. 24.	Sample No. A. 25.	Sample No. A. 26.
Manganese peroxide .	60·84	47·71	71·64
Manganese protoxide .	2·68	2·66	2·19
Ferric oxide . .	19·42	21·71	13·00
Baryta . . .	1·72	1·22	0·56
Silica (combined) . .	2·90	7·70	2·00
Silica (free) . . .	0·50	2·60	2·50
Phosphoric oxide . .	0·46	1·105	1·06
Water (combined) . .	6·10	6·20	3·90
Moisture at 100° C. .	0·70	1·35	0·60
These are equivalent to :—			
Manganese . . .	40·54	32·21	46·98
Iron	13·60	15·20	9·10
Silica (total) . . .	3·40	10·30	4·50
Phosphorus . . .	0·200	0·482	0·461

From this it is seen that the Sonpuram and Bankuruvalsa samples just come within the limits for manganese-ores proper (see page 499), whilst the Mámidipilli sample must be described as ferruginous manganese-ore.

Mr. Caplen informs me that ferruginous manganese-ores of the following analysis are now (1906) being quarried at Rámabhadrapuram :—

Manganese	37·11
Iron	14·22
Silica	5·65
Phosphorus	0·455
Insoluble	9·63

At the time of my visit a series of bore-holes was being put down on the unopened ground between the Mámidipilli and Bankuruvalsa workings. The bore-holes were 6 inches in diameter and were drilled by percussion boring with a chisel on the end of $1\frac{1}{4}$-inch square iron rods. The rock was therefore brought up in the powdered form as a sort of mud, which was washed and the larger chips kept. Any lithomarge or ochre would, of course, have been lost in this process, but was saved by making small bricks out of the slimes. The rods were actuated by means of the horizontal trunk of a palm-tree, pivoted near the bore-hole end and moved up and down by 5 men at the farther end of the trunk, while 3 men rotated the boring rods by means of a brace-head. The mud and sand were recovered from the bore-hole by means of an iron sludger 2 inches in diameter and 4 feet long, with a valve at the bottom.

Boring operations.

In the S. E. corner of the most easterly Mámidipilli pit a thickness of 12 feet of thin-bedded quartzites was exposed, dipping at about 50° to S. 25° E. and overlying the ore, lithomarge, etc., seen in this pit. The bore-holes were located to the south of the line of strike of these quartzites when produced to the east. Hence any ore encountered in the bore-hole before reaching the quartzite must belong to a different band of rocks overlying the quartzites. One such bore-hole passed through the following rocks before reaching what was probably the quartzite :—

13 feet . . .	clay.
36 feet . . .	ore.
10 feet . . .	fragments of quartz and ore mixed.
8 feet . . .	ore.
1 foot . . .	ore and quartz.
4 feet . . .	quartz powder (=? quartzite).
72 feet	

and hence indicates the existence of such a second band of ore-bearing rocks, and also proves the existence of ore at a depth of 67 feet.

A bore-hole had also been put down in Bankuruvalsa and ore was found to continue at intervals to 100 feet, where good pyrolusite was found. Subsequently the first pit noticed on page 1110 was sunk at this spot.

None of the pits were more than about 20 feet deep. Owing to the irregular character of the ore-bodies and the rather poor quality of the ores, and the fact that Rámabhadrapuram is 30 miles from the nearest railway station (Vizianagram), it seems doubtful if very much work can be done at this locality until the railway from Vizianagram to Raipur, which will pass close to Rámabhadrapuram and Sálur, is constructed, except at times of high prices.

The working of the deposit.

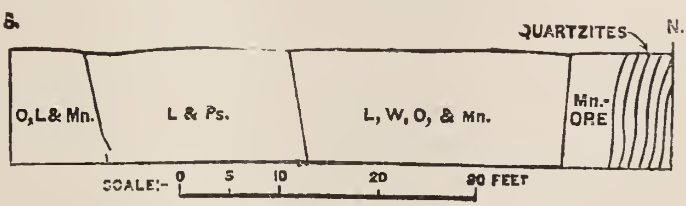
Output.

The following are the output figures for Rámabhadrapuram :—

Year.	Manganese-ores.	Ferruginous manganese-ores.	Total.
1901	10	..	10
1902	140	..	140
1903	173	..	173
1904	50	..	50
1905	110	..	110
1906	50	446	496
1907	..	1,733	1,733
Total.	533	2,179	2,712

20a. Sonpuram (West Mound).

In the largest of the Sonpuram pits at its west end, the rock exposed indicated the section shown in fig. 91.



L = lithomarge ;
Mn. = manganese-ore ;
O = ochre ;
P = psilomelane ;
W = wad ;

Fig. 91.—Section across one of the Sonpuram pits.

The quartzites.

The quartzites seen on the north wall were in layers 1 to 2 inches thick and varied in character from a coarse vitreous quartz-rock to a fairly fine-grained quartzite, one layer of which contained abundant tiny reddish garnets. These quartzites, especially the finer-grained varieties, often contain abundant scattered kaolinic patches, corresponding probably to original felspar. Interbedded with the quartzites were layers of psilomelane ½ to 1 inch thick formed obviously by the replacement of the quartzites. The 5-foot ore-band shown in the above section expands to 8 feet in the middle of the pit. Further east in this pit the dip of the quartzites becomes definite—namely 50° to S. side of strike (E.10°-25°N.). In some of the ore there are patches of brown and black chert. One specimen of felspathic rock undergoing replacement to ore is interesting.

Psilomelane concretion in lithomargic rock.

It consists of a mixture of soft black manganese oxide and white kaolin with a central core or globule, 1¼ inches in diameter, composed almost entirely of psilomelane and black oxide arranged concentrically.

Banded pyroxenic quartzite.

On the unopened ground between the Sonpuram and Mámidipilli workings there is an outcrop of a banded rock composed of a pyroxenic quartzite with lighter quartzose bands. The dip is 30° to S. 5°E. The outcrop closely resembles some of the waved banded spessartite-quartz-rock outcrops of the Central Provinces, but the microscope shows the above to be the real composition of this rock.

20b. Mámidipilli (Middle Mound).

Kodurite.

The Mámidipilli (also known as Itlamámidipilli) excavations are of great interest, as they show a large amount of apatite-spandite-orthoclase-rock (kodurite). The two main pits showed a band of this rock partly converted to manganese-ore. In one place the ore-band was 15 feet thick and consisted of a fairly compact mass of psilomelane and pyrolusite containing abundant remains of quartz and felspar. In this ore were some residual patches of kodurite in which the felspar was fairly fresh, forming a granular aggregate, the granules averaging to ¼ inch in diameter. One hand-specimen of this shows at one end that the felspar is being converted into manganese-ore by replacement, with the production of pseudomorphs in manganese oxide after felspar showing the original cleavage of the felspar. In this part the garnet remains unaltered. In another part of the same specimen the felspar is fresh (giving a potassium reaction), while the garnets are represented by ochreous spots, the manganese having been removed in solution. By the completion of these two processes, accompanied by kaolinization, this piece of rock would at one end become psilomelane studded with garnets, and at the other end kaolin or lithomarge with ochreous spots.

Another section showed psilomelane in large patches joining together in the kodurite, the ore forming the major portion of the rock. The kodurite was here largely kaolinized with a great abundance of apatite weathering out. The apatites were mostly rounded stumpy prisms, sometimes showing hexagonal faces, and up to $\frac{1}{4}$ inch long.

In one place in this section the surface of the manganese-ore formed by replacement and alteration of the kodurite was coarsely botryoidal, the spherules being nearly 2 inches in diameter. The outer layer of the spherules, about $\frac{1}{8}$ to $\frac{1}{4}$ inch thick, was composed of limonite.

Biotite-kodurite.

In another pit I found an unique rock, namely an altered form of a biotite-kodurite. This is practically the only example I have found of mica in the Vizagapatam manganese-intrusives (see also page 252). The other example was at Perapi, where in one pit was a coarse quartz-felspar-rock, the felspar being predominant, with a fair amount of small scattered scales of an altered biotite-mica The Perapi rock is not, however, certainly a part of the kodurite series of intrusives. The Mámidipilli rock is largely converted into chalcedony and ochre (often forming together a brown chert), but still shows biotite scales (now no longer elastic) averaging about $\frac{1}{8}$ inch across, spandite, and apatite. There is no longer any felspar left, but, judging from numerous examples I have found of chalcedonized or opalized kodurite, in which the garnet remains fresh while the felspar is changed to chalcedony or opal, it can fairly be deduced that at least a portion of the chalcedonic ground-mass of this rock corresponds to original felspar and that the original rock was a biotite-apatite-spandite-felspar-rock; *i.e.*, a biotite-kodurite.

Apatite-quartz-microcline-rock.

Another interesting rock seen in one of these pits is a band of quartz-microcline-rock 4 feet thick with a sort of fluidal structure, the rock suggesting a pegmatite that has moved at the time of solidification. Since a few grains of greenish blue apatite up to $\frac{1}{8}$ inch long can be seen in both the quartz and the felspar, while under the microscope many smaller grains can be seen included in the quartz, it seems probable that this rock is a part of the kodurite series.

20c. Bankuruvalsa (East Mound).

One pit, 20 feet deep, showed very disturbed laminated quartzites forming a sort of anticline, in which the central portion was laminated lithomarge, wad, and decomposed quartzite, with segregations of pyrolusite forming pockets here and there.

Quartzites containing apatite, garnet, and graphite.

In a larger pit to the east of this the ore-band is at least 15 feet thick, the dip being 30° to the south. It is overlain by a fine-grained granular quartzite containing an abundance of minute apatite prisms in the quartz grains. Some bands of the rock contain an abundance of minute pink garnets, while a layer resembling vein-quartz contained graphite scales up to nearly $\frac{1}{4}$ inch across.

21. Táduru.

(See Plate 55.)

My attention was first drawn to this locality by Mr. C. S. Middlemiss of the Geological Survey of India, who had found numerous externally blackened boulders, of rhodonite and other manganese-silicates, lying in the valley down which a little stream flows from near Wodangi, past the village of Táduru or Tadiyur (Tadur on map).

As the result of a careful search I was able to trace these pebbles and boulders to their source, namely a band of manganese-silicates situated on the hillsides at a point about $1\frac{1}{4}$ miles due south of Táduru. The way to find this outcrop is to go up the valley from Táduru by a path that constantly crosses the little winding stream. At the 9th ford there is a 14-foot waterfall over a rounded surface of gneissose granite. This fall, as seen at the end of December, was of very small volume, leaving most of the granitic surface dry. Gradually ascending from here in a direction W. 5° S. up a long slope of gneissose granite, and then up a slope covered with loose blocks of manganese-silicate-rocks and some of calcareous gneiss, the manganese-silicate band is finally reached on the northern slope of a jungle-covered hill at a point some 150 or so feet above the lower ground cut out by the stream to the north. The map shown in Plate 55 is a very rough sketch-plan made during the course of the one day that was spent in the examination of this occurrence. It does not, therefore, pretend to show the geology in any but a very approximate manner.

The strikes and dips, for instance, are shown in a generalized fashion and are, of course, really much more complicated and varied. The position of the manganese-silicate band is shown only where it was seen. It crops out at a fairly uniform level along the hill side above-mentioned and to the west it appears to die out. To the east it is not exposed in the stream, and no attempt was made to ascertain if it reappeared on the hills to the east of the valley.

The probable relation of the manganese-silicate band to the associated rocks is explained in the section shown in Fig. 2 along the line A B in Plate 55.[1]

The manganese-pyroxenites.

The manganese-silicate band measured 8 paces across the outcrop at two different points; assuming a dip of about 30° to the south, *i.e.*, into the hill, the thickness of the band must be about 12 feet. It shows considerable variations in composition, but is composed mainly of 4 minerals. The chief of these is a rich *brown*, sherry-coloured to orange-red, *manganese-pyroxene*, usually forming a granular aggregate of granules averaging $\frac{1}{8}$ to inch diameter; and less abundant are *pink rhodonite* usually assuming prismatic forms, in places up to an inch long, and a rich *green manganese-pyroxene* occurring usually in small granules, say $\frac{1}{16}$ inch in diameter, often enclosed in the rhodonite. The fourth mineral is a rich orange *manganese-garnet*, in some places forming a fair proportion of the rock; in others it is quite absent. Although the three pyroxenes are so easily distinguished in hand-specimens by their different colours, yet in really thin sections they are very difficult to discri-

[1] This is very similar to a section sketched for me by Mr. Middlemiss before my visit.

minate under the microscope, as they all show extinctions up to 45° referred to prismatic cleavages. In somewhat thicker sections, however, the rhodonite remains colourless, whilst the brown pyroxene assumes a pale yellowish or brownish tint and the green pyroxene a pale yellowish green tint. As pyroxenes make up the main bulk of these rocks they can be best designated *manganese-pyroxenites*. One variety composed almost entirely of brownish green pyroxene contains little prisms of pale greenish apatite up to ¼ inch long.

The loose blocks and pebbles of manganiferous rocks found on the hill slopes and in the stream-bed were doubtless, at least partly, derived from the band noticed above. But some of them may have been derived from another band of these rocks situated further up the valley and as yet undiscovered. The majority of these boulders was composed of the various varieties of manganese-pyroxenites like those mentioned above. A few of them, however, showed other minerals in addition.

Graphite-apatite spandite-rhodonite-quartz-rock.

Thus one block showed a layer of quartz containing scattered deep orange-coloured spandite grains and a few scattered graphite scales. This layer rested on one composed of a rather fine-grained aggregate of quartz, spandite, and rhodonite. Under the microscope this rock was seen to contain sphene also, and a few grains of a mineral suggesting pyrrhotite, besides fairly abundant apatite.

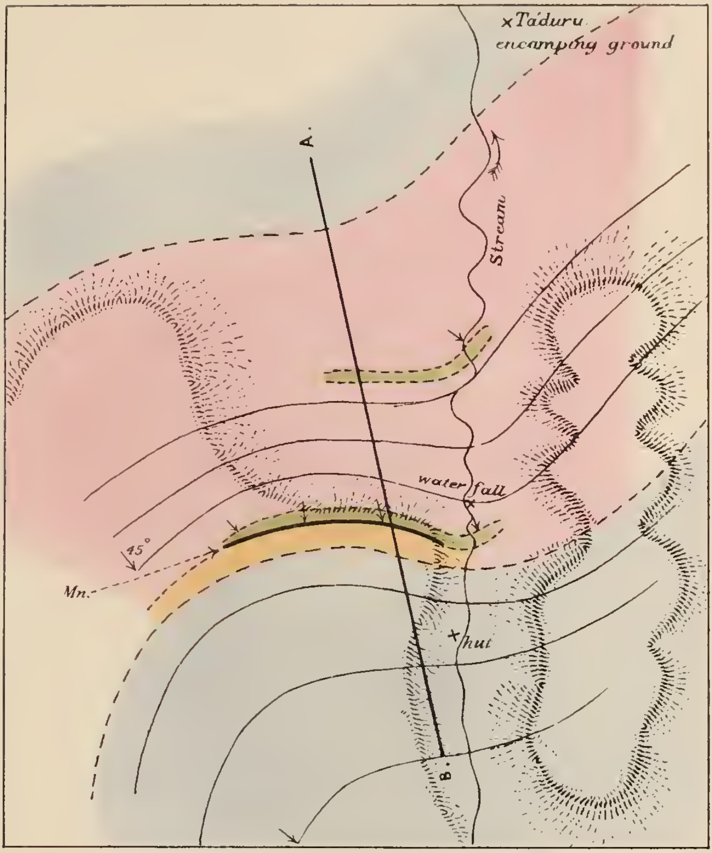
Apatite-garnet-graphite-rock with manganese-ore.

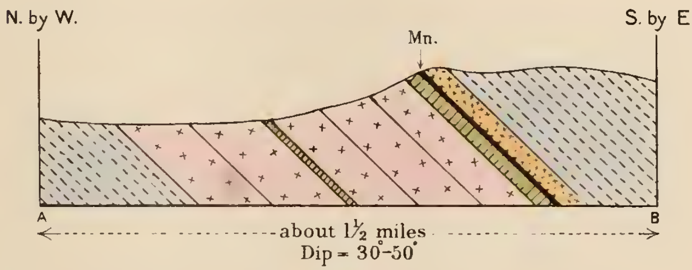
Another boulder was an ochreous very graphitic rock, seen under the microscope to contain abundance of apatite and pale yellowish garnet in a dark matrix composed apparently of graphite, brown iron-ores, and black manganese-ore, of which the last-named is evidently replacing both garnet and apatite.

Another boulder was composed of the garnet in a matrix of manganese-ore and probably represents original spandite-rock.

The calcareous gneisses.

Where the ore-band crops out, exposures of both the overlying and underlying rocks can also be found. The underlying rock is always some variety of the calcareous gneisses. At one place this rock was a wollastonite-gneiss, containing subordinate pyroxene, plagioclase, sphene; at another it was a scapolitic gneiss composed of scapolite and green pyroxene with





Gneissose granite — Biotite-pyroxene-gneiss

Khondalite — Calcareous gneiss (often scapolitic)

Manganese-pyroxenite

GEOLOGICAL SKETCH MAP AND SECTION OF ROCKS NEAR TADURU

some untwinned felspar, calcite, and sphene; whilst at yet another spot it was composed of sphene, pyroxene, labradorite, and scapolite, all present in abundance, with a little iron-ore (? ilmenite).

Biotite- and garnet-pyroxene-gneisses.

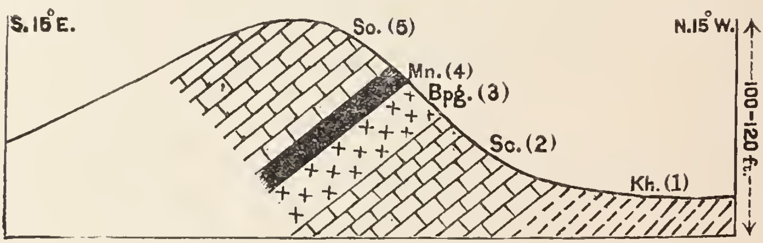
The overlying rock is also somewhat variable in composition. At one place it is composed of biotite, rhombic pyroxene, labradorite and apatite, with a little quartz, whilst at another it consists of pink garnet, hypersthene, augite, black iron-ore, labradorite, and apatite. In each case the rock is fairly fine-grained and shows gneissose structures. They are rather difficult to name but may be described as noritic gneisses, or as biotite-pyroxene-gneiss and garnet-pyroxene gneiss, respectively.

Reference to Fig. 2 of Plate 55 shows that the noritic gneisses, manganese-pyroxenites, and calcareous gneisses, occupy a position at the junction of the khondalite and gneissose granite suggesting that they may be either the basal beds of the khondalite series or contact products resulting from the interaction of the gneissose granite and the khondalite. The latter hypothesis is extremely improbable, considering the probable chemical composition of the various rocks; the former hypothesis may be true as regards the calcareous gneisses, but not for the other rocks. If the manganese-pyroxenites have any connection with the kodurite series of this district, then they must be regarded as in all probability intrusive. Both here and at Chintelavalsa, however, they differ from the manganese-pyroxenites seen elsewhere in that they frequently contain graphite. This constituent may, however, not be an original one; but may have been obtained from the khondalite series, a formation which is characterized by abundance of graphite.

This occurrence possesses no economic value; for the rocks are mostly very fresh and altered only at the outcrops.

22. Chintelavalsa.

As with Táduru, my attention was first drawn to the occurrence of manganese-ores near this village by Mr. Middlemiss, who found pebbles and boulders of rhodonite and other manganese silicates externally altered to manganese oxides, scattered at intervals along the road from Buijavalsa to Chintelavalsa. He did not, however, have time to find where they came from. Therefore I specially went over this route and found many pebbles of spandite-rock blackened outside, and one of rhodonite-rock containing orange garnets. It was only after several fruitless deviations from the path that I succeeded in finding the rock *in situ* in a small conical hill 100 feet or more high, situated to the south of the path 2 or 3 furlongs west of Chintelavalsa village.



Kh = khondalite ; Sc = scapolitic or calcareous gneisses.
Bp = biotite-gneiss : Mn = manganese-pyroxenite.

Fig. 92—Section across hill near Chintelavalsa.

Owing to the débris the thickness of the rocks could not be determined, but Fig. 92 gives a rough idea of their succession.

The scapolitic or calcareous gneisses.

Two specimens of the calcareous gneisses were collected. The typical rock in bands Nos. 2 and 5 is a medium-grained whitish rock composed essentially of pale green pyroxene, scapolite, and wollastonite. The latter is very noticeable in the hand-specimen on account of its pearly lustre. The rock also contains a small amount of calcite and quartz. The upper band must be at least 50 feet thick. In it there is a layer 3 to 4 inches thick of a rather fine-grained pyroxene-scapolite-rock, these two minerals being in about equal proportions. The rock also contains a little sphene and a trace of calcite.

The biotite-gneiss.

This rock immediately underlies the manganese-silicate band. Unfortunately I did not collect a specimen of it, because it looked like an ordinary rather fine-grained foliated gneiss of biotite, quartz, and felspar; but

MAP
OF A PORTION OF THE
VIZAGAPATAM DISTRICT
MADRAS PRESIDENCY
showing the
MANGANESE-ORE LOCALITIES.

Scale 1" = 4 Miles.

LEGEND.

Index to Manganese-ore Localities.

+ Indicates situation of deposit. When this is not known the village name is underlined in red.

1	*Garividi*	13	*Gadasám*
2	*Kodur*	14	*Avagadem*
3	*Duvvám*	15	*Aitanavalsa*
4	*Devâda*	16	*Gotnandi*
5	*Sadánandapuram*	17	*Bondapilli*
6	*Sivarám*	18	*Gurraráju Chipurupalli (Garuja)*
7	*Perapi*	19	*Perumáli*
8	*Itakerlapilli*	20	*Rámabhadrapuram*
9	*Mulagám*	21	*Tâduru*
10	*Garividipuram*	22	*Chintalavalsa*
11	*Garbhám*	23	*Thonam*
12	*Kotakarra (I & II)*		

Geology.

The whole area of this map is occupied by Archæan rocks well exposed in the Eastern Ghâts, the fringe of which appears at the western edge of the map, where they have been mapped as—

(1) Gneissose Granite

(2) Charnockite Series

(3) Khondalite Series

The larger part of the area, however, is occupied by plains of which the geology is largely obscured by alluvium and where these three groups of rocks have not been separately mapped.

Geology by C. S. Middlemiss.

No. 211, Geol. Survey of India.—July 1909.

Litho., S. I. O. Calcutta.

it is probably the same rock, a biotite-pyroxene-gneiss, as that found overlying the manganiferous band at Táduru (see page 1113).

The graphite-bearing manganese-silicate-rock.

The band of manganese-silicate-rock is of great interest owing to its variable mineral composition. It varies from fine-to coarse-grained and contains the following minerals:—manganese-garnet, green pyroxene, rhodonite, biotite, quartz, apatite, sphene and graphite. The special feature of this rock is, of course, the graphite, which is usually most intimately associated with the more quartzoes layers and occurs in scales up to $\frac{3}{4}$ inch across.

24. Other Localities.

Sandápuram.

Just by the village of Sandápuram, on the path leading from Burjavalsa Inspection Bungalow to Chintelavalsa (page 1113), I found, in addition to a pebble of psilomelane, several pebbles of a dark manganiferous rock, of which the one taken was shown by the microscope to be an apatite-spandite-rock in which both apatite and garnet were partly replaced by manganese-ore. The source from which these pebbles were derived was not apparent. About 200 yards east of Sandáupram there is a well-wooded rounded ridge. Where I crossed this at the northern end I saw only khondalite (with spots of secondary manganese oxide); but a more careful search might reveal the existence of a band of manganiferous rock in this hill.

Sandápuram is not marked on the map (Plate 56), but is probably about $\frac{1}{2}$ a mile north of Sedaralavalsa (Chedulavalsa on the map), situated some two miles E. by N. from Chintelavalsa.

Kantikapilli.

Mr. Colville, prospecting on behalf of Mr. Blechynden, found an occurrence of manganese-ore and manganese-silicate-rock near Kantikapilli village, $5\frac{1}{2}$ miles N. N. E. of Kothavalsa railway station. The occurrence was described as a 'solid lode about 20 yards wide', but the specimens brought by Mr. Blechynden consisted of a heavy, altered, coarsely crystalline rock that the microscope shows to be composed of rhodonite, a brownish green pyroxene, and spandite, with a little apatite. This locality is not shown on Plate 56 of this Memoir, as it is some 18 miles S.W. of Vizianagram.

CHAPTER XLI.

DESCRIPTIONS OF DEPOSITS—*continued.*

Maldive Islands and Mysore.

Maldive Islands.

It is interesting to note that during an expedition to these islands conducted by Prof. A. Agassiz [1] small nodules of manganese-ore were brought up 'in two of the soundings in the channels between the composite atolls.' They were 'much in the condition in which they were dredged up by the "Blake" in the Straits of Florida.' The figures given for soundings in such channels, range between 100 and 769 fathoms, but it is not stated at what particular depths the manganese-ore was found.

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[1] *Amer. Jour. Sci.*, 4th Series, XIII, p 301, (1902).

Mysore.

The earliest mention of manganese in India refers to this State. Dr. W. Ainslie[1] in 1813 says that —

'this metal, it is to be presumed, is not common in India. Captain Arthur, however, informs me that he found it in Mysore, massive, in an indurated ochre, combined with oxide of iron.'

History.

Newbold,[2] also, refers to the occurrence of manganese-ores in Mysore. Ores from this State were exhibited at the Madras Exhibitions of 1855 and 1857, but even then no exact localities for the ores were stated. During the last eight years the field work of the Mysore Geological Department, especially of Mr. H. K. Slater, has led to the location of a considerable number of manganese-ore deposits, noticed in the Records of the Department. Several of these have proved to be of economic value, and various companies have been formed to work them. The pioneer company was the Mysore Manganese Company, Limited, now the New Mysore Manganese Company, Limited. As the result of the success of this company and the high prices of manganese, there has been a manganese boom in Mysore during 1906 and 1907, leading to the formation of the Peninsular Minerals Company of Mysore, Limited, and the Shimoga Manganese Company, Limited, and also of numerous small syndicates. Besides these, many individuals have obtained concessions for manganese, but it seems probable that in many cases the concessions obtained do not contain manganese-ore. Further details as to the companies mentioned above will be found in Part III of this Memoir, on pages 429 and 430.

I am not able to give a full account of the deposits of this State, because my personal examination was confined to an eleven days' visit. In this time, however, I was able, through the courtesy of the officials of the different companies, to see a considerable number of the more important of the deposits.

Mode of occurrence and origin.

Generally speaking it may be said that the manganese-ores occur either in superficial mas of lateritoid rock, or in the lithomarges and decomposed quartzites underlying this lateritoid. The lateritoid is a mixture of iron and manganese-ores, usually more or less cavernous in

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1 'Materia Medica of Hindoostan,' p. 57.

2 *Mad. Jour. Lit. Sci.*, XI, p. 45, (1840); *Jour. Roy. As. Soc.*, VII, p. 214, (1843): *Op. cit.*, VIII, p. 155, (1846).

character and showing a considerable resemblance to laterite. The outcrops, especially, have the same rugged cavernous aspect, and are usually lichen-covered. The manganese-ores in the lateritoid are usually psilomelane, with often some wad and pyrolusite. The lateritoid often shows remains of the underlying rocks, quartzite, lithomarge, or phyllite, and the examination of a considerable number of sections has led me to the conclusion that this lateritoid has been formed by the superficial alteration and metasomatic replacement of the rocks corresponding to the altered rocks now found beneath the lateritoid. These altered rocks consist of interbanded lithomarges of various colours, ochres, wads, and decomposed quartzites. The quartzites often contain a considerable quantity of pyroluside in the form of nests and patches formed by impregnation and replacement ; whilst in the lithomarges, ochres, and wads, there are often considerable quantities of concretionary psilomelane. The lithomarges probably correspond to original phyllites and slates, and probably suffered alteration to their present condition at the same time as the lateritoid was formed, and as a part of the same series of changes. The evidence for the statements given above is scattered through the descriptive accounts of the deposits in the following pages, but attention may be directed to the accounts of the Bikonhalli, Sádarhalli, and Tumkur deposits, as affording the best evidence on these points. Since the Mysore deposits bear considerable resemblance, at least in mode of formation, to those of the Sandur Hills, it is not necessary in this place to go further into their origin. Most of the points considered in the account of the Sandur deposits apply here. I have, however, treated the question more fully under the heading of the Shimoga district.

As will be judged from the account given above of the way in which the ores occur, they are as a rule distributed in a very pockety and uncertain manner, the only exception that I saw being the Kumsi deposit. They are also all superficial in character and will not be found to continue to any considerable depths—rarely below 50 feet, and often to much smaller depths only. The chief difference between these deposits and those of Sandur is that, with the exception of Kumsi, none of the deposits I saw seemed to be of any considerable size.

In addition to psliomelane, pyrolusite, and wad, the Mysore deposits often yield the light grey crystalline mineral found in Sandur (in one case—Bikonhalli—doubtfully identified as polianite), and occasionally pseudo-manganite.

Quality.

In quality, as in mode of origin, the Mysore ores bear considerable resemblance to those of Sandur. That is, they are comparatively low in manganese, so as to be classed as 2nd and 3rd grade ores, correspondingly high in iron, and low in silica and phosphorus. When the ores are not carefully picked, however, the silica percentage may at some deposits easily rise to a high figure.

Exports.

During 1906 and 1907 the following amounts of ore were raised :—

	1906.	1907.
	Tons.	Tons.
Chitaldrug district	712	3,125
Shimoga district	40,773	96,591
Tumkur district	4,827	13,091

But no ore was actually sent away from the Chitaldrug district in 1906. During 1907 ore has also been despatched from the Chitaldrug and Kadur districts. The port of shipment for all the manganese-producing parts of Mysore is Mormugáo in Portugese India, the ore being railed over the Southern Mahratta Railway. In the future, however, a certain proportion of the ore may possibly be railed eastwards to the port of Madras.

Bangalore District.

Specimens of 'iron ore and manganese in alternate strata' and 'brown wad and brown fibrous manganese' from Bangalore were shewn at the Madras Exhibitions of 1855[1] and 1857;[2] and at that time black earthenware was manufactured at Bangalore from a 'fine dense clay that contains both manganese and iron'.[3] Recent analyses[4] of gneiss from Bangalore show 2·69 to 2·71 per cent. of manganese protoxide (MnO). Columbite, a niobate and tantalate of iron and manganese, has been found by Mr. B. Jayaram[5] in pegmatite about ½ a mile north of Masti.

1 Reports by the Juries, p. 6, (1856).
2 *Ibid.*, p. 2, (1857).
3 *Ibid.*, p. 120, (1856).
4 *Rec. Mys. Geol. Dept.*, II, pp. 30, 34, (1898-99).
5 *Ibid.*, III, p. 182, (1900-01).

Chitaldrug District.

The manganese-ore deposits found in this district are, as far as I know, all associated with the belt of Dhárwár rocks designated the Dambal-Chiknáyakanhalli band by Foote. The eastern edge of this band has been separated by the Mysore Geological Department under the name of the Jádanhalli belt of schists, and the remainder named the Chitaldrug belt. It is in the latter portion of this belt that all the Chitaldrug manganese-ore deposits have been found. Mr. P. Sampat Iyengar of the Mysore Geological Department has given an interesting account of the geology of the part of the Chitaldrug belt of Dhàrwàr schists lying n the Chitaldrug districts.[1] He claims to have found conglomerate layers separating this series of rocks into three formations, which he designates as follows in ascending order :—

1. The Jávanhalli fromation.
2. The Chitaldrug formation.
3. The Gudad-Rangavanhalli formation.

These three formations are characterized in the main by the following rocks :—

1. Hornblende-schists.
2. Chlorite-schists.
3. Clays.

He thinks that the last-named formation has affinities with the Kadapáhs. Even if the truth of the necessity of breaking up the schists of this area into three formations be established, I still do not think it is necessary to regard the three formations as anything else than three divisions of the Dhárwár series. The term *Dhárwár* is a comprehensive one and can be applied to all the sedimentary schists lying below the Eparchæan unconformity. It is extremely probable that there are many breaks in this schistose formation in different parts of India, but we can hardly hope to be able to correlate such breaks in different parts of India with any degree of certainty, and hence must make use of a general term to include the whole of this series of schists without taking any notice of the breaks. The term 'Dhárwár' seems to be the term to use thus. Further, from what I have seen of Mr. Sampat Iyengar's Gudad-Rangavanhalli formation, or as he calls

[1] *Op. cit.*, VI, Part II, pp. 57-93, with a geological map, (1904-05).

it for short the G. R. formation, I am inclined to believe that the clays were not deposited in their present condition, but merely represent altered phyllitic rocks forming an integral portion of the Archæan schists, and hence are not to be correlated with the Kadapáhs, which are of Purána age. If my doubt be sustained in this respect, then one must wonder if it really be a fact that there is a unconformity between the chlorite-schist formation and the clays, which might possibly have been formed in part by the alteration of chlorite-schists or phyllites.

Mr. Sampat Iyengar describes the G. R. formation as consisting of conglomerates, red and white mottled clays, ferruginous clays, grits and sandstones, and jaspery and brecciated hematite-quartzites. He mentions the occurrence of lateritic caps on top of the clays and says that manganese occurs as nodular lumps in this laterite. He further says that the hematitic quartzites are often found brecciated and always occur associated with the red mottle clays, and that manganese-ores, chiefly pyrolusite, are found in the cavities of the quartzites.[1] The localities given for these hematitic-quartzites are the hills N. and N. W. of Jammapur; east of Basavankote (Jagalur taluk); hills close to Bhimasamudram, and to the south of Chitaldrug. Mr. Iyengar also mentions the occurrence of manganese-ores in the clays.

I do not propose to discuss here the origin of the ores found in this district, for I have seen only one deposit, namely that at Sádarhalli. Here the evidence seems fairly clear that the manganese and iron-ores have been formed by the superficial replacement and alteration of original quartzites and argillaceous rocks, probably phyllites. For details see the account of this deposit.

The following is a list of the deposits of which I have any information :—

1. Sádarhalli.
2. Dod Kittadhalli.
3. Madadkere.
4. Nirgudda Hills.
5. Iplára Hills.
6. Iodimaradi.

[1] *Ibid.*, p. 84.

According to the one-inch map, deposit No. 1 is in the Holalkere taluk, and the remainder in the Hosdurga taluk; whilst, according to the Atlas Sheets, Nos. 1 and 3 are in the Holalkere taluk and the remainder in the Hiriyur taluk. The nearest deposit to the railway is Sádarhalli, which is only 4 miles from Chik Jájur Station on the Southern Mahratta Railway. The other deposits all lie some 16 to 20 miles to the east of the railway as measured in a straight line.

Mr. W. W. Coen of Hubli is working at Sadarhalli, and Haji Ismail Sait of Bangalore in the same area; the Peninsular Minerals Company of Mysore, Limited, is at work in the Dod Kittadhalli area; whilst Mr. C. N. Surya Narayana Row of Bangalore has concessions in the Nirgudda and Iplára Hills. There are probably others working in various parts of the district, but concerning this I have no information. The Peninsular Minerals Company reported an output of 712 tons of manganese-ore in this district in 1906, but no ore was exported. During 1907 some 3,125 tons of ore were raised by various prospectors. As regards the quality of the ores I have little information; they are probably similar to those of other parts of Mysore, namely comparatively low in manganese and high in iron, low in silica, and fairly low in phosphorus, with a tendency for the silica to become high when the ore is not carefully cleaned.

1. Sádarhalli.

The manganese-ore deposit being worked by Mr. W. W. Coen lies about $1\frac{1}{2}$ miles E.N.E. of Sádarhalli village on top of a hill rising to 200 to 250 feet above the neighbouring low ground. It is a little over 4 miles E. N. E. of Chik Jájur Station on the Southern Mahratta Railway. As shown on Mr. Sampat Iyengar's map it is just near the western edge of the Chitaldrug belt of schists. At the time of my visit a considerable amount of preliminary work had been done on the deposit. The numerous sections showed that the hill is covered with a thin skin of lateritic rock or lateritoid, in some places very like some varieties of true laterite. In some places the thickness of this lateritoid is only 2 or 3 feet, whilst in others it must be as much as 20 feet or even more. The rock underlying this is found to be a series of interbanded lithomarges, ochres, and wads, sometimes with associated psilomelane. In this series there are sometimes some bands of fine-grained quartzite of white colour, but irregularly impregnated with limonite so as to produce the effect of a mixture of brown and white quartzite. In this quartzite nests of pyrolusite are often found, there being every stage between the fresh quartzite, through quartzite blackened by the deposition of thin films of manganese oxide round each separate quartz grain, to pyrolusite in which all the quartz has been replaced by manganese oxide. The quartzite that is being replaced by manganese oxide has often become affected so that the grains of quartz have all become separate and the rock all tumbles into a fine white quartz sand on being handled. The lithomarges are sometimes seen to retain traces of slaty or shaly structure, and in places, instead of lithomarges the rocks underlying the lateritoid are seen to be laminated rocks suggesting altered slates or phyllites. Although there is some merchantable psilomelane associated with the lithomargic rocks, and some merchantable pyrolusite associated with the decomposed quartzites, yet the main mass of the manganese-ore worth extracting is in the lateritoid, where it occurs mainly in the form of psilomelane, mixed in varying proportions with limonite. This lateritoid often shows residual quartzite or slaty rock, so that it seems that it is the final product of the process of alteration and replacement that has evidently affected the whole of the mass of rocks situated near the surface of this hill. From the mode of occurrence of the ores it will be seen that they are only to be found near the surface, and that as the workings are deepened it will probably be found that the manganese-ores decrease in quantity and finally disappear. They will probably be found to extend deepest along the bands of quartzite, which seem to be more susceptible of replacement than the argillaceous rocks. Although the total quantity of ore in this hill cannot be large, yet I shall not be surprised if as much as 10,000 tons be extracted. The strike of the rocks revealed in the pits is generally N. N. W. to N. W., with the dips sometimes to the east and sometimes to the west side of the strike.

Interesting forms of lateritoid.

In one place the lateritoid is very interesting. On the south slope, extending to some 50 feet below the summit of the hill, is a big outcrop of the lateritoid. At the base of this outcrop there is a shallow excavation showing a soft rock composed of manganese-ore pisolites set in a soft clayey matrix of dark brown colour. This gives way above to ferruginous rock composed of red-ochre pisolites in a matrix of red ochre, the outer shell of the pisolites being limonitic. In places this form of the rock tends to give way to the manganiferous form again. Higher up this rock gives place to cavernous limonitic rock, sometimes more compact, and in places passing into psilomelane, the cavernous, psilomelanic, limonite rock extending right to the top of the hill. The various varieties of rock described above would often, if seen in detached pieces, be called 'laterite.' And indeed it seems as if this lateritoid, and consequently all the lateritoid containing manganese-ore that I have seen in Mysore, is really a form of true laterite, formed by the surface alteration and metasomatic replacement of quartzites, phyllites, and other Dhárwár rocks. I shall still call it lateritoid, however, to distinguish it from the form of laterite that is found in horizontal sheets.

Manganiferous ochre.

Amongst the ochres and wads there is a dark brown rock of light weight, cutting like soap, that dissolves entirely in hydrochloric acid. It must be a manganiferous ochre intermediate in composition between ochre and wad.

Nature of the ores.

The ores are partly psilomelane, often spoilt by limonite, or remains of quartzite or argillaceous rock, and containing either botryoidal psilomelane or pyrolusite needles in cavities; and partly pyrolusite, usually fine-grained, with either quartz or pyrolusite crystals in cavities, and also showing remains of quartzite. The ores hence tend to be high in silica.

2. Dod Kittadhalli.

Specimens of brown hematite from this place assayed 1·46 to 3·54 % MnO,[1] whilst some black iron sand showed 1·10% MnO.

3. Madadkere.

This place is some 4 miles to the south of Dod Kittadhalli. According to Mr. V. S. Sambasiva Iyer[2] a dark brownish black soft earthy ore of manganese, soiling the fingers and yielding about 44 % of MnO, corresponding to 34 % Mn, with less than 1 % of insoluble residue, occurs intimately associated with hematitic quartzite and earthy and ferruginous limestone in the long low hills east of Madadkere. The

[1] *Op. cit.*, II, pp. 42, 43, (1898-99).
[2] *Op. cit.*, IV, pp. 160, 161, (1902-03).

specimen that gave the above assay was taken from a long outcrop of about 6 feet broad on the east slope of the low hill called Dhupa-damaradi, about 1½ miles east of Madadkere. A substance very similar to the above, but less manganiferous and more ferruginous, occurs under similar conditions along slopes of hills forming the north and south continuation of the hill noted above. Thus a sample taken from a band of the material 7-8 feet thick on the western slope of the most easterly hill range, about ¼ mile south of the 15th milestone on the Hiriyur-Hosdurga road, showed only 14% MnO, corresponding to nearly 11% of Mn, and 37% of hematite. Material very similar to the above was found also in bands on the western slope of the low hill range about ¼ mile east of Madadkere.

In all these cases hematitic quartzites or a quartz-hematite-breccia cap the hills, while earthy ferruginous limestone alternating with the earthy manganiferous material underlies the quartzite, and on the other side is in contact with granite, gneiss, or grey crystalline lime-stone.

Besides the bands of manganiferous material Mr. Sambasiva Iyer says that extensive areas are covered to a depth of 2 to 3 feet, and occasionally even more, by a dark manganiferous earth yielding on analysis 9% MnO and 70% insoluble residue, and suggests that a close prospecting of this earth might lead to the discovery of workable ores.

4. Nirgudda Hills.

The Nirgudda Hills lie about 4 miles E.N.E. of Dod Kittadhalli. In one of them, called Munisinganagudda, workable ores of manganese-ore are said to have been found, the concession being held by Mr. C. N. Surya Narayana Row of Bangalore.

5. Iplára Hills.

This name may be given to the range starting about 2 miles south of Nirgudda and running for 4 miles south by a little west to the Hiriyur-Hosdurga road near Madadkere. The highest point is Iplára, 3,078 feet. In 1899 Dr. W. F. Smeeth[1] found some loose pieces of manganese-ore on the Iplára Hills.

'A few of these are good manganese-ores, but the majority are iron-ores containing variable proportions of manganese with some silica and small quantities up to 1 dwt. or so) of gold.'

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[1] *Op. cit.*, II, p. 167, (1898-99); IV, p. 24, (1902-03).

Mr. C. N. S. N. Row holds a concession in this area.

6. Bodimaradi.

Dr. Smeeth also mentions Bodimaradi Hill, which

'is one of a chain of small hills running north and south about three miles east of Dod Kittadhalli. The hills are composed of ferruginous quartzites and schists, in which are variable quantities of manganese-ore and a little limestone.'[1]

It is evident from the above that Bodimaradi must be near Iplàra Hill, although it is not marked on the 1-inch map of this area.

Hassan District.

A crushed granite-porphyry from the Kempinkote mine showed 4·97% MnO^2.

The Kadur District.

Only two occurrences of manganese-ore in this district have come to my notice. These are near Ubráni and in the Hádikere forest, respectively, both being in the Tarikere taluk.

1. Ubráni.

Mr. Slater mentions[3] the occurrence of rounded lumps of manganese-ore on the cart track leading from Gangur (in the Shimoga district) to Ubráni. I do not know if any of this ore was actually found within the limits of the Kadur district.

2. Kannikalmatti (Hádikere).

bout 1¼ mile E. S. E. of Shiddarhalli village in the Shimoga district is a hill called Kannikalmatti. This is just over the border, in the Kadur district and some 3½ miles N. 10° W. of Hádikere village. It

[1] *Op. cit.*, V, Part I, p. 17, (1903=04).
[2] *Rec. Mys. Geol. Dept.*, II, p. 59, (1898-99).
[3] *Op. cit.*, VI, Part II, p. 26, (1904-05).

is shown by Mr. Slater on his map[1] of this area as having manganese- and iron-ores on top. These are said to be of no value and similar to the occurrences on the top of Urumanjanmatti. On the sloping and level ground on the north-west base of Kannikalmatti, however, somewhat extensive deposits of detrital ores have been found. Those portions of these deposits lying in the Kadur district are he'd by the Shimoga Manganese Company, and those portions lying in the Shimoga district by Messieurs Jambon and Cie. Most of the openings show detrital nodules and boulders of manganese-ore in a matrix of clayey soil. But in two places what is possibly ore *in situ* seems to have been found. In one of these, isolated concretions of psilomelane are seen in a matrix of yellow ochre. The other occurrence is in a big trench running N.30°E. and as much as 25 feet deep in places. The ore is mixed with clay and yellow ochre and seems to be more or less massive in places, but I am not certain that this is not really a closely packed detrital deposit. That some of the ore is probably *in situ* is indicated by the presence of broken veins of quartz, partly replaced by manganese-ore in places. The whole occurrence is, however, obscure. In any case it is probable that a considerable proportion of the detrital ores of this area has been derived from the top of Kannikalmatti. The ore consists of both the dull grey and lead-like varieties of psilomelane, with a tendency for the boulders to show a coating of wad. The distance to Tarikere Railway Station, Southern Mahratta Railway, is about 9 miles.

Shimoga District.

(*See Plate 57.*)

History.

This is the district in Mysore in which manganese-ore deposits of economic value were first found and also worked. As long ago as 1855 'sesquioxide of manganese' from this district was exhibited at the Madras Exhibition and was then used at the Madras School of Arts for colouring glass and pottery[2]. In 1899, Mr. H. K. Slater of the Mysore Geological Department[3] discovered indications of the Kumsi deposit, which he

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1 *Loc. cit.*, Plate II.
2 Reports by the Juries, p. 6, (1856).
3 *Rec. Mys. Geol. Dept.*, IV, pp. 19, 138, (1902-03); V, Part I, p. 34, (1903 04).

examined more closely in 1903. During the field season of 1904-05 Mr. Slater extended his surveys of the Shimoga district, and found manganese-ores at or near Shiddarhalli, Hoshalli and Gangur.[1] No attempt was made to open up any of the Mysore deposits till the end of 1904, when Messrs. Hamilton Holmes, J. Short, and Eardley Norton took out prospecting licenses for some blocks near Kumsi. Their work has culminated in the formation of the New Mysore Manganese Company, Limited. For the history of this enterprise and the development of the industry in the hands of other individuals and companies, especially during 1906, when the manganese boom in Mysore can fairly be said to have started, see pages 429—430 of Part III of this Memoir. The first export of manganese-ore from this district, and therefore from Mysore, was in 1906, when 40,773 tons of ore were exported by the Mysore Manganese Company, Limited, since become the New Mysore Manganese Company, Limited.

Output.

The output for 1907 was 96,591 tons divided as follows :—

	Long tons.
New Mysore Manganese Co.	76,894
Shimoga Manganese Co.	15,729
Tata Sons & Co.	1,427
Jambon & Cie.	816
Various licensees	1,725
	96,591

Physical character of the country.

The general plains level of the country varies from about 1,900 to 2,200 feet. From this spring up ranges of hills, mostly due to the Dhárwár series of rocks, the granites and gneisses tending to occupy the low country in between.

The heights reached by these Dhárwár ranges vary from a hundred or two feet above the level of the plains to 2,800 and sometimes over 3,000 feet above sea-level, one of the highest peaks in the manganese area being Shankargudda, 3,393 feet above sea-level. The low-lying gneissic and granitic country is usually given up to cultivation, except where the rock crops out at the surface; whilst the Dhárwár ranges tend to be covered with very thick jungle. Consequently a considerable

[1] *Op. cit.*, VI, Part II, pp. 24-26, (1904-05).

proportion of the manganese-ore deposits lie in reserved forest, and to work them it is necessary to clear the jungle first.

Geology and origin.

For our knowledge of the geology of this district we are indebted mainly to Mr. Slater, who has produced unusually detailed maps for Archæan areas. In Vol. 4 of the Records of the Mysore Geological Department there is a map (Plate III), on the scale of 1″=4 miles, of portions of the district north and N. W. of Shimoga. In Vol. 5 there is a map (Plate II), on the same scale, of the portions of the district to the west and S. W. of Shimoga town, and in Vol. VI there is a map (Plate II), on the scale of 1″=1 mile, of parts of the district east and N. E. of Benkipur station. On these maps are to be found all the manganese-ore localities yet known. From them it will be seen that the whole of the district is covered by two divisions of the Archæan series—the Dhárwár Schists and the Granites and Gneisses. The Dhárwárs are probably older than the granites; but there are some portions of the gneisses that are said to be of pre-Dhárwár age. As might be expected the manganese-ores occur only in association with the Dhárwárs. The Dhárwárs of this district form, of course, a portion of the Dhárwár-Shimoga band of Dhárwárs of Foote. They comprise a great variety of rocks, as described by Mr. Slater. The most prominent of these to one visiting the manganese areas are the phyllites, slates, and resultant clays; the dolomites and limestones; the quartzites and ferruginous quartzites. The manganese-ores occur in cappings—often on the tops of hills—resting on these rocks, and chiefly on the phyllites—or rather their decomposed equivalents—and quartzites. They almost invariably crop out in the form of irregular *lateritoid*—*i.e.*, resembling laterite—masses of more or less horizontal upper surface. When they are quarried into they nearly all show a downward passage from the mixed manganese- and-iron-ores into decomposed wads, lithomarges, and friable saccharoidal quartzites. Thus, although many geologists would probably not be disposed to regard these rocks as true laterite, like the laterite that forms horizontal sheets of some considerable extension, there seems to me little doubt that they are closely related to laterite, and are really one variety of it. According to the evidence of the many deposits I examined, they are formed by the superficial replacement of the phyllites and quartzites.

The best proof that the Mysore deposits are, almost without exception, of this origin, is the evidence to be seen in almost every working of a gradual impoverishment of the deposits in depth, with the appearance of larger and larger quantities of lithomargic rocks and remains of quartzite and quartz. The miscroscope shows that it is a case of replacement. Even in the best deposit—namely Kumsi, where the downward passage has not yet been exposed—there can be little doubt that a similar explanation holds. For in one place I found remains of quartzite partly replaced by pyrolusite; at another, residual patches of white quartzite filling in the meshes of a sort of network of manganese-ore (psilomelane); and in a third place, a phyllite, probably a talcose one, larg ly impregnated with manganese. The first two instances were right in the ore-body, and the third on the southern edge. Further evidence at Kumsi is the occurrence in a considerable proportion of the ores now being quarried, even from the best parts of the deposit, of occasional quartz grains and patches of quartzite. which in some parts of the deposits become very important in quantity.

Nature of the ores.

The three chief ores are psilomelane, wad, and pyrolusite. The pyrolusite seems to form directly by the replacement of quartzites, with which it is associated in preference to lithomarges. The wads on the other hand seem to form more readily in the lithomargic rocks, by the gradual replacement of which they grow. As in Sandur, the wad gradually passes into psilomelane, good examples of the passage being common at many of the deposits. The Kumsi deposit seems to be an aggregate of large boulders. From the evidence of remains of replaced rocks I do not think these boulders are of derivative origin, *i.e.*, rolled to their present position. I think rather that their shape is the result of their mode of origin and that they have grown *in situ*. These boulders often show an interior composed of psilomelane, sometimes with a few tell-tale grains of quartz, and an outer zone, 1 to 2 inches thick, of wad, with a zone of passage between the two. Sometimes the conversion seems to have been complete, with the result that the boulder is composed almost entirely of psilomelane. At other times it has not advanced nearly as far, and the boulder shows a mottled mixture of wad and psilomelane.

A common variety of ore is one showing pisolitic or oolitic structures. In this variety of ore the spherulitic grains range from $\frac{1}{16}$ to $\frac{1}{8}$ or even $\frac{1}{4}$ inch in diameter; perhaps $\frac{1}{8}$ inch is the most usual size. These spherules frequently show a concentric structure, and are composed of psilomelane. The matrix in which they are set is often softer and then gives a brownish black streak and is to be called wad. At other times the matrix itself is composed of psilomelane, which in both pisolites and matrix is of the lead-like variety. It seems as if the ore first formed is wad in which the pisolites grow, and as if at a later stage the wad matrix itself changes into psilomelane. Another mineral that is fairly common in these deposits is a hard bright crystalline one that occurs in irregular patches, streaks, spots, and veinings, scattered throughout the psilomelane of the ores at the various deposits. This mineral has not yet been closely examined; from its association with psilomelane and general appearance it suggests hollandite, or possibly braunite. The one specimen I tested gave a siliceous residue on solution in acid, but it did not seem to be gelatinous. On the other hand the solution did not react for barium, as it probably would if it were hollandite. Hence until a complete quantitative analysis be made it will not be possible to assign it a name. The bright crystalline mineral seen in different specimens, however, may not always be the same. It seems almost certain that a certain proportion of it must be hollandite, and not improbable that some of it is braunite; it is further possible that a portion of it may represent polianite (see page 1119) or even a new species. The only mineral I have seen in the Shimoga deposits showing definite crystalline forms is pyrolusite, which is often found lining cavities, in the form of beautifully developed crystals of small size, showing various prisms, capped as a rule by the basal plane.

Quality of the ores.

With regard to the quality of the ores I am not able to give figures based on the analyses of samples taken by myself. But Mr. C. S. Fawcitt, chemist to the Mysore Manganese Company, Limited, has kindly furnished me with the figures shown in the first and second columns below; and Miss A. E. Dawson, of the Shimoga Manganese Company, with analyses from which the figures shown in the third column are taken. Mr. Fawcitt's figures relate to the Kumsi deposits, and those of Miss Dawson to the deposits round Shiddarhalli, Hoshalli, Shikarpur, and Hosur.

	New Mysore Manganese Company.		Shimoga Manganese Company.
	Higher grade.	Lower grade.	
Manganese	44 56	30—44	34·51—55·94
Iron	2—10	10—20	4·01—17·25
Silica	1—3	2—6	0·22— 5·75
Phosphorus	0·015—0·06	0·01—0·06	0·01— 0·14
Moisture	About 1	About 1	..

The New Mysore Manganese Company has kindly supplied me with the figures of manganese contents for all the cargoes shipped since the beginning—1st February 1906—of work till the 28th June 1907. They represent 21 cargoes and a tonnage of 60,404 tons of manganese-ore. The analysts are Pattinson & Stead, J. & H. S. Pattinson, W. H. Pearson & Co., and E. Riley & Co. Excepting one cargo, they all ranged between 45·06% and 50·90% manganese. The exception was a cargo of over 4,000 tons, that gave 41·75% and 43·40% Mn according to different analysts. The calculated average of all the cargoes, making allowance for the different tonnages, is 47·67% Mn. The bulk analyses of the ores from the deposits of the Shimoga Manganese Company are said to range between 34% and 49% Mn according to the deposit, the 34 figure being unusual. From the foregoing figures it will be seen that the characteristics of the Shimoga ores are manganese lower than in the Central Provinces, with a proportionately higher amount of iron, and very low silica and phosphorus. The Shimoga ores are in fact to be classed as 2nd and 3rd grade, although a small quantity of first grade ore might be selected.

Communications and transport.

As regards railway communications, some of the Shimoga deposits are favourably situated, and some unfavoucably. The favourably situated ones are those round Shiddarhalli, from which it is only about 6 miles to Masarahalli station, and 9 miles to Tarikere. The unfavourably situated ones are those round Hoshalli, at an average distance of 14 to 15 miles from Benkipur station ; those near Kumsi, the

Kumsi deposit itself being 20 miles by road from Shimoga station; and those round Shikarpur, this place being 31 miles from Shimoga. The New Mysore Manganese Company is laying down a 2-foot gauge steam-tramway from Kumsi to Shimoga by a route 29 miles long. At present nearly all carriage of ore is done by means of bullock-carts, the rate being about 4 to 4½ annas per ton mile, except from Kumsi to Shimoga, where a rate of over 5 annas prevails.

List of deposits.

The following is a list of all the deposits in this district about which I have any information :—

1. Itigehalli.	I.—Shikarpur Group.
2. Vadderpur.	
3. Hosur.	
4. Ballur.	
5. Kaginelli.	
6. Tuppur.	II.—Ayanur Group.
7. Short's Block.	
8. Kumsi (Holmes' Block).	
9. Bikonhalli (Norton's Block).	
10. Aladhalli (Haji's Block).	
11. Shankargudda.	III.—Shankargudda Group.
12. Tirandur.	
13. Sulekere.	IV.—Channagiri Group.
14. Gaddikalmatti.	
15. Buddamatti Peak.	
16. Hoshalli.	
17. Treasury Hill.	
18. Bhadigund.	V.—Shiddarhalli Group.
19. Gangur.	
20. Kanjiganagutti.	
21. Urumanjanmatti.	
22. Ragikalvadikinakeri. Bhaui Nagalagutti.	

Of these deposits Nos. 1 to 5 are in the Shikarpur taluk, Nos. 6 to 11 and 18 to 22 in the Shimoga taluk, No. 12 in the Tirathalli taluk, and Nos. 13 to 17 in the Channagiri taluk.

I.—The Shikarpur Group.

I have not visited any of the deposits of this group. They are all situated to the east and south-east of Shikarpur in the northern part of the district, at distances of 5 to 12 miles. The nearest of these to the railway is probably Itigehalli, which is about 28 miles distant by road. The first four are held by the Shimoga Manganese Company, Limited, and the fifth by Mr. C. N. Surya Narayana Row of Bangalore. I have no information about the mode of occurrence or extent of these deposits.

II.—The Ayanur Group.

All the deposits of this group given on page 1133 are held by the New Mysore Manganese Company, Limited, which has been granted a preferential right over all the deposits within a 13 miles' radius of Ayanur, till the end of December 1909 (see page 429). The nearest of these to the railway is Aladhalli—9 miles from Shimoga—and the farthest is Tuppur—about 24 miles from shimoga station.

6. Tuppur.

I have not visited this deposit: but Mr. Fawcitt tells me it is situated on a hill just to the south-west of the village. A specimen of dull grey psilomelane from here analysed by Mr. Fawcitt showed:—

Manganese	32·10
Iron	28·11
Silica	2·03
Phosphorus	0·065

7. Short's Block.

This also I did not visit. It is now worked out according to Mr. Fawcitt and consisted of four occurrences of ore situated in the hills a mile or so to the north-west of Kumsi, 2 on each side of the Shimoga-Anantapur road. Analyses by Mr. Fawcitt, of two samples representing 1,500 and 1,000 tons of ore, respectively, are as follows:—

	No. 1.	No. 4.
Manganese	42·32	39·16
Iron	12·04	9·91
Silica	5·53	10·46
Phosphorus	0·008	0·019

Out of over 70,000 tons of ore shipped by the New Mysore Manganese Company up to the end of 10th August 1907, some 4,000 tons only were mined from Short's Block.

8. Kumsi.

(*Plate 57.*)

In 1899, Mr. H. K. Slater discovered an occurrence of manganese-ore near Kumsi.[1] This he examined more closely in 1903. Owing to the heavy jungle and covering of rich brown soil the dimensions of the deposit could not be properly ascertained; but Mr. Slater reported that:—

'it is undoubtedly of considerable extent and a very pure form of the oxide is obtainable.'

'A large number of smooth rounded lumps of ore are to be found in the bed of the Nulla at the north-eastern base of the hill $1\frac{3}{4}$ miles E. N. E.—N. E. of 2805 or 3 miles N. N. E. of Kumsi.'

In 1904 prospecting licenses were taken out for various blocks in this area by Messrs. Holmes, Short, and Norton. From these, the deposits have passed successively to the Madras Mysore Mining Syndicate, the Mysore Manganese Company, Limited, and the New Mysore Manganese Company, Limited, the last named of which now holds them. The ore has been located *in situ* on the northern slope of the hills north of Kumsi, at a point $3\frac{1}{2}$ miles N. by a few degrees W. of Kumsi, and $1\frac{1}{2}$ miles N. by a little E. of hill 2805. The geology of the country immediately surrounding the deposits is much obscured by jungle; but such cuttings as are available indicate that the rocks are phyllites and fine-grained schists, vitreous quartzites, hematite- and magnetite-quartzites, and dolomites. The strike of these rocks as mapped by Mr. Slater is on the average about north and south. This also agrees with my observations. This strike is interesting to note, because the strike of the manganese-ore deposit seems to be, as far as one can judge from the obscure indications exposed in the workings, about west by a little south. If this be the true strike of the deposit, and it has been formed by replacement of the Dhárwár rocks at the surface, then it means that

[1] *Rec. Mys. Geol. Dept.*, IV, pages 19, 138, (1902-03); V, page 34, 1903-04.

the replacement has taken place in a direction at right angles to the strike of the rocks and independently of their nature. Since, however, the remnants of Dhárwár rocks exposed in the manganese-ore deposit seem also to have this westerly strike of the ore deposit, the more probable explanation of the strike of the deposit being roughly at right angles to the prevailing strike of the rocks in the neighbourhood is that there is a local twist in the strike of the rocks, and that it is this that is represented in the strike of the deposit. From the evidence of the remnants of rocks seen in various places in the workings I should say that the rocks that have been replaced here are vitreous quartzites, sericitic phyllites, subordinate talcoid phyllites, and possibly some vein quartz.

At first sight the deposit seems to be composed almost entirely of huge boulders of ore from 1 to 3 or more feet in diameter, with a comparatively small quantity of interstitial clay. In some places, however, there seem to be distinct signs of bedding in the deposit. From the transition shown by many of these boulders from wad into psilomelane as noticed on page 1130, I am inclined to think that they are not detrital boulders, as might at first sight be thought; but that they have grown *in situ* by the gradual replacement of quartzites and phyllites, with the formation first of wad and later of psilomelane, the residual quartz, quartzite, and lithomargic shale (representing original phyllite), being evidence of this change.

As exposed in the workings, the length of the deposit in a west by a little south direction is 352 paces, or say about 1,000 feet. The deposit being on the slope of the hill near its bottom, the workings are not horizontal, but at an angle of about 20°, this probably being about the original slope of the surface before work was begun. Measured along this slope, the width across the middle of the deposit is about 340 feet, equivalent to about 320 feet on the horizontal. From these figures one can easily make a rough estimate of the amount of ore in the deposit, if it be assumed that the deposit will continue to a depth of 50 feet without serious deterioration.

Quantity of ore.

[At the time of my visit the workings were nowhere deeper than 25 feet, and at this depth the ore had not shown signs of any serious deterioration.] Taking as the effective length and width of the deposit 800 feet and 180 feet respectively, the amount of ore down to a depth of 20 feet may be estimated as roughly $\frac{800 \times 180 \times 20 \times 62{\cdot}5 \times 4}{2240 \times 3} = 107{,}000$ tons, on the assumption that only one-third of the ore would be found up to the grade at present being shipped, and that the average specific gravity of the ore is 4. A depth of 50 feet would therefore give 250,000 tons of ore. As about 100,000 tons of ore had already been extracted by September 1907, I think that the foregoing figure may be too pessimistic, owing perhaps to a larger proportion of the ore than one-third being despatched. Perhaps 300,000 tons of ore may be given as the probable maximum output of this deposit down to 50 feet, with a bare possibility of 500,000 tons. Of course, should the deposit be found to continue productive to a greater depth, the foregoing figures would have to be increased.

This deposit is the only one in the whole of Mysore, of those I examined, that showed indications of any large quantity of ore.

Nature and quality of the ores.

The ores of this deposit, as noticed on page 1130, are largely psilomelane with wad. The ore as seen in the sun has, when composed largely or entirely of psilomelane, a beautiful light blue colour, which is of course light grey in the shade. It often contains veinlets and patches of the bright crystalline mineral noticed on page 1131. At the eastern end of the deposit there is a considerable amount of soft pyrolusite, associated with decomposed quartzite and yellow ochre. There is also a considerable amount of yellow ochre associated with the psilomelanic ores. On the northern side of the deposit there is a large quantity of the oolitic ore noticed on page 1131.

As regards quality, the ores of this deposit are very variable, owing to the replacement of manganese by iron. The best ore could possibly be selected to run over 50 per cent., but the majority of the ore as shipped runs between 45 and 50 per cent. Mn (see page 1132). The deposit also yields a considerable quantity of ore of lower grade than this, probably ranging down to 35 per cent. Mn; but such ore is not at present made use of.

In addition to the analytical figures given on page 1132, I give below 11 analyses by Mr. Fawcitt of selected specimens of the Kumsi ores; their physical characters are given in the note to the analyses. The phophorus was not determined, but according to Mr. Fawcitt can be taken as averaging 0·05. The chief features of these analyses are the very variable proportions of manganese and iron in specimens all of which look like manganese-ore. The iron, it will be seen, tends to be lowest in the pyrolusites, fairly high in the wads, and highest in the pisolitic or oolitic psilomelanes, in which there is also an exceptionally large amount

Analyses of hand-specimens of Kumsi manganese-ores.

	1	2	3	4	5	6	7	8	9	10	14
MnO_2 . .	82·97	87·82	69·76	83·33	75·51	65·41	70·29	76·55	52·19	40·06	33·58
MnO . .	1·75	2·93	1·73	3·67	4·58	3·40	4·29	1·74	1·99	1·18	*Nil*
Fe_2O_3 . .	7·85	1·85	19·23	6·64	10·09	18·08	11·76	14·20	26·24	39·46	44·16
Al_2O_3 . .	2·50	1·80	2·82	1·51	2·41	5·48	5·84	3·06	12·74	12·12	13·04
CaO . .	1·03	0·98	0·76	0·68	0·59	1·34	2·28	1·01	1·94	1·72	1·91
MgO . .	0·36	0·37	0·28	0·31	0·30	0·52	0·74	0·30	0·67	0·40	0·36
K_2O & Na_2O	0·53	0·59	0·81	1·04	0·49	2·35	2·32	0·70	1·52	1·12	..
SiO_2 . .	0·95	0·90	1·05	0·60	2·80	1·22	1·36	0·54	1·24	2·72	2·90
Combined water.*	2·06	2·76	3·56	2·22	3·23	2·17	1·02	1·85	1·62	1·36	4·02
P_2O_5 . .	..	..	..	..	..	..	..	..	..	..	0·03
Total .	100·00	100·00	100·00	100·00	100·00	99·97	99·90	99·95	100·15	100·14	100·00
Manganese .	53·82	57·81	45·44	55·52	51·29	43·98	47·74	49·75	34·54	26·87	21·23
Iron . .	5·50	1·21	13·46	4·65	7·00	12·66	8·23	9·94	18·37	27·62	30·91

* Water determined by difference in Nos. 1 to 5, and 14.

Notes:—

1. Cavernous mixture of crystalline pyrolusite with dull pyrolusite or wad.
2. Massive pyrolusite, with some of the bright grey crystalline mineral, and possibly a little psilomelane, somewhat cavernous.
3. Black wad (dark brownish-black streak) with thin veinlets of psilomelane.
4. Dull grey psilomelane, with a fair quantity of the bright grey crystalline mineral, and a little black wad.
5. Light grey psilomelane with hard bright specks.
6. Dull grey psilomelane with a few minute bright specks.
7. Lead-like psilomelane.
8. Compact firm black wad, passing into, not very hard, nearly black psilomelane with light grey psilomelane veinlets.
9. Oolitic, almost lead-like psilomelane; matrix and oolites the same, former more abundant, fracture passes through the oolites.
10. Oolitic, with black wad matrix; and oolites of softish psilomelane, fracture passes round the oolites.
14. Oolitic, with brownish black matrix (chocolate streak); oolites tend to consist of psilomelane.

of alumina. The manganese on the other hand tends to be highest in the pyrolusites and lowest in the pisolitic or oolitic psilomelanes. It will also be seen that in all the ores, practically the whole of the manganese is present in the peroxide form, with very little in the protoxide form. This of course points to the general absence of braunite, which is borne out by the small amounts of silica, which, though it may be present in the form of braunite in some cases, is probably nearly always present as free quartz. The mean of the figures in this table is as follows :—

Manganese	46·68
Iron	10·86
Silica	1·34

Photographed by L. L. Fermor. *Bemrose, Collo., Derby.*

MANGANESE-ORE DEPOSIT AT KUMSI, SHIMOGA DISTRICT, MYSORE.

The working of the deposit.

The deposit seems to have been opened up very badly at the outset and was only beginning to recover from its initial bad treatment at the time of my visit. It is now being worked in a series of trenches parallel to the length of the deposit and therefore horizontal. Lines of rail are being run along these trenches for the removal of the ore and waste. The waste, of which there is a considerable quantity, is being run to the east and west of the deposit on the line of strike; although the waste is thus dumped on the line of strike of the deposit, I am told that it was first ascertained that the deposit did not continue in either of these directions. Plate 57 shows a portion of this deposit. All the material heaped on the unopened ground left standing up between the cuttings is manganese-ore, which had been quarried faster than it could be removed. The steam tramway being constructed to join up this mine with Shimoga Station, by a 29-miles' route *viâ* Choradi, leaves the deposit at its western end. The gauge is 2-foot with 20 lb. rails, and the gradient in favour of the load, with a maximum of 1 in 80, the maximum gradient against the load being 1 in 100. The trucks used are of two sizes, the larger taking a maximum of 3 tons of ore and the smaller of $1\frac{1}{8}$ tons. In September 1907 there were still some 10 miles of rail to be laid down.

9. Bikonhalli.

Bikonhalli village is situated north of Shimoga near the 8th mile on the road from Shimoga to Shikarpur. The deposit—usually referred to by the New Mysore Manganese Company as Norton's Block—lies $1\frac{3}{4}$ miles W. S. W. of the 8th milestone, on top of a hill rising to some 400 or 500 feet above the level of the road at Bikonhalli. This hill is $\frac{7}{8}$ mile W. N. W. of Δ 2,766 feet. According to Mr. Slater's map, the rocks in the hills immediately surrounding the hill in which the deposit lies are quartzites, quartz-keratophyres, limestones, hematitic quartzites, and schists.

The top of the hill has a N. N. W. strike, and is formed by two small peaks separated by a neck not many feet lower, and some 40 paces long. The total length of the two peaks together with the neck between is about 180 paces. The neck is comparatively free from ores, whilst the two peaks are due to lateritoid cappings of mixed manganese- and iron-ores. The outcrops of these ores have the usual lichen-covered laterite-like aspect. The numerous workings in these two peaks indicate that there is a small thickness, 5-10 feet, of the lateritoid mixture of ores passing downwards into slates and quartzites, through a zone in which these two rocks are partly replaced by the ores. The slates (or phyllites) are now mostly represented by white soft clayey rocks retaining signs of slaty structure ; but in some cases the slates are fresh, then being grey to silvery grey in colour. The quartzites are white fine-grained, saccharoidal rocks. The replacement of these rocks by manganese- and iron-ores is very irregular ; in general a network of ores isolates patches of partly replaced or comparatively fresh rock ; but in places the ores expand into pockety masses of considerable size.

The strike of the rocks as shown in these sections seems to be that of the ridge, namely N.N.W., with a variable dip, usually fairly steep, to the east side. In two sections in the southern and more important of the two peaks thicknesses of replaced beds of 13 and 12 paces, respectively, are seen, and the thickness of the replaced rock does not seem to be anywhere greater than this.

From the way in which the lateritoid outcrop passes downwards into the mixture of slate, quartzite, and ores, it does not seem likely to me that this deposit will be found workable at a profit to a greater depth than about 50 feet ; but it is probable that the replacement extends inwards for a greater distance than this, though in a very irregular manner. In the cuttings in the path on the way down the hill there are several sections showing bluish grey limestones and dolomites. These are seen under the microscope to contain an abundance of minute black specks that tend to show squarish though blurred outlines. Chemical tests show the rock to be somewhat manganiferous, so that it is probable that these specks are, at least partly, manganese oxide. It is not possible to say if they are original or secondary introductions. If the former be the case then they may be the source from which the manganese oxides replacing the rocks at the surface to form the manganese-ore deposit were derived. If the second be the case, then the manganese may have been introduced at the time of formation of the manganese- and iron-ores on the top of the hill above.

A rough analysis of this dolomite by Mr. Fawcitt showed :—

$CaCO_3$	48·35
$MgCO_3$	34·70
Fe_2O and Al_2O_3	5·10
Mn_3O_4	1·87
Siliceous matter	10·10
	100·12

The chief manganese-ore is pyrolusite, whilst the chief iron-ore is limonite, sometimes in the form of yellow ochre, but more often in the form of the dull hard variety. This is often traversed by veinlets of pyrolusite, which, in cavities, pass into very pretty aggregations of pyrolusite crystals of considerable perfection, but small size. Along cracks the limonite often forms mammillated radiate layers, and in places this limonite seems to be darker than usual and to be highly manganiferous; but it is not quite certain that the manganiferous character of the limonite may not be due to some minute shining specks that are sparingly scattered throughout it. Sometimes concretionary psilomelane is also found along cracks. There is also a little of the hard grey crystalline mineral (?polianite; see below).

Nature and quality of the ores.

As might be expected from the mode of occurrence, the ores are very siliceous, and it is doubtful if any system of cleaning, except crushing and washing, could bring down the silica to a small figure, without enormous loss of ore. The following three analyses by Mr. Fawcitt give some idea of the chemical character of the ores :—

——	No. 1.	No. 2.	No. 3.
MnO_2	76·03	88·03	
MnO	1·74	3·74	
Fe_2O_3	13·60	2·96	
Al_2O_3	2·06	2·04	
CaO	1·18	1·03	
MgO	0·76	0·68	
Alkalies	trace	trace	
SiO_2	3·62	1·24	9·66
Combined water	1·00	0·37	
	99·99	100·09	

—	No. 1.	No. 2.	No. 3.
Manganese	49·42	57·75	45·23
Iron	9·52	2·07	10·36
Phosphorus	0·07	0·07	0·053

No. 1 was a specimen of pyrolusite, mixed with some of the grey crystalline mineral, and some wad.

No. 2 was a piece of light grey crystalline ore mixed with a little psilomelane. An analysis of a purer piece of this crystalline mineral is given on page 78; and judging from this analysis I suppose that the mineral is probably polianite. If it be, then the specimen of which the analysis is given here is simply a more impure piece. No. 3 is an analysis of a sample of 933 tons of ore stacked on the mine in August 1907. The phosphorus in Nos. 1 and 2 was not determined, and the figures given are those that are taken as the average figures for the deposit.

Besides the ore *in situ* there is a considerable quantity of detrital ore exposed in quarries on the slopes. I am told that the best portions of these detrital deposits lie on the N. and N. W. slopes of the hill.

10. Aladhalli.

Aladhalli is about 2 miles E. N. E. of Bikonhalli village. Mr. Fawcitt tells me that there are 2 outcrops of ore on the hillside in the hills south of Aladhalli village.

III.—The Shankargudda Group.

Shankargudda is the name of a peak 3,393 feet high situated at the northern end of a long range of Dhárwár hills aligned almost due north and south for many miles. This range can well be called the Shankargudda Range after this peak. Shankargudda peak is situated 10 miles due west of Shimoga town. I have not visited the range, but according to Mr. Slater's map it consists of schists, hematitic quartzites, conglomerates, with hornblende-schists, micaschists, and cappings of laterite.

The discovery of manganese-ore at Kumsi lead Mr. Slater to infer the probability of its existence on the Shankargudda range, which is situated practically due south of Kumsi and on the line of strike of the Kumsi rocks. His search in the field-season of 1903-04 on Shankargudda was successful, ore being found at several localities.

11. Shankargudda.

According to Mr. Slater[1] the first indication of manganese-ore :—

'was found on the crest of the ridge $\frac{1}{2}$ mile S. E. of △3393 (Shankargudda). Here the ore, which is of the pisolitic character appears to be of considerable solidity, and entirely forms the small cone of the hill. Portions are decomposed into the ochery state. The whole presents the appearance more or less of a conglomerate.

'The quality appears to be decidedly good. Indications were also observed at two other points, also along the crest of this ridge. The first lies about $1\frac{1}{8}$ mile S. S. E. of △ 3393 and the second $1^3/_4-2$ miles S. 10° E. of △ 3393. In both localities the manganese-ore is found in loose rounded blocks in a lateritic matrix. On fracture they sometimes revealed the pisolitic structure, at others a more compact, with splintery fracture.'

In another place[2] Mr. Slater, writing of the Shankargudda Range, says :—

'Bands of laterite of peculiar interest are to be found in the northern portion to the N. N. E. of Hanagere. Embedded in this laterite are blocks usually rounded varying up to 2-3 feet in diameter of Manganese-ore, sometimes pisolitic, at others more massive, giving a splintery fracture, sometimes binding angular fragments of a darker mineral or enclosing portions of silver-like appearance.'

Hanagere is a village 5 miles S. S. W. of Shankargudda peak.

Deposits are now being worked on the Shankargudda range by the New Mysore Manganese Company, and I believe in some places by other operators.

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[1] *Rec. Mysore Geol. Dept.*, V, (Part II), p. 54, (1903-04); also Part I, pp. 32, 34.
[2] *Loc. cit.*, Part II, p. 45.

In the following are given some analyses of the Shankargudda ores by Mr. Fawcitt. Nos. 1 to 4 are hand-specimens and No. 5 a sample of 1,500 tons of stacked ore, badly sorted, and not cleaned :—

——	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
MnO_2	85·42	78·64	58·81	56·89	
MnO	2·06	5·06	5·03	6·07	
Fe_2O_3	6·06	6·89	26·16	24·03	
Al_2O_3	2·38	2·87	3·28	6·02	
CaO	0·50	0·72	0·56	0·56	
MgO	0·56	0·68	0·72	0·51	
Alkalies	0·32	0·89	1·15	0·93	
SiO_2	1·01	1·61	1·13	3·66	3·20
Combined water	1·65	2·57	3·05	1·42	
	99·96	99·93	99·89	100·09	
Manganese	55·6	53·69	40·92	40·67	38·06
Iron	4·24	4·68	18·31	16·82	18·48
Phosphorus	0·06 (Nos. 1–4)				0·063

NOTES :—

1. Mainly hard bright crystalline mineral scratched by a knife with great difficulty, with some psilomelane and wad.
2. Dull grey psilomelane, with minute cavities or cells, and a very small proportion of minute bright specks.
3. Very smooth dark grey psilomelane, tending to be lead-like.
4. Pisolitic psilomelane, with lead-like pisolites up to ½ inch diameter, set in a matrix of dull grey psilomelane.

As far as I am aware no ore had been shipped from Shankargudda up to September 1907.

12. Tirandur.

Mr. Slater also records[1] the find of a loose block of manganese-ore 3 furlongs east of Tirandur, a small village midway between Manda-

[1] *Loc. cit.*, p. 54.

gadde and Malur and some 14 miles south of Shankargudda. I do not know whether the deposit is on the Shankargudda band of schists, or on the band immediately to the west of the Shankargudda band.

IV.—The Channagiri Group.

With the exception of Sulekere, some 12 miles farther north, these deposits are all situated within a radius of not much more than a mile from the forest bungalow of Hoshalli, about 14 miles N. E. of Benkipur Station by road. The deposits to be noticed here are all on the southern side of the bungalow, and to the east of the road, which is a good one. The occurrence of manganese-ores in this area was noticed by Mr. Slater in 1904-05, [1] and Mr. Slater's map shows for this area schists, felspathic grit, limestone, quartz-porphyry, iron-ore, and manganese-ore. The deposits have been secured by the Shimoga Manganese Company. The ore is at present carted to Benkipur, but in future it is to be carried by a steam wagon constructed to carry 10 tons.

13. Sulekere.

A deposit of manganese-ore is said to exist on hill △ 2673 feet at the western end of Sulekere tank in the Channagiri taluk in the N. E. corner of the Shimoga district. It is 18 miles W. by S. of Sásalu station on the Southern Mahratta Railway, and is held on prospecting license by Mr. Subramania Moodaliar of Bangalore.

14. Gaddikalmatti.

This is a little peak about ¼ mile S. E. of a point on the road 46½ miles from Chitaldrug. The original outcrop on top of this hill was, judging from a small portion of it left, composed of the usual lateritoid mixture of iron- and manganese-ore. Its strike must have been about N. 15° W., this strike being indicated by a series of irregular excavations. These seem to have largely passed through the ore, the chief rock seen in them being a very soft quartzite, much impregnated and partly replaced by manganese oxide, and showing indications of a steep dip to the east side of the strike. The ores of this deposits consist largely of psilomelane, sometimes compact, and sometimes cavernous or cellular.

[1] *Op. cit.*, VI, Part II, p. 26, (1904-05).

In the cavities or cells there may be either remains of quartzite or radiate tufts of pyrolusite. Mixed with the psilomelane there is also pyrolusite, and a fair quantity of the grey crystalline mineral and some wad, besides limonite and yellow ochre, some of these constituents appearing in one piece of ore and others in other pieces. It seemed to me that the most important portion of the ore lay not in the cap on top, but in the detrital deposits on the slopes; and that from these a considerable quantity of ore might be won.

15. Buddamatti Peak.

This deposit is on a hillock situated a little to the east of the road to Chitaldrug at about 45¾ miles from Chitaldrug. There is here a lichen-covered lateritoid outcrop, which seems to be composed almost entirely of iron-ore—limonite, ochre, and hematite—and is probably 10-15 feet thick. By the side of this lateritoid outcrop there is a large irregular excavation indicating doubtfully a strike of west by a little north. The rock exposed is yellow ochre mixed with psilomelane, and containing big patches of pyrolusite. There is also some whitish lithomargic rock. The deposit was examined when it was getting dark, and so I am not able to express an opinion as to the quantity of ore.

16. Hoshalli.

This name is applied to three hills to the S. S. E. of the village of Hoshalli. Of these I visited one (No. 1) lying about 1¼ miles from Hoshalli. I chose this one, because, although it was said to be the least valuable of the three, a large trench had been dug. The ore here crops out on the edge of a sort of shelf some 500 feet below the summit of the hill, and some 150 feet above the forest lane at the base. The outcrop has the usual lateritoid aspect, and, judging from the trench, is some 15 to 20 feet thick. The lateritoid is a mixture of limonite, hematite, manganese-ore (mainly psilomelane), and brown cherty quartzite, the latter often predominating. The rocks exposed below this in the trench, which runs in a southerly direction down the hill slope, are many feet of wad, ochres, and lithomarges, often thinly banded, and with a dip of 10°-70° into the hill. They probably represent decomposed slates or phyllites with some quartzose layers. This deposit is not regarded as having any value and has not been worked.

17. Treasury Hill.

This is situated about ¼ mile south of Hoshalli No. 1. This name has been given to it on account of the find of some fine specimens of radiate pyrolusite lining cavities. This pyrolusite is rather hard and resembles closely the pseudo-manganite of the Sandur Hills. The mode of occurrence of the ores at this deposit is different to what I have seen at any other deposit in India. The ore consists of rather lead-like psilomelane, often intimately associated with a compact rather horny iron-ore of red colour, giving a red streak with a tinge of orange in it. This ore tends towards a limonite colour in places. I shall refer to it here as hematite. The most interesting section is seen in a trench cut in a N. N. E. direction at right angles to the strike of the rocks. The section shown in this trench was as follows, starting from the N. N. E. end :—

Black wad	12′	+
Psilomelane and hematite	3′	
Yellow ochre	7′	6″
Psilomelane with yellow ochre and some hematite .	2′	9″
Yellow ochre with indications of a band of the mixed iron- and manganese-ore	7′	9″
Psilomelane with some hematite	2′	
Yellow ochre	3′	7″
Psilomelane	0′	3″
Yellow ochre with signs of a psilomelane band . .	4′	2″
Manganese-ore (psilomelane and pyrolusite) . .	0′	4″
Yellow ochre	1′	+

The psilomelane is greater in quantity than the hematite in most of the bands. It also tends to occur in isolated concretions in the ochre, and there are sometimes concretionary projections from the ore-beds into the ochre. One of the bands of ore shown in the above trench is further exposed by a strike trench some 9 paces long as a vertical surface of ore showing slickensides grooving, and overturned sometimes to the south side and sometimes to the north. In the ore-stacks the ore is all in big lumps, and consists of mixtures of psilomelane with horny hematite, and some horny limonite ; it often contains big yellow ochre patches. Some pieces show some remains of quartzite; these must have been derived from a different part of the deposit. There is also some of the pisolitic ore.

V.—Shiddarhalli Group.

These deposits are situated in the south-east corner of the Shimoga district. Those near Shiddarhalli seem to have been first found by Mr. Slater, and to have been independently discovered by Mr. A. Ghose, agent for Messieurs Jambon & Cie., who hold the licenses for Nos. 20, 21, and 22. The deposit known as Kanikalmatti in the Kadur district really belongs to this group. The deposits near Shiddarhalli are only some 6 to 7 miles from Masarahalli station, Southern Mahratta Railway, whilst those near Gangur and Bhadigund are 4 to 7 miles further away, according to their situation.

18 and 19. Bhadigund and Gangur.

Mr. Slater records [1] the occurrence of iron-and manganese-ores in an area comprising some 2 to 3 square miles N. N. E. of Gangur. He says :—

'From △ 2740 (app.) northwards for a distance of two miles, extending along the crest of the ridge are numerous old workings. The material is of a hæmatitic, pisolitic, lateritic, manganiferous nature. Worked pits also extend along the northern spur of the hill $1\frac{1}{4}$ mile N.-E. of △ 2740 and are still more extensive on the W. N.-W. spur of the hill $\frac{1}{4}$ mile S.-E. of the deserted village of Bhadigund.

'The crest of this small hill carries the manganiferous jaspery quartzite, an extension of which may be found cresting the small hill, 1 mile N. 30° W. of Bhadigund.

'Other workings are found on the south spur of △ 2964 where a botryoidal ore occurs. Excavations in the hæmatitic manganiferous laterite were also observed on the south slope of the knoll 9 furlongs E. N.-E. of △ 2740 app.'

The hill △ 2740 is about 1 mile N. E. of Gangur village and the hill △ 2964 about 1 mile east of Bhadigund on the boundary between the Shimoga and Kadur districts. Mr. Slater also refers to the Gangur manganese-ores on page 26 of the paper cited. By the word lateritic used in the passages quoted above Mr. Slater probably refers to the same rock as I have called lateritoid. Mr. C. N. Surya Narayana Row of Bangalore holds a prospecting license over a deposit situated on the slope of hill △ 2740 on the Gangur side, and in September 1907 claimed to have extracted about 1,000 tons of ore. Two specimens he shewed me were :—(1) lead-like psilomelane, (2) light-grey psilomelane with numerous patches and specks of the light-grey crystalline mineral.

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[1] *Loc. cit.*, pp. 24, 25.

20. Kanjiganagutti (Shiddarhalli Main Deposit).

This deposit lies about ¾ mile due north of Shiddarhalli village on a little ridge situated on the eastern slope of a N. W.-running ridge of hills. This little ridge is capped by a lateritoid rock composed of a mixture of iron- and manganese-ores. The outcrop of this rock is about 95 paces long and runs first N. by a little W. and then N. N. E. It shows signs of a dip to the west side, this dip being doubtless that possessed by the rock from which the lateritoid has been formed by replacement. The deposit is held by Messieurs Jambon and Cie. and has been opened up by means of a series of parallel trenches at right angles to the strike of the ridge, and on its western slope. At the eastern end the trenches are sometimes as much as 18 to 24 feet deep and then show interesting sections. The following may be taken as typical and as indicating that the lateritoid has been formed by the replacement of some original argillaceous rocks such as slates or phyllites :—

5 feet. Lateritoid, composed in some places of the corneous hematite noticed at Treasury Hill (see page 1147), often with pisolitic spots of wad and psilomelane; and in some places entirely of the pisolitic lead-like psilomelane.

9 feet. Of psilomelane becoming waddy and ferruginous with increasing depth, and with patches of clay.

10 feet. The foregoing passes downwards in the next 10 feet into a mottled clay showing streaks and patches of red-brown clay in a soap-like, finely mottled, cream and brown clay. In this clay there are numerous veinlets and ring-shaped concretions tending to be limonitic and consequently harder than the associated clay, so that it looks as if this rock might turn into the overlying lateritoid by a continuation of the process of introduction of iron. Occasional patches of soapy wad are also still present. At the very bottom of the cutting, cream-coloured lithomarge, still mottled and streaked with the brown clay, begins to appear.

The cream-coloured clay or lithomarge seen at the bottom of the cutting shows when broken signs of original slaty structure, and so may be taken as representing an original slate or phyllite. The evidence of the foregoing section is I think very strong in favour of the lateritoid having been formed by the alteration of the original slaty or phyllitic rocks, with replacement by oxides of iron and manganese from the surface downwards. Another cutting showed a concretion of psilomelane about 10 inches in diameter, situated in the clay at a depth of 17 feet below the surface.

Some 200 tons of manganese-ore had been obtained from these excavations. The stacked ore seemed to be of fairly good quality, and consisted mainly of psilomelane varying from the dull grey to the lead-grey variety, and often showing signs of pisolitic character. There was also a little wad in some pieces.

21. Urumanjanmatti.

This is the name of the higher ridge referred to above, on the eastern slope of which the Kanjiganagutti deposit is situated. This ridge seems to consist, as far as seen, of quartzite that has been partially impregnated and replaced at the surface by oxides of iron and manganese, so as to produce the breccia-like mixtures of quartzite, iron-ore, and manganese-ore, that are so common on the outcrops of Dhárwár quartzites. The replacement of the quartzite has taken place along a network of lines, so as to isolate angular residual patches of the quartzite in the darkened portions of the rock, which have been either impregnated with or replaced by iron or manganese oxides. Nowhere did I see any manganese-ore worth the extraction. In one place, however, there is an old iron-working from which the natives of Shiddarhalli have obtained hematite for their iron-furnaces. This is the excavation referred to by Mr. Slater, [1] who was the first to notice the occurrence of manganese-ores on this hill. With regard to the origin of the iron- and manganese-ores of this hill, Mr. Slater makes the following remarks, [2] with which I cannot agree, however :—

'With the exception of the presence of chalcedony, an identical mode of occurrence of such quartz has been noticed in almost pure manganese. Whatever may be the mode of formation of the latter—and evidence points distinctly to its being a molten intrusion—such an origin must be ascribed to much of the laterite in the Shimoga District. The form of a mud lava is suggested on this hill and in the stream running in an E. 15 ° S. direction, one mile S. E. of Shiddarhalli, where we find pebbles of quartz, ferruginous quartzite, and manganese, caught up and bound together in a lateritic matrix.'

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[1] *Loc. cit.*, p. 23.
[2] *Loc. cit.*, p. 24.

In the first place I should not describe as laterite the brecciate rock noticed above, and in the second place I see no need for any theory of igneous origin to explain occurrences that are probably the result of the superficial replacement of rocks by means of aqueous solutions. This occurrence of manganese-ore is also held by Messieurs Jambon & Cie.

22. Ragikalvadikinakeri Bhaui Nagalagutti.

This deposit, also held by Jambon and Cie., is situated about ¼ mile S. E. of the Kanjiganagutti deposit, on nearly level ground at the east base of Urumanjanmatti Hill. It is a detrital deposit formed of pebbles and boulders of manganese-ore in a matrix of soil, and probably derived from the top of Urumanjanmatti by denudation. The existence of this detrital deposit indicates that formerly there must have been a considerable amount of marketable ore on the summit of Urumanjanmatti. Some 125 tons of ore had been extracted from a comparatively small area of this ground in the course of 2 weeks previous to my visit. The ore consisted largely of good hard grey psilomelane, with a certain proportion of lead-like psilomelane. Some of the ore contained minute crystalline specks, and some contained patches of the light grey crystalline mineral. The ore was being won in a systematic way by means of a series of parallel trenches (see page 565). I give the deposit the above lengthy name—the meaning of which would in English fill up about two lines of print—because there seems to be no other; it might be shortened to Nagalagutti.

Tumkur District.

The occurrence of manganese-ore in this district seems to have been known as far back as 1857, for 'good samples' of ore, similar to the 'silicated sequioxide' (*i.e.*, the braunite) of the Vizagapatam district, were sent from Tumkur to the Madras Exhibition of this year.[1] The exact locality, however, was not stated, and it was not till 1906, when the boom in the manganese industry lead to active prospecting for this mineral all over Mysore, that the actual position of any deposits seems to have been ascertained. In this year the Peninsular Minerals Company of Mysore, Limited, started work, and extracted 4,827 tons of ore during the year, 4,128 tons of which were railed. In 1907 the same company extracted 13,091 tons of ore.

[1] Reports by the Juries, p. 2.

The deposits all lie in the southern extension of the Chitaldrug or Dambal-Chiknáyakanhalli belt of Dhárwrá rocks; and all lie to the east and S. E. of Chiknáyakanhalli, within a radius of 12 miles. They are also all situated to the north of the Southern Mahratta Railway line from Birur to Bangalore. The stations to which the ore is carted are Bánasandra for most of the deposits, and Yelladbági for a few of them. The deposits can be divided into three groups:—

The Chiknáyakanhalli Group:—

1. Honnebági.
2. Hoshalli.

The Kárekurchi Group:—

3. Sondenhalli (Solid Hill mine).
4. Muskondli (Rowe's mine).
5. Kárekurchi (Camp mine).
6. Hattyál (Temple Hill mine).
7. Hárenhalli (Government Road mine).

The Kondli Group:—

8. Mávinhalli.
9. Kondli (Donkey mine).
10. Kondli (Government Hill).
11. Shivasandra (Dodguni).

The names given in brackets are those by which the deposits are known to the Peninsular Minerals Company. Of the deposits enumerated above, Nos. 1, 2, and 3, are in the Chiknáyakanhalli taluk, Nos. 5 and 6 in the Tiptur taluk, and the remainder in the Gubbi taluk. My visit to this area being limited to one day, I was able to visit the deposits of the Kárekurchi group only and consequently shall not refer further to the others.

It will be seen from the descriptions given below that the ores are very irregularly scattered through the rocks in which they occur, and that they are very much mixed with limonite, and residual patches of quartzites and argillaceous rocks. In fact their average quality cannot be high, probably not more than 42 to 45°/₀ Mn as despatched. They must also be fairly high in iron, but may, if well selected, be fairly low in silica, though there must be a tendency for this constituent to run to very high figures when pyrolusite-impregnated quartzites are mistaken by coolies for pyrolusite and mixed in with the other ores.

3. Sondenhalli (Solid Hill Mine).

This hill is situated about $1\frac{1}{4}$ miles W. by a little N. of Mávinhalli village. Several pits on the N. E. slope of the hill show yellow ochre with patches of pyrolusite and hard limonite. The dip seen in one place was about 60° to W. S. W. On the top of the next hillock to the N. W. of this one there is a lateritoid outcrop which, when broken into, often shows remains of quartz or quartzite, and in one place showed manganese-ore, this being impure psilomelane. In another place an opening in this lateritoid showed a considerable quantity of manganese-ore, consisting of a mixture of pyrolusite and psilomelane; frequently the ore contained patches of a soapy mineral, probably representing some phyllites of talcoid appearance seen close to the lateritoid. The rocks seen between this deposit and the Temple Hill mine some $2\frac{1}{4}$ miles to the south are banded ferruginous (magnetite and limonite) quartzites, often containing a fibrous amphibole, which is colourless under the microscope; and soft sericitoid phyllites. The dips in these rocks are sometimes to the east and sometimes to the west side of the strike, which is N. N. W.

4. Muskondli (Rowe's Mine).

This deposit is situated on low ground about a mile N. 15°E. of Kárekurchi village. A trench, deepened in places into small pits, shows rubble for the first 2 or 3 feet, and then below this wad and ochre with abundant residual patches of white quartzite. This quartzite is often seen partly replaced by manganese oxide and limonite. The small quantity of ore extracted consists mostly of cavernous pyrolusite, with occasional pieces of harder ore. Close to this excavation is an outcrop of quartz or quartzite partly replaced by limonite.

5. Kárekurchi (Camp Mine).

This is about $\frac{1}{2}$ mile E.10°N. of the village of the same name and is on very slightly elevated ground lying to the east of the range of hills in which Nos. 3 and 6 lie. The outcrop takes the forms of a lateritoid rock composed largely of limonite with patches of yellow ochre and rarer patches of manganese-ore. From the excavations, which have in one place reached a depth of 15 to 20 feet, it is seen that the ores occur in irregular patches, partly in this lateritoid rock of limonite and yellow ochre, and partly in the variegated mixture of wad, lithomarge, and ochre, that accompanies and underlies the harder lateritoid. In neither case does the proportion of manganese-ore seem to be high, but the mode of occurrence is such that at any moment pockets of good manganese-ore of some size may be encountered. The ores are both psilomelane and pyrolusite, and all the ores, both iron and manganese, often show remains of quartzite and vein quartz. There is little doubt that in this case also the ores have formed by the replacement of a series of interbanded quartzites and argillaceous rocks, probably originally phyllites. Some of the ores show concretionary structures, such as botryoidal and stalactitic shapes. In some stalactites there are concentric layers of limonite and psilomelane, the limonite coating the psilomelane. The limonite in these stalactites is sometimes very dark in colour and is then found to react for manganese, so that it is evidently a manganiferous limonite.

6. Háttyál (Temple Hill Mine).

This deposit is in a valley between two ridges about $\frac{3}{4}$ mile S. S. W. of Kárekurchi village. In the workings here there is a good section of white lithomarges and 'sandstones.' The former are banded with wad, whilst the latter are patched with pyrolusite. The ore won is usually pyrolusite, often with some wad, and occurs as patches in both the lithomarges and sandstones. The rock I have referred to as 'sandstone' breaks down into a white quartz sand on being handled. In all probability it is really a decomposed quartzite, and has become friable by the union between the separate grains of quartz being severed or loosened during the changes that have affected the whole of this series of rocks. Here again it seems probable that the ores have been formed by the impregnation and replacement of original quartzites and phyllites or slates, the latter rocks having been altered to lithomarges at the same time as the manganese-ores were deposited.

7. Hárenhalli (Government Road Mine).

This is situated just to the north of the 71st milestone on the Tumkur road. It is essentially similar to the Kárekurchi deposit and needs no separate description here.

CHAPTER XLII.

DESCRIPTIONS OF DEPOSITS—*concluded.*

North-West Frontier Province, Punjab, Rájputána and the United Provinces.

North-West Frontier Province—Kohát district.

Punjab—Jhang district—Kángra district—Lahore district—Patiála State.

Rájputána—Ajmere—Alwar State—Banswára State—Bundi State—Jodhpur State.

United Provinces—Mirzapur district.

North-West Frontier Province.

Kohát District.

In 1906 Amin Khán, one of the students at the Cawnpore Agricultural College, collected some geological specimens in the Kohát district, amongst which Pandit Tej Shankar Kochak, instructor in geology at this college, recognized manganese-ore.

The specimen sent to the Geological Survey Office is a small black flattish concretion about 1¼ inches in diameter, which under the microscope is seen to be the result of the impregnation and partial replacement of a limestone by oxide of manganese.

According to the information received, the locality from which the specimen was obtained is Tajut Hill near Ibrahim Zai in the Hangu tahsil of the Kohát district, and 'on the western side of this hill, in the middle zone, there is an outcrop of a bed, which contains innumerable pieces of this ore'.

The hill referred to is presumably the one shown on the Atlas sheet as situated 2 miles to the south of Ibrahim Zai, and named 'Taghoot Sir'. This, according to A. B. Wynne's geological map of this area, consists of nummulitic limestone.

It is not probable that the occurrence is of much, if any, economic value.

Punjab.

Jhang District.

In the Kirána Hills, which are composed largely of quartzites with clay slates and are probably of Arávalli age, Dr. A. Fleming [1] found pyrolusite 'filling small cracks in the sandstone of some small specimens.'

Kángra District.

Mr. Marcadieu [2] reports the find, during the construction of a canal at a point 4 miles N. W. of Dharmsála, of crystals of a mineral that 'approaches by its composition and crystalline form to .... marcelline' (an impure form of braunite), the nidus being a ferruginous and manganiferous siliceous limestone. Judging from the map of this area by H. B. Medlicott [3], this limestone must be the Krol limestone. Mr J. Calvert [4] mentions pyrolusite in his list of minerals from Kulu. It should also be noted that Newbold, as early as 1840, mentioned the occurrence of manganese associated with iron in the Himálayas [5] and was possibly referring to this district.

Lahore District.

Mr. Baden H. Powell says that manganese is found in the Lahore bazaar as a binoxide (peroxide), called 'jugní' or 'missí siya' [6]. In another place he calls it 'nijní' or 'injaní (or inganí)' [7], and says that it is principally used at Lahore to remove the colour of glass containing iron and is said to be imported from Kashmir and Kábul [8]. Balfour [9] says that manganese occurs in the bazaars of the Punjab 'in the form of a silicated sesquioxide and a peroxide'.

Patiála State.

Mr. P. N. Bose [10] records the existence about Goela, Durga ka Nangal, etc., in the Narnaul district of this State, of extensive deposits

1 *Sel. Pub. Corr. Punjab*, II, No. x, p. 362, (1854); *Jour. As. Soc. Beng.*, XXIII, p. 94, (1854).
2 *Sel. Pub. Corr. Punjab*, II, No. vii, p. 4, (1854).
3 *Mem Geol. Surv. Ind.*, III, Pt. 2.
4 Kulu: its beauties, etc., pp. 91 and 92, (1873).
5 *Mad. Jour. Lit. Sci.*, XI, p. 45.
6 Punjab Products, I, p. 25, (1868).
7 *Ibid.*, p. 100.
8 *Ibid.*, p. 113.
9 Cyclopædia of India, III, p. 128, (1873).
10 *Rec., Geol. Surv., Ind.*, XXXIII, p. 58, (1906).

of limestone and shale impregnated with manganese oxide. Some specimens brought to the Geological Survey Office consisted of limestone largely replaced by soft black manganese oxide, and scattered through the limestone were remains of a mineral that could not be with certainty identified, but which was probably an amphibole, in which case the original rock was an amphibolitic limestone. In none of the specimens, however, had the replacement advanced far enough to give them the commercial importance which Mr. Bose supposes them to possess, except perhaps for local use as a colouring medium for glasses and enamels.

Rájputána.

Ajmere.

In the Geological Survey Museum are specimens of stalactitic psilomelane with limonite,[1] from Ajmere, while recently a specimen of pyrolusite said to represent a deposit of this mineral has been sent to the Geological Survey by Mr. R. D. Kanga. It was found near Kharwa.

Alwar State.

According to Mr. C. A. Hacket [2] large quantities of iron-ore exist at two places near the base of the Arávalli series, one near Bhangarh and the other near Rájgarh. Judging from the workings, which are several hundred yards long and in places 20 to 30 wide, an immense quantity of iron must have been produced from these mines. He then says that an ore from Bhangarh that was a mixture of limonite, magnetite, and oxide of manganese, contained 59·67% of iron and 12·7 of manganese. If this ore be representative of the Bhangarh ores then there must be at this place large deposits of manganiferous iron-ore. In this case one would expect the iron made by the natives to be of a superior quality like the *kheri* of Ghogra in the Jabalpur district, Central Provinces; but on this point there is no information.

Banswára State.

Manganese-ores have been found in this State by Messrs. Kiddle, Reeve and Co. of Bombay. The localities are Itala, Sagwa, Ghatia,

[1] F. R. Mallet, Mineralogy, p. 61, (1887).
[2] *Rec. Geol. Surv. Ind.*, X, p. 91, (1877): *Ibid*, XIII, p. 248, (1880).

Khunda, Sivonia, and Garadia, good ore being found at Khunda and Sivonia; but the amount is not known. A specimen sent by Mr. H. J. Winch showed some prismatic crystals of pyrolusite on manganese-ore composed of a fine-grained mixture, probably of braunite and psilomelane. A complete analysis of picked crystals of the pyrolusite by Mr. C. S. Fawcitt is given on page 82. This shows :—

Manganese	61·68
Iron	0·02
Silica	0·41

and is hence exceptionally pure pyrolusite, the percentage of MnO_2 being 97·04, the highest yet found in any Indian pyrolusite.

Bundi State.

Small veins of oxide of manganese occur in fault-rock near Datunda; according to Mr. Hacket these have not been worked. [1]

Jodhpur State.

A specimen sent to the Geological Survey Office by Major F. C. Hughes turned out to be partly-altered rhodonite. The locality was given as near Haripur, Jodhpur State.

United Provinces.

Mirzapur District.

A specimen of rhodonite was obtained by Mr. F. R. Mallet [2] from a *lohari*, who found a quantity of it a foot or two beneath the surface, in the southern part of this district.

[1] V. Ball, Economic Geology, p. 331, (1881).
[2] Mineralogy, p. 84, (1887).

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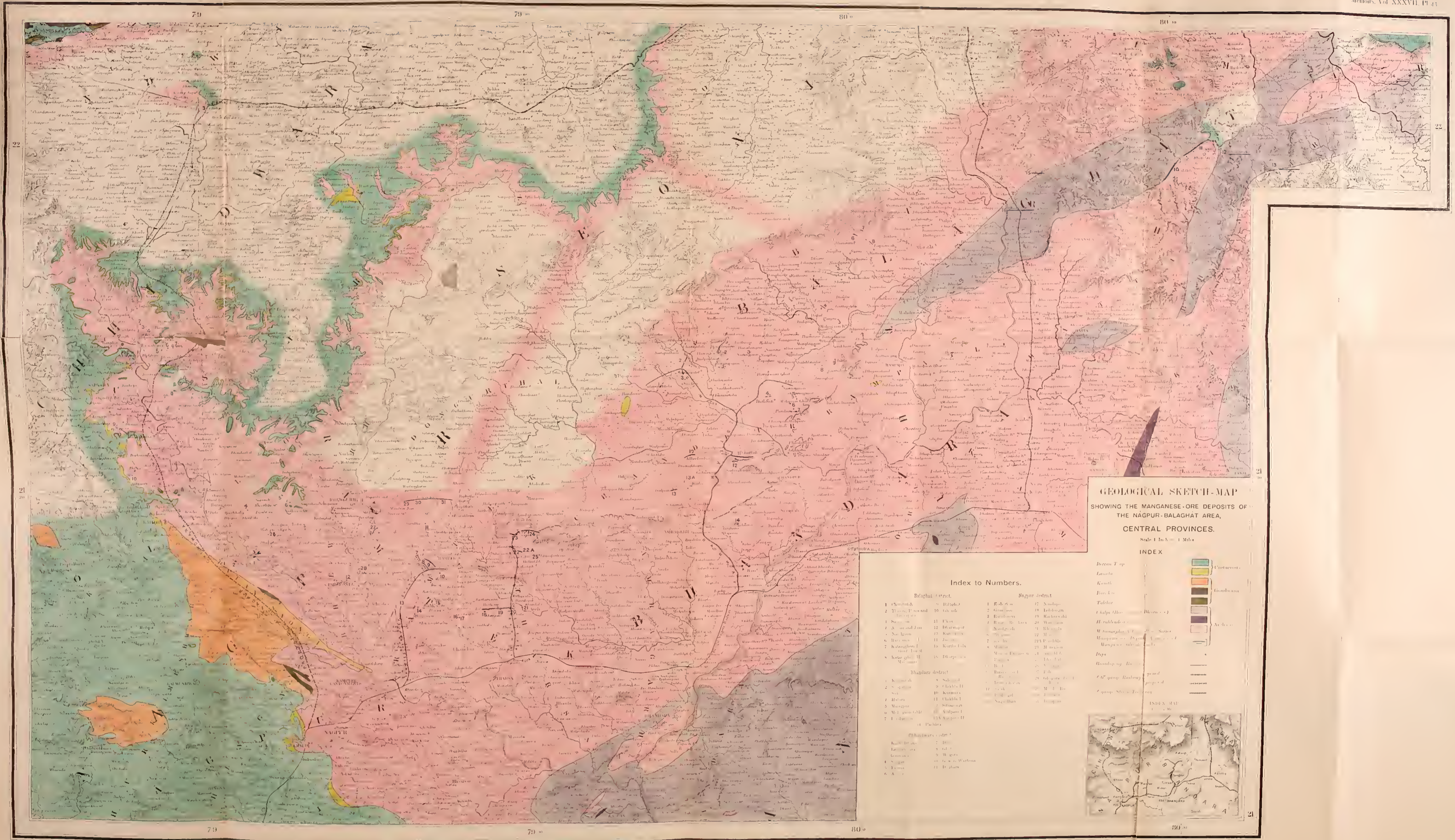

Geology compiled from the maps of W. T. Blanford, P. N. Bose, P. N. Datta, L. L. Fermor, E. J. J[illegible] & L[illegible] Kishen Singh.

THE

MANGANESE-ORE DEPOSITS OF INDIA

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APPENDIX II.

GEOGRAPHICAL INDEX.

This index contains only the Indian localities. The foreign ones mentioned in the text are given in the general index. And of the Indian localities this index contains as a rule only the smaller geographical units, such as villages, towns, nálás, rivers, and hills. Such larger units—*e.g.* districts, provinces, large rivers, and mountain ranges—as are sufficiently well-known not to require specification by means of geographical co-ordinates are given in the general index. In cases where several page references are given to one locality the more important ones are usually printed in **heavy type**. In particular, the description of a deposit is usually indicated thus. In a few cases I have been unable to locate the place mentioned, and so to give the geographical co-ordinates.

Locality.	Latitude.		Longitude.		Page.
	°	′	°	′	
Alada-marada Banda, *Sandur* .	15	0	76	40	1002-3, 1013-4, 1028—30, 1031.
Alada-marada Haruvu—*see Kamátaru.*	..		..		1003.
Aladhalli, *Shimoga* . . .	14	2	75	41	1133-4, 1142.
Alesur, *Chhindwára* . .	21	43	78	57	141, 790, 792.
Allahabad, *Allahabad* . .	25	26	81	54	241, 397.
Alwar, *Alwar* . . .	27	33	76	40	1157.
Ambagarh, *Bhandára* . .	21	26	79	44	313, 733-4.
Amla, *Chhindwára* . . .	21	46	78	54	779.
Amlamál, *Jhábua* . . .	23	0	74	27	679, 689.
Anantapur, Shimoga . .	14	5	75	16	1134.
'Annapangree Nullah' — *see* Muggurkutta Nálá.	..		..		698, 741-2.
Anne-marada Gadda—*see* Kamátaru.	..		..		1003.
Anu, Jaunsar, *Dehra Dun* .	30	52	77	52	122.
Arjoni, *Bálághát* . . .	21	46	79	57	426, 695, 706-8.
Ásalpáni I, *Bhandára* . .	21	30	79	43	139, 141, 346, 734-6, 763-4, 933.
Ásalpáni II (Kárli), *Bhandára* .	21	31	79	44	141, 346, 397, 426, 437, 460, 735, 765-7.
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Part 1.—Annual report for 1885. International Geological Congress of Berlin. Palæozoic Fossils in Olive group of Salt-range. Correlation of Indian and Australian coal-bearing beds. Afghan and Persian Field-notes. Section from Simla to Wangtu, and petrological character of Amphibolites and Quartz Diorites of Sutlej valley.

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Part 1.—Annual report for 1886. Field-notes from Afghanistan : No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traversed through Jaunsar-Bawar and Tiri-Garhwal. Geology of Garo Hills. Indian image-stones. Soundings recently taken off Barren Island and Narcondam. Talchir houlder-beds. Analysis of Phosphatic Nodules from Salt-range, Punjab.

Part 2.—Fossil vertebrata of India. Echinoidea of cretaceous series of Lower Narbada Valley. Field-notes : No. 5—to accompany geological sketch map of Afghanistan and North-Eastern Khorassan. Microscopic structure of Rajmahal and Deccan traps. Dolerite of Chor. Identity of Olive series in east with speckled sandstone in west of Salt-range in Punjah.

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Part 4.—Indian fossil vertebrates. Geology of North-West Himalayas. Blown-sand rock sculpture. Nummulites in Zanskar. Mica traps from Barakar and Raniganj.

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Part 1.—Annual report for 1888. Dharwar System in South India. Wajra Karur diamonds, and M. Chaper's alleged discovery of diamonds in pegmatite. Generic position of so-called Plesiosaurus Indicus. Flexible sandstone or Itacolumite, its nature, mode of occurrence in India, and cause of its flexibility. Siwalik and Narbada Chelonia.

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Part 1.—Annual report for 1890. Geology of Salt-range of Punjab, with re-considered theory of Origin and Age of Salt-Mart. Graphite in decomposed Gneiss (Laterite) in Ceylon. Glaciers of Kabru, Pandim, etc. Salts of Sambhar Lake in Rajputana, and 'Reh' from Aligarh in North-Western Provinces. Analysis of Dolomite from Salt-range, Punjab.

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Part 4.—Mammalian Bones from Mongolia. Darjiling Coal Exploration. Geology and Mineral Resources of Sikkim. Rocks from the Salt-range, Punjab.

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Part 2.—Earthquake in Baluchistan on 20th December 1892. Burmite, new amber-like fossil resin from Upper Burma. Alluvial deposits and Subterranean water-supply of Rangoon.

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Part 1.—Annual report for 1893. Bhaganwala Coal-field, Salt-range, Punjab.

Part 2.—Petroleum from Burma. Singareni Coal-field, Hyderabad (Deccan). Gohna Landslip, Garhwal.

Part 3.—Cambrian Formation of Eastern Salt-range. Giridih (Karharbari) Coal-fields. Chipped (?) Flints in Upper Miocene of Burma. Velates Schmideliana, Chemn., and Provelates grandis, Sow. sp., in Tertiary Formation of India and Burma.

Part 4.—Geology of Wuntho in Upper Burma. Echinoids from Upper Cretaceous System of Baluchistán. Highly Phosphatic Mica Peridotites intrusive in Lower Gondwana Rocks of Bengal. Mica-Hypersthene-Hornblende-Peridotite in Bengal.

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Part 1.—Annual report for 1894. Cretaceous Formation of Pondicherry. Early allusion to Barren Island. Bibliography of Barren Island and Narcondam from 1884 to 1894.

Part 2.—Cretaceous Rocks of Southern India and geographical conditions during later cretaceous times. Experimental Boring for Petroleum at Sunkur from October 1893 to March 1895. Tertiary system in Burma.

Part 3.—Jadeite and other rocks, from Tammaw in Upper Burma. Geology of Tochi Valley. Lower Gondwanas in Argentina.
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VOL. XXIX, 1896.

Part 1.—Annual report for 1895. Acicular inclusions in Indian Garnets. Origin and Growth of Garnets and of their Micropegmatitic intergrowths in Pyroxenic rocks.
Part 2.—Ultra-basic rocks and derived minerals of Chalk (Magnesite) hills, and other localities near Salem, Madras. Corundum localities in Salem and Coimbatore districts, Madras. Corundum and Kyanite in Manbhum district, Bengal. Ancient Geography of "Gondwanaland." Notes.
Part 3.—Igneous Rocks from the Tochi Valley. Notes.
Part 4.—Steatite mines, Minbu district, Burma. Lower Vindhyan (Sub-Kaimur) area of Sone Valley, Rewah. Notes.

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Part 2.—Cretaceous Deposits of Pondicherri. Notes.
Part 3.—Flow structure in igneous dyke. Olivine-norite dykes at Coonoor. Excavations for corundum near Palakod, Salem District. Occurrence of coal at Palana in Bikanir. Geological specimens collected by Afghan-Baluch Boundary Commission of 1896.
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