MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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Dr. F. H. Hatch.

Photogravure

Survey of India Offices, Calcutta, December, 1900.

FOLDED CALCITE STRINGERS IN "COUNTRY ROCK".

Photographed by T. H. Holland.

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INTRODUCTION.

As a field for the scientific study of the geology of vein-deposits or for an enquiry into the technical processes of gold-recovery, the Kolar gold mines have, perhaps, exceptional advantages. The lodes show in full clearness the characteristic phenomena of quartz veins, such as the limitation of the pay-ore to well-defined "chutes", and present in addition unusual and interesting structural features, such as the formation of enriched and enlarged zones of pay-ore along folds in the plane of the vein; while both underground and on surface the mining properties are sufficiently equipped with plant and machinery for the successful exploitation and metallurgical treatment of this class of gold ores.

Modern mining at Kolar dates from the year 1881; but long before that the search for gold, and no doubt its successful exploitation, had been conducted by ancient native miners, as is abundantly testified by the existence of extensive old workings, some of which were carried to a depth of close on 300 feet. In this fact, as well as in general geological features, the field bears a striking resemblance to the Gold Districts of Rhodesia in South Africa. There, as here, the gold occurs in "chutes," of comparatively limited extent, in veins of dark-coloured quartz and are confined to belts of hornblende schist occurring in an area of ancient gneisses and granites ; and there, as here, present mining operations have been invariably started on the site of the ancient excavations and piles of débris known as "old workings."[1]

Since the commencement of modern mining the Kolar gold-field has enjoyed, after the difficulties usually associated with the starting of new mining enterprizes were once overcome, a steady growth and development. It has produced, during the period that has elapsed since that date, gold to the value of 11½ millions sterling, and has paid dividends amounting to close on 5 millions.

In the following report, which I have undertaken at the request of the Government of India, my endeavour has been to present as accurate a picture as possible of the present development of the field and to indicate along what lines further progress may be expected.

Without the assistance of others I could have accomplished little, and I have great pleasure, firstly, in acknowledging the courtesy with which Messrs. John Taylor & Sons, the London Managers of the great majority of the Kolar properties, have afforded me access to the mines and works under their control ; secondly, in thanking the Superintendents, Engineers and other Officers of the mines for their many friendly services. Especially must I mention in this connection the following names :—Mr. R. Bullen, Superintendent of the Ooregum Mine, Mr. R. Hancock, Superintendent of the Mysore Mine, Mr. F. Hosking, Chief Engineer of the Mysore Mine, Mr. H. A. Leslie, Cyanide Chemist to the Mysore Mine, Mr. T. E. Piercy, Chief Engineer of the Champion Reef Mine, Mr. T. Richards, Superintendent of

[1] The striking resemblance described above, taken in conjunction with the intimate geological connection known to exist between South Africa and Southern India, makes it seem likely that a correlation may be established between the ancient granite-gneisses with their gold-bearing schist belts of Rhodesia, and the gneissose rocks and associated Dharwar beds of Mysore.

the Nundydroog and Balaghat Mines and Captain James Rowe, Superintendent of the Champion Reef Mine. I have further to express my indebtedness to Mr. W. F. Smeeth, the head of the Mysore State Geological Department, who most kindly placed at my disposal the valuable resources of his department in regard to maps,[1] specimens and rock-sections; also to Mr. Pigott, Conservator of Forests in Mysore, to Mr. J. Cameron, the Superintendent of the Lal Bagh at Bangalore, and to Dr. G. Watt, the Reporter on Economic Products to the Government of India, for their assistance in identifying the various timbers in use on the Kolar gold-field.

In the statistics with which this report has been furnished as fully as possible, the Imperial or long ton of 2,240lbs. has been used throughout; and the Rupee has been taken at 1*s.* 4*d.* or R15 to the pound sterling. The returns of output, revenue, profits, etc., are complete to the end of June 1900.

A general plan of the Kolar mining properties is given on Pl. 20.

[1] See Pl. 21.

CHAPTER I.

GENERAL GEOLOGICAL DESCRIPTION OF THE FIELD.

THE belt of schists in which the quartz veins of the Kolar gold-field occur is a part of the great group of Transition Rocks. This and other similar schistose belts were first separated by Bruce Foote [1] from the old gneisses with which they had till then been classed, and given the name "Dharwars" or "Dharwar System" on account of their occurrence in typical development in the Collectorate of Dharwar, Bombay Presidency.

Bruce Foote described the Kolar schistose band as a "synclinal trough resting on the adjacent granite-gneiss rocks;"[2] but although it may be true that the Dharwar schists are younger than the bulk of the granite-gneisses, recent work of the Mysore Geological Department shows that the stratigraphical relations of the two systems are obscured by a later intrusion of granite along the margin of the schist belt. If reference be made to the geological map (Pl. 21) which is the result of the recent labours of the Mysore State Geological Department, and which has been kindly placed at my disposal by Mr. W. F. Smeeth, the present head of that Department, it will be seen that the schist belt is invaded on both sides by granitic intrusions.

The "granite-gneiss" is divided by the Mysore Geological Department into three types: (1) the grey gneiss with marked banded structure and dark basic segregation veins and patches, consisting chiefly of biotite and hornblende, these minerals being also characteristic of the gneiss itself; (2) an older prophyritic

[1] "Report on the auriferous tracts in Mysore." Selections from the Records of the Mysore Government, Bangalore. Mysore Government Press, 1887, p. 1, and Rec. Geol. Surv. Ind., Vol. XXI, p. 40, 1888

[2] Notes on a traverse across some gold-fields of Mysore. Rec. Geol. Surv. Ind., Vol. XV, Part 4, 1882, p. 193.

granite; (3) a younger intrusive granite which is certainly later than the schists, as it is intrusive in them in their western border. The proportion in which these three types are represented in the area under description will be seen by reference to the map (Pl. 21). For petrographical details see the appendix to this report.

The schist belt strikes north and south and extends to Srinivaspur, about 30 miles north of the Mysore Mine at Marikuppam; while to the south it has been traced for about 20 miles and passes into the Madras Presidency.[1] In width it is variable, being of lenticular character. In the widest places it measures about 4 miles across and in its narrowest about $\frac{3}{4}$ of a mile. At Yerrakonda, a prominent-hill about 3 miles south of Marikuppam station, the schists split into two bands separated by the older granite; and 10 miles further south, a similar separation is found. Its synclinal character is only indicated by a converging dip from opposite sides of the belt; the dip on the west side being to the east and on the east and in the central zone, to the west. The bulk of the beds consists of hornblende schist, but near the western margin runs a ridge of ferruginous and jaspery quartzite much crumpled and brecciated in places. The quartzite beds dip under the hornblende schist and are succeeded by a band of mica schist which separates them from the granite-gneiss.

This quartzite ridge can be followed along the western border of the schist belt until it rises into the peak of Malapakonda, 9 miles south of Marikuppam. On the eastern side the only place where the quartzite may be seen is at Yerrakonda, 3 miles south of Marikuppam, where the beds crop out with a westerly dip. These banded hornstones and ferruginous quartzites are a common feature of the lower beds of the Dharwar formation.[2] The iron is present partly in the form of magnetite, partly as hematite.[3]

Along the eastern margin of the schist belt north of Yerrakonda (*e.g.*, at the village of Marsika, east of Marikuppam, and at Pedpalli,

[1] Report on the Kolar Gold-field and its Southern extension, by P. Bosworth-Smith. Madras, 1889.

[2] Manual of the Geology of India, 3rd edition, p. 49.

[3] See appendix for an analysis made by Mr. T. H. Holland.

east of the Coromandel Mine) a remarkable rock, having the appearance of a conglomerate, outcrops. Imbedded in a fine black hornblende matrix, in which a marked pseudo-flow structure is perceptible, are sub-angular "boulders," "pebbles" or fragments of a granitic rock. A striking feature is the often elongated or rod-like form and rude parallelism of the fragments and further their tendency to tail off into streaks and veinlets of pegmatite or quartz. The tendency to elongation has been ascribed in other Dharwar conglomerates to a deformation of the pebbles;[1] but it appears almost certain that at Kolar the reverse is the case, namely, that the pseudo-pebbles have been formed by the deformation of granite veins occurring in a schistose rock; or, in other words, that we have here to do with a fine example of dynamic or autoclastic conglomerates, similar to those described by Barlow[2] and others as occurring among Archaean rocks in Central Ontario. According to Barlow "the supposed conglomerates were in reality autoclastic rocks and the so-called pebbles extremely deformed portions of a series of more or less parallel dykes, evidently highly differentiated apophyses of the neighbouring plutonic mass." This explanation of the origin of the supposed conglomerates seems quite applicable to the present case.

The hornblende schists which make up the bulk of the Dharwar formation at Kolar consist mainly of altered trap-flows of basic composition and as such may be termed epidiorites. Under the microscope several good examples of well-defined ophitic structure such as characterize diabase rocks are found; but, of course, the original augite has in every instance been completely altered to green uralitic hornblende. The felspars retain their original lath-shaped character, but their substance is altered to a granular aggre-

[1] Manual of the Geology of India, 3rd edition, p. 49.

[2] A. E. Barlow "On the Origin of some Archaean Conglomerates." Geological Society of America. New York, December 28, 1898. *See* also Van Hise, 16th Annual Report, U. S. Geological Survey, pp. 679, 894-95.

The term "autoclastic" is defined as applicable to rocks which "have formed in place from massive rocks by crushing and squeezing without intervening processes of disintegration or erosion, removal, and deposition."

gate of secondary minerals. In a few cases the felspars are of a porphyritic character occurring in longish crystals with well preserved rectangular boundaries. Ilmenite or titaniferous iron-ore, with its accompanying alteration-product—leucoxene, is plentifully distributed in many of the rocks. In the near neighbourhood of the quartz lodes a characteristic brown mica is abundantly developed, and so much so is this the case that its plentiful occurrence may be regarded as an indication of the near presence of a lode. It appears probable that this brown mica is genetically connected with the mineralization of the lodes, whether by vapours from below or by ascending mineralizing solutions.[1] While touching on this point it may be pointed out that the suggestion made by Dr. W. J. Evans[2] that the quartz lodes of the Kolar gold-field are not veins, but interbedded seams of true metamorphic quartzite of similar origin to the Witwatersrand beds of the Transvaal, must be rejected. There is not the slightest indication of such an origin or of any resemblance to the Rand conglomerates. The Kolar deposits are typical quartz veins and can only be termed bedded in so far that the quartz has been deposited from mineralizing solutions along the foliation planes of the schists in which they lie.

In addition to true epidiorites, *i.e.*, hornblende schists, which are undoubtedly derived from basic igneous rocks of diabasic character, there are others in which no igneous structure is apparent and which Mr. Holland suggests may possibly be derived from basic ash beds associated with the trap-flows.

The latest rocks in the geological tract under description are the basic dykes which traverse the schist belt and granitic rocks, generally transversely or east and west, but also occasionally north and south. These dykes vary in width from a few feet up to over a hundred feet and are frequently encountered underground in the

[1] Mr. Holland suggests (*vide* appendix) that the brown mica has been produced by deep-seated vapours attacking the hornblende and supplying the requisite amount of water and alkalies.

[2] Rec. Geol. Surv. Ind., Vol. XXIX (1896), p. 82, and Vol. XXX (1897), p. 2.

course of mining operations. They are typical unaltered dolerites or diabases evidently of much more recent origin than the rocks in which they are intruded. Under the microscope they are seen to consist of fresh lath-shaped felspars and granular augite in approximately equal proportion. They closely resemble the dyke-rocks described from other parts of Southern India, which are regarded by the Geological Survey of India [1] as underground representatives of the Cuddapah lava-flows.

The specimens collected by me in the field were sent to the office of the Geological Survey in Calcutta where they were cut and examined under the microscope by Mr. T. H. Holland, officiating Superintendent of the Geological Survey. His notes are appended to this report. Thanks to the kindness of Mr. W. F. Smeeth, acting State Geologist to the Mysore Government, I have also had the privilege of examining the collection of rock-slides made from specimens collected by the officers of the Mysore Geological Department.

[1] Rec. Geol. Surv. Ind., Vol. XXX (1897), p. 16, and Quart. Journ. Geol. Soc., Vol. LIII (1897), p. 405.

CHAPTER II.

THE LODES.

THE auriferous lodes of the Kolar gold-field consist of a series of parallel quartz veins occupying a central position in the belt of Dharwar schists and striking north and south, *i.e.*, in the direction of the foliation of the beds in which they lie. The dip also, which is about 50°—55° west, is, in the main, that of the schistose beds. Consequently these deposits may be regarded as bedded veins, or in other words, as having been formed by the deposition of quartz and other minerals from solution along open channels or planes of weakness which in general coincided with the foliation of the schists. To this fact must be ascribed their marked lenticular character, for both in the direction of strike and of dip they are found to swell and pinch at irregular intervals in conformity with the foliation of the schists.

Although there are on the Kolar gold-field several parallel veins, *e.g.*, the Champion lode, Mundy's lode, the West Balaghat lode, the Oriental lode, etc., it is on the Champion lode that the paying mines have alone been developed, and it is therefore to this lode that I shall devote particular attention in the following notes.

The mines at present working on the Champion lode are:—the Mysore, Champion Reef, Ooregum, Nundydroog, Tank Block (Mysore West and Mysore Wynaad), Coromandel and Balaghat. Those working on the West Balaghat and Oriental lodes are the "Gold-fields of Mysore," Nine Reefs and Road Block. The situation of these properties is shown on the accompanying plan (Pl. 20) which I have prepared from material furnished by the companies.

The quartz of the Champion lode is of a dark bluish-grey colour with vitreous lustre, and irregular to sub-conchoidal fracture. In those places, however, where the deposit has been subject to great stress consequent on the bending of the vein into acute folds, as will be explained later on, the quartz has the appearance of a subtranslucent hornstone or flint with a well developed banded or laminated structure. As a rule, gold is not visible in the hand-specimen, still specimens containing "visible" gold are not infrequently found on the picking floors. In such specimens the gold occurs in small seams and is disclosed in scaly and granular aggregates on the two faces produced by breaking the rock along such a seam. It is of a rich yellow colour and of great purity, the average fineness of the gold being about 920 parts in 1,000. Where *slickensides* have been formed by differential movements in the vein, the gold sometimes occurs as a fine film on the slickensided surface.

Associated with the gold in the quartz are the following minerals:—*iron pyrites*, *magnetic pyrites* (*pyrrhotite*),[1] *arsenical pyrites* (*mispickel*) *blende*, *galena* and *copper pyrites* (*chalcopyrite*); but in the Champion lode the average amount of pyritic and other heavy metallic minerals probably does not amount to more than one quarter per cent.[2] Other minerals occurring in close connection with the lode deposit are *green hornblende* (*actinolite*), the chief constituent of the schistose "country rock"; *pale-green pyroxene* sometimes occurring in bands in the quartz; *brown mica*, usually occurring in great abundance in the immediate neighbourhood of the lode, and no doubt an alteration product of the hornblende effected probably by the same agencies as gave rise to the vein formation; *calcite*, an alteration product occurring in small seams in the hanging

[1] Mr. Holland informs me that he found nickel in the specimen of pyrrhotite I sent him from the Champion Reef Mine.

The chemical analysis was—

Sulphur	40·05 %
Iron	58·16 ,,
Nickel	1·84 ,,
	100·05 ,,

[2] A concentrate made by panning quartz from the Ooregum Mine contained a mixture of pyrite minerals, amongst which were mispickel and a whitish metallic mineral containing both cobalt and nickel. The concentrate on analysis yielded about 1½ per cent. of mixed oxides of nickel and cobalt according to an analysis made by Dr. Walker in the laboratory of the Geological Survey.

wall rock near the lode and, owing to the liability of the rock to break along these seams, a common cause of "heavy ground" and falls of rock (especially in the Ooregum Mine); *chlorite*, an alteration product of the hornblende, sometimes found in films in the quartz itself (Nundydroog Mine); *epidote*, another alteration product, associated with the calcite (Mysore Mine). *Fibrous asbestos* associated with a clayey matter occurs as a casing to the lode, and where this is the case the quartz is often replaced by a brown or green *opaline variety of silica* (Nundydroog and Champion Reef Mines). In the Champion Reef Mine small veins of black fibrous *tourmaline* are occasionally found, similar to that already described by Judd[1] from Kolar. The quartz of the Oriental vein worked by the Nine Reefs and Road Block Companies contains a much higher percentage of pyritic constituents (iron pyrites, pyrrhotite and mispickel) than the Champion lode and consequently is more refractory to treat. The West Balaghat, on the other hand, is more allied to the Champion lode as regards its freedom from base minerals.

As has already been remarked, the veins follow the foliation of the schist beds, in places bulging to big bodies (*e.g.*, 30 to 40 feet wide in Crocker's chute, Mysore Mine), in other places thinning to mere stringers. The walls of the lode are, as a rule, well-defined, especially where the quartz occurs in one solid vein; and the separation of the lode from the country rock is easily accomplished. But in places the vein is split into numerous small stringers alternating with layers of the country rock; the whole width of ore-body has then to be stoped in the mines and the waste country rock picked out afterwards on the sorting floors. In such places the stoping width may be considerable, although the pay quartz remaining after the valueless country rock or "waste" has been picked out on the sorting floors, is only perhaps 30 to 50 per cent. of the ore broken down in the stopes. This is more especially the case in the mines situated in the northern part of the field (Coromandel, Balaghat, Road Block, Nine Reefs).

[1] Min. Mag., Vol. XI, pp. 61—63 (1895).

Apart from the fact that the pay-ore occurs in limited sections ("chutes") separated by zones of barren ground, and that there are occasional small branches or splits in the vein, the Champion lode runs a fairly steady and uniform course through the Mysore, Champion Reef and Ooregum properties. North of the latter, however, the lode begins to show signs of disturbances, which are either due to faulting or to the separation of the vein into several parallel branches. Thus the Nundydroog Company works two sections of lode, lying about 300 feet apart: the main Champion lode extending from the south boundary to about half-way through the property, where it dies away to small stringers, and the so-called Kennedy's lode, which is about 300 feet to the east, and worked only in the northern section of the property. Whether this is a case of faulting or of branching in the lode has not yet been determined. It may be that Kennedy's lode is a continuation of a branch that splits off in the Ooregum Mine and is there known as the East lode.

In the Tank Block, development work has been confined to Kennedy's lode, but in the Coromandel we again find developments on two lodes separated by about 500 feet, that worked in the southern portion of the property being supposed to be the continuation of Kennedy's lode and that in the northern portion, the continuation of the Champion lode.

In Balaghat, the next property to the north, the easterly or Kennedy's lode, although traceable at the surface has not been opened, the main developments being on the Coromandel or supposed Champion lode. But the problem is still further complicated by the appearance of a third branch or off-shoot which is marked by a line of old workings about 500 feet west of the Coromandel lode. This lode is in course of development by levels driven from a new vertical shaft (Tennant's) which cuts the vein at 285 feet. North of the Balaghat none of the off-shoots of the Champion lode have as yet been proved payable although trial pits have been sunk to test them on the Road Block property; but that company, and its neighbour the Nine Reefs, are at present devoting themselves to an extensive trial of the more westerly veins, the Oriental and West Balaghat lodes.

South of the Mysore Mine the Champion lode is ill-defined and broken, and although considerable prospecting work has been done by the Kempinkote, Mysore Reefs and Yerrakonda Companies to locate a payable section on the southern extension of the lode, no favourable discoveries have as yet resulted.

An interesting feature of the mines are the folds along the axes of which particularly large and valuable bodies of ore are found. In these folds the vein is doubled back on itself, the axis of the fold having a northerly dip in the plane of the vein. This may be illustrated by making a fold or pleat diagonally across a rectangular sheet of paper. If the paper be held with the edge horizontal and directed north and south to represent the outcrop of the vein and the plane of the paper be inclined at a steep angle to the west to represent the "underlie" of the lode, the pleat running from the top south corner to the bottom north corner of the paper will very faithfully represent the course of the folds in the vein. (See figure 1.)

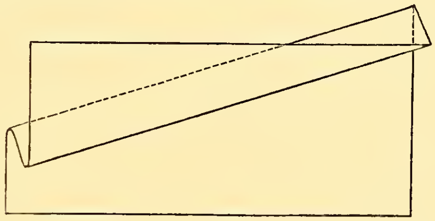


FIG. 1.—Diagram illustrating the formation of folds.

The folds are well developed in the Mysore, Champion Reef and Nundydroog Mines: and, on account of the thick masses of quartz developed along the top and bottom angles of the folds, have given rise to valuable reserves of ore, the stopes on these portions being occasionally of great width, *e.g.*, as much as 33 feet on the eastern limb in the Champion Reef. It is a fortunate circumstance that the ore stoped from these places is generally of exceptionally good grade. The cross-sections drawn to scale of the Champion Reef and Nundydroog Mines will illustrate the nature of the folds (see Pls. 12 and 13). In connection with the folding there is often a branch split off from the main lode which encloses a large horse of the country rock. The so-called East lode which branches off near the north boundary of the Nundydroog Mine and continues into the Tank Block Mine is an apophysis of this character. (See Pl. 13.)

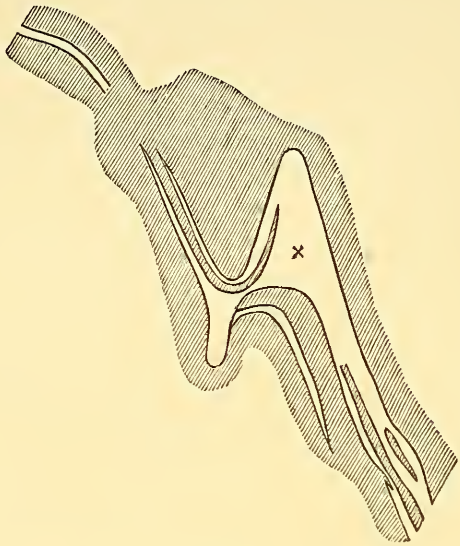


Fig. 2.

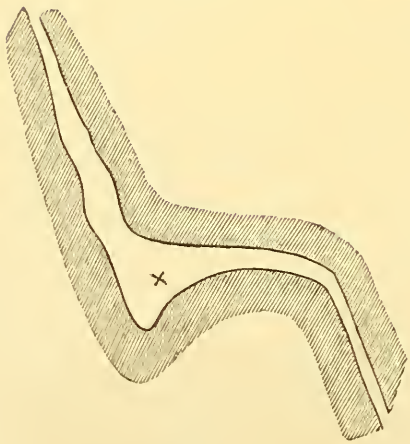


Fig. 3.

Figs. 2 & 3.—Folding of calcite stringers in chlorite schist forming the "country rock" of the Champion lode, illustrating on a small scale the formation of "chambers" or large "pockets" of ore by the folding of the lode. *Drawn to natural scale.*

The production of these enlarged ore-bodies by folding is well illustrated on a small scale by a hand-specimen of country rock taken from the neighbourhood of the lode in the Ooregum Mines. The rock consists of hornblende schist seamed with calcite and is folded in exactly the manner described above. With the difference that the veinules are of calcite instead of quartz, all the peculiarities of the folded quartz veins are reproduced in the hand-specimen. (See Pl. 1; Frontispiece.)

The diagrams, figs. 2 and 3, drawn from this specimen will serve to illustrate the formation of "chambers" of ore by folding. The thickened part of the fold or "chamber" is marked in the figures by a ×.

As to the origin of the folds, there is no doubt that they are the result of enormous lateral pressure acting on the schist beds subsequent to the formation of the quartz veins, for the quartz in the folded portions of the veins has a peculiar banded hornstone-like structure, which is a result of the great stress to which it has been subjected.[1]

Another noteworthy feature of the Kolar veins is the occurrence of the pay-ore in more or less well-defined "chutes." The distribution of gold in quartz veins in definite areas within the plane of the vein is a well-known characteristic of quartz lodes: but nowhere could a better illustration of the phenomenon be found than on the Kolar gold-field. In the accompanying longitudinal sections the shaded portions indicate the chute-areas as far as proved by present developments. It will be seen that they have a fairly constant dip to the north within the plane of the vein, which itself dips west. This

[1] Mr. Holland describes specimens of this quartz as follows :—

"Dark grey quartz with white bands and hornblendic bands and lenses near the margin. Specimens show a tendency to break into regular flat cakes through the prevalence of joint planes crossing one another nearly at right angles. Fracture away from joint planes, conchoidal with pitchstone lustre. Films of calcite along the best developed joints. Under the microscope the quartz is seen to be granulated to an excessively fine degree and trained out into bands almost as perfect as flow structure; nevertheless, the parallelism of many grains gives an approximately simultaneous extinction over a large area. Thin long sheets occur with undulose extinctions, but crystallographically continuous across the 2″ field. There are streaks and eyes of foreign minerals, hornblende, felspar, mica and rods of tourmaline."

has an important bearing on the development of the mines: for an inclined shaft put down on the true underlie of the vein, *i.e.*, at right angles to its strike, will sooner or later emerge from payable into unpayable quartz. For this reason it has been deemed expedient in some cases to sink the inclined shafts and winzes in the direction of the dip of the chute instead of on the true underlie of the vein. Notable instances are Crocker's and Ribblesdale's shafts in the Mysore Mine which have been sunk in this manner. It will also be clear that a valuable pay-chute which has been developed near the northern boundary of a mine will, in consequence of its northerly dip, pass sooner or later into the property of its next neighbour to the north. The only clear case of a chute dipping to the south instead of to the north is found in the West Balaghat lode of the Gold-fields Mine, where there is a chute 50 feet long having this dip.

Within the limits of the chutes the quartz veins are of fair, sometimes of considerable, width, as in the instance already given of Crocker's chute, where stopes of 30 to 35 feet have been worked. With regard to the distribution of the gold-contents, although the whole of the chute-area is, as a rule, payable, the gold is by no means uniformly distributed, patches and spots of high-grade ore alternating with areas of poorer ore. Outside the limits of the chute the veins are pinched to few stringers which carry but little gold, or there may be no quartz at all, the position of the lode being only indicated by the presence of divisional planes (hanging and foot walls) enclosing sheared rock or, in miners parlance, "lodey matter." Reference to the sections of the mines (Pls. 7 to 11) will show that there are in places considerable stretches of barren ground between the pay-chutes. Thus the Mysore Mine is divided into three independent sections by intervening stretches of barren ground. Between the central and northern sections the unpayable portion of the vein is 2,000 feet in length: while between the central and southern sections there is a similar belt of valueless ground 1,500 feet in length. In the northern section, which is developed by Gilbert's and Tennant's shafts, the principal chute is that known as "Gilbert's." Its northerly dip soon carried it, however, into the Champion Reef Mine where it has been extensively developed and has yielded a valuable supply of pay-quartz. There are two other chutes opened in this section of the mine, but they are of no great length, and the width of the ore-body is seldom above 3 feet. In the southern section which has been opened by McTaggart's and Shaw's shafts, there is an irregular patch of pay-ore some 300 to 400 feet in length, but the ore-body is of small width and the quartz is not of high grade. These two sections of the mine are at present not contributing more than $\frac{1}{5}$ of the ore sent to the mill.

The main-stay of the Mysore Mine is the central section which has been developed by Crocker's, Rouse's, Plummer's, Taylor's and Ribblesdale's shafts. In this section are situated the main chutes from which has been derived the rich ore which has made the Mysore Mine famous. They are three in number and are known as Crocker's, Champion and South or Rouse's chutes. It was this part of the mine that first attracted attention on account of the very extensive old workings that existed at the surface. Taylor's shaft was started in 1881 to unbottom these old workings and it was found that they extended to a depth of 236 feet, thus proving that the ancients had been working on a chute of exceptional value. Four years after the commencement of sinking, a level driven from Taylor's shaft at a depth of 300 feet opened up a vein of ore which was reported to have a width of from 3 to 7 feet and a value of 4 oz. to the ton. This was the commencement of the Champion chute; Crocker's chute was not discovered till much later. These two chutes are in reality one, for although on the upper levels there was a poor zone of ground between the two which extended to about the 1,620 foot level, in the lower levels they are only separated by the big north and south dyke; and below the 1,620-foot level they have come together.

If therefore the two chutes be taken together, the ore-body has a length along the strike of some 700 to 800 feet and has had a width in the best places of from 30 to 35 feet (*e.g.*, on the stopes above the 1,160-foot level). Moreover, it has yielded rich ore, as shown by mill and cyanide returns which for several years have shown an average of 30 dwts. of fine gold to the ton. But in depth both width of vein and gold-contents have diminished, and below the 1,620-foot level the width of the ore-body is only from 2½ to 8 feet, the average being about 3 feet, while the grade of the ore is also lower. It remains to be seen whether in the course of future developments these chutes will open out again in depth as their lenticular character indicates they may do. Separated by about 300 feet of barren ground from them is the so-called South chute, which although of irregular dimensions has yielded ore of high value.

In the Champion Reef Mine the position of the chutes was also indicated by extensive old workings which extended to an average depth of 150 feet and to a greatest depth of 275 feet. There are two chutes separated by a zone of barren ground where the vein is pinched to a few stringers for a distance varying from 400 to 1,000 feet. The southern is the largest of these chutes. It is known as Garland's or Gilbert's chute and extends on the 1,140-foot level (Garland's shaft) from Dalyell's shaft to beyond Ribblesdale's shaft, a distance of over 2,000 feet. More recent developments, however, have shown that this was an exceptional length of chute; for on lower levels (1,240 and 1,340 Garland's) the chute has a length of from 1,200 to 1,500 feet. For a part of its length it is split into an eastern and western branch by a "horse" of country rock.

The northerly chute or Carmichael's carries a big body of ore along the fold already referred to. On account of its great width and the high-grade quality of the quartz it has been a valuable asset to the mine. The fold appears to be diminishing in depth, but although the stoping width is not so great, the ore maintains on the whole its good quality. Present developments show that by reason of its northerly dip this chute is rapidly passing into the property of its northern neighbour, the Ooregum Mine, where it is being opened up by levels driven from Taylor's shaft.

In the Ooregum Mine old workings were found along the whole length of outcrop extending to an average vertical depth of about 100 feet. The richer spots were followed down to greater depths, the ancients going in one place as deep as 250 feet. Two chutes of ore have been worked: the southern chute, developed by Wallroth's and Taylor's shafts, and the northern by Probyn's and Low's. On the upper levels the southern chute had a lateral extent of close on 1,800 feet, and the northern, of about 900 feet. Below the 760-foot level the southern chute has not been found to have the same extent as on upper levels as will be seen in the section (Pl. 9). It is just possible, however, that the development work has been done on a poor branch of the lode, the pay-ore being perhaps confined to an eastern branch, which has not been explored. Near the southern boundary a valuable chute of ore has come in from the Champion Reef property, and in depth every successive level has developed a greater extent of it. The 1,610-foot level, as far as at present driven, has developed 1,000 feet of good ore having a stoping width of 4 to 5 feet. In consequence of these chutes coming in from the Champion Reef, the prospects of this mine are certainly encouraging.

On the other hand the best portion of the northern or Probyn's chute has passed into the Nundydroog property. This chute which has an average length of about 500 feet has been extensively developed in that mine, the ore-body being in places of considerable size, namely, 8 to 20 feet, although the average width probably does not exceed four feet. Between this chute and the one next to the north, there is in the Nundydroog Mine about 1,800 feet of unprofitable ground. Then comes Kennedy's chute, which in the best place (on the 370-foot level) had a length of 1,300 feet, the ore-body averaging from 4 to 5 feet in width. Lower levels have not developed as much pay-ore on this chute. The best portion, in which a thick deposit of quartz along the axis of a fold in the vein gave stopes up to 30 feet in width, has passed above the 440-foot level into the Tank Block Mine. In the latter mine work has for sometime been practically confined to the development and stoping of the ore contained in the thick part of the fold, and in a branch given off from it, which, after first dipping to the east, runs flat for about 50 feet and then pinches out (see section). It is a valuable chute of ore, but being of small lateral extent does not yield a large supply. The mine must depend for its chief supply of ore on the western or main branch of the lode. The whole northern portion of the Tank Block property is now neglected on account of the unsuccessful issue of earlier prospecting operations.

The next property to the north of the Tank Block is the Coromandel. The main work in this mine has been done on a chute some 300 feet long, situated in the northern section, and on a fold in the vein about 100 feet south of the main chute. Although only 40 to 50 feet in length, the latter has yielded a considerable quantity of good ore, stopes on it having been from 10 to 16 feet wide. In the main chute the stoping width is from 2 feet 6 inches to 3 feet and the quartz is much intermixed with country rock. This chute goes into the Balaghat between the 500 and 800-foot levels. Besides these chutes a patch of ore some 400 feet in length and of irregular shape has been developed in the southern portion of the mine on the supposed extension of Kennedy's lode. Here the ore is largely mixed with country rock and is consequently of low grade. In the central part of the property, some 600 feet of ground which has been opened up by levels driven from Prospect shaft, has hitherto yielded no pay-ore. Future work in this mine will have to be confined for sometime to come to prospecting operations with the view to locating chutes of pay-ore.

In the Balaghat Mine the main chute of ore is that developed by Ogle's and Haine's shafts in the northern portion of the property. The chute has a length of 600 to 700 feet which it maintains in depth as far as developed, namely, to the 1,050-foot level. The extension of the 1,050-foot level south appears to have opened up a new chute 200 feet in length on the average and of good value. With regard to width there is much variation from level to level, as the ore-body has a marked lenticular character. Before milling a considerable percentage of country rock has to be picked out from the ore on the sorting floors. The Coromandel chute, west of the big dyke, is also being developed on the south boundary, but as yet not much work has been done on it. A small chute has been found on the lode opened up by Tennant's shaft. Some good ore has been developed, but the lateral extent of the chute hitherto proved appears to be small.

Gold-contents.—The recoverable gold-contents of the best part of the Champion lode is well over an ounce to the ton, as will be seen in the following tabular statement of the average yield of the different mines working on it, expressed in pennyweights of fine gold to the ton milled, for each year since the commencement of operations:—

Period.	Mysore.	Champion Reef.	Ooregum.	Nundydroog.	Balaghat.	Coromandel.	Tank Block.
	dwts.	dwts.	dwts.	dwts.	dwts.	dwts.	dwts.
1882	...	...	...	1·3	...	...	...
1883	...	...	...	13·5	...	...	...
1884	18·0	...	...	...	...	...	...
1885	42·8	...	...	...	...	...	...
1886	48·0	...	...	15·7	4·6	...	...
1887	21·2	...	...	30·4	42·6	...	...
1888	17·1	...	33·6	31·8	37·7	...	...
1889	28·0	...	37·3	28·4	36·5	...	...
1890	27·9	...	37·9	29·2	11·6	...	...
1891	30·5	...	39·8	35·7	12·3	...	...
1892	26·4	17·3	39·6	30·5	16·0	...	...
1893	24·0	24·7	34·9	18·9	16·7	...	...
1894	15·7	25·9	26·9	17·5	8·8	...	9·3
1895	21·0	25·1	23·2	16·3	7·8	7·0	15·6
1896	31·2	22·6	18·2	20·1	...	12·4	7·6
1897	31·6	24·1	14·3	20·0	...	14·3	11·6
1898	33·7	27·1	13·6	19·4	10·9	11·6	5·4
1899	31·0	29·5	16·8	22·0	12·4	4·3	4·1
1900 (Six Months' crushing).	26·1	30·9	23·3	22·7	17·8	9·9	3·8
Average yield	27·5	26·6	22·4	21·7	18·0	10·2	7·0

The yield of mines working on lodes other than the Champion lode is shown in the following table:—

	Nine Reefs.	Road Block.	Gold-fields of Mysore.
1895	6·9	...	...
1896	5·8	...	...
1897	2·5	...	...
1898	3·7	...	...
1899	7·4	...	5·3
1900 (To the end of June) .	5·5	1·9	13·9
Average yield	5·5	1·9	5·9

CHAPTER III.

MINING PRACTICE.

Development and Stoping.—The mines are developed by shafts, levels and winzes. With the exception of the first hundred feet or more the shafts are on the underlie of the vein. From them levels are driven off at intervals of about 100 feet. The ore-body is then blocked out for stoping by making winze-connections between the levels at every 100 to 200 feet. On the average, there is one shaft to every 500 feet of ground, measured along the strike of the vein. This seems an unnecessarily large number; but many of them were sunk during the early exploration of the mines and have not been continued below the upper levels.

The shafts at present in use on the four principal mines are as follows:—

Name of property.	Length of property along out-crop.	Number of shafts in use.	New vertical shafts now being sunk.
Mysore	7,650	9	1
Champion Reef . . .	3,600	6	1
Ooregum	3,360	5	1
Nundydroog	3,230	5	1

The dimensions of the shafts within timbers are 5 by 10, 6 by 12, 5 by 14, 6 by 14, 6 by 16½, and 8 by 16 feet, according to the various requirements of the different mines. The smaller ones are divided into three compartments, *viz.*, two skip-ways and a third compartment for ladder-way and pit-work, if pumping is carried on in the shaft; the larger shafts are usually divided as regards the vertical portions into eight compartments, namely, two cage-roads, two skip-roads, two ladder-ways, one capstan-shaft (for lowering big balks of timber rails, etc.) and one compartment for pit-work. In Oakley's shaft of the Ooregum Mine (see Pl. 3), the cage-roads are 3 ft. $8\frac{3}{4}$ inches by 3 ft. $1\frac{1}{2}$ inches; the skip-roads, 3 ft. $5\frac{3}{4}$ inches by 3 ft. $1\frac{1}{2}$ inches; the two ladder-ways, 4 ft. 6 inches by 3 ft. $5\frac{3}{4}$ inches; and the capstan and engine shafts, 4 ft. 6 inches by 3 ft. $8\frac{3}{4}$ inches. In the inclined portion of the shaft there are of course no cage-roads, and the two skip-roads occupy the space of the four hoisting compartments of the vertical portion. In the new vertical shaft of the Champion Reef Mine (see Pl. 2), the skip-roads are 3 ft. 9 inches by 3 ft. 6 inches; the cage-roads, 4 ft. 2 inches by 3 ft. 9 inches; the capstan and engine shaft, 7 ft. 6 inches by 5 ft. 6 inches; and the ladder-way, 7 ft. 6 inches by 2 ft. 1 inch. In the Ribblesdale shaft of the Mysore Mine (see Pl. 2), which within timbers measures 12 by $6\frac{1}{2}$ feet, the skip-roads are 3 ft. by 3 ft.; the cage-roads, 3 ft. 4 inches by 3 ft.; and the engine shaft 5 ft. by 4 ft. 8 inches. The inclined portion of the shaft is four feet longer than the vertical portion, to provide an extra road for a trolley or gig to raise and lower men, and for hoisting deads from development work for filling in the old stopes, the power being furnished by a small air-hoist at the top of the incline. The new shaft (Edgar shaft) which is being sunk to develop the deeper levels of the Mysore Mine is circular, the diameter inside the brick walling being 18 feet; the details of the division into compartments have not yet been fixed.

As a general rule the inclined shafts follow the true underlie of the vein, but in two cases in the Mysore Mine (Crocker's and Ribblesdale's shafts) they have been sunk along the dip of the ore-chutes. This method has the advantage of obviating the driving of long levels through barren ground, when the chutes have dipped away from the underlie shafts. The same plan is followed in regard to winzes which are sunk to develop the big and rich folded sections of the vein. The method usually adopted for transferring the skip during its passage to the surface from the runners of the inclined portion to the guides of the vertical portion of the shaft is shewn in fig. 4.

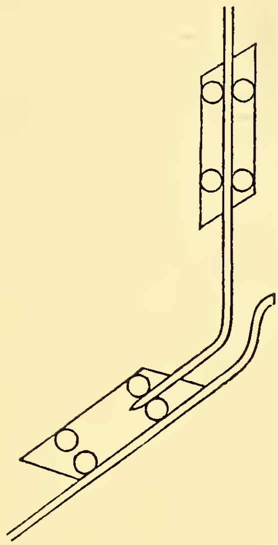


FIG. 4.—Diagram showing the method of running the skip in the inclined and vertical portions of a shaft, respectively.

Drives and cross-cuts are of the usual dimensions, namely, about 7 feet high by 5½ feet wide. Main cross-cuts, to take a double track, measure 7 feet high by 8 feet wide. The main cross-cut to the Champion Reef new vertical on the 780-foot level is 9 feet high by 8 feet wide, the additional height being to allow for a water conduit under the tram-road.

With regard to stoping, both "overhand" and "underhand" methods are in use, the two being frequently used in combination, or in some cases the stopes are started, and for some distance kept, parallel to the sides of a winze. The underlie of the vein (50° to 55°) is rather in favour of underhand stoping, but the angle of slope is not sufficiently steep for the quartz to run by gravitation alone. On account of the high grade of the ore as to gold-contents it is usual to leave no pillars except at the shafts, the roof of the stopes being supported by careful timbering. In the big stopes in the Mysore and Champion Reef Mines, timbers may be seen over 25 feet in length with a diameter of from 18 to 24 inches. These timbers consist of native woods brought from the Malabar District of the Madras Presidency.[1] Protection to the back of the levels is afforded by waste rock or stulls resting on lagging supported by stout stull-pieces which are renewed as soon as they show signs of crushing. Where waste rock is available, additional security is obtained by packing it into the worked-out stopes. If it be desired to keep the level open after the ground beneath has been stoped away, the floor of the level is relaid on timbers. In particularly heavy ground, however, as in the Ooregum Mine, an arch or pillar of solid ground is often left intact under the level; but this has not always been found satisfactory on account of the treacherous nature of the hanging wall, and the tendency of the quartz to blister off on exposure.

Development work is done almost entirely by the aid of machine drills, the Climax and Little Hercules patterns being especially favoured. It is carried out by native contractors under European supervision. The contractors are paid at a fixed rate per foot driven, with sometimes an additional bonus, when the monthly footage exceeds a certain minimum. They purchase (from the company) their own explosives, steel and lights, while the company provides the machines, and the power to run them, sharpens the drills and does whatever timbering and pumping may be necessary. In the stopes hand-drilling is the rule, although machine drills are also used. This work is done by contract at a fixed rate per square fathom. The rock broken in development work and in stoping is trammed in small trucks or waggons propelled by hand, to the hauling shaft, where it is either tipped into bins under the plats or the trucks are hoisted in cages or drawn up on rails (as in Crocker's shaft) to the surface. In sinking winzes and shafts the deads are either carried up to the levels by natives in baskets, as at the Ooregum Mine, or hoisted in a bucket or kibble by a windlass, or by a small Lark hoist driven by compressed air. This is generally a part of the sinking contract. Tramming along the levels from the

[1] See p. 58 for a description of the native timbers in use on the Kolar gold-field.

working faces or stopes is made the subject of a separate contract, the muckers being paid per foot sunk or driven, or per cubic fathom stoped, or per skip hoisted.

Pumping.—Beyond the water produced by seapage from the surface, which is a variable quantity according to the season of the year, there is no great amount of water to contend with, especially in the lower levels of the mines. Occasionally, however, an unexpectedly large influx of water is met with during development, caused no doubt by the intersection of a cross-course or dyke forming a natural water-channel. Such an outburst occurred in January 1898 in the Nundydroog Mine, the flow of water during the first few days being estimated at 30,000 gallons per hour, resulting in the temporary flooding of the mine.

The system of drainage in vogue is common to all mines. The most conveniently situated shafts are provided with pit-work and the water is brought to them along channels cut in the levels and cross-cuts. There it is collected in cisterns and elevated to the surface by Cornish pumps. In the bottom stage the water is usually elevated by a bucket-lift, afterwards by plunger-lifts. The diameter of the plunger-lifts varies usually from 6 to 14 inches. In the new vertical shaft at Champion Reef to which the drainage of the mine has been concentrated, the water is brought to the surface in 10-inch plunger-lifts in stages of 400 feet. At Nundydroog a Cornish pump with 14-inch rams has been put in to cope with the increased supply of water from the outburst referred to. The pump spears are usually made of teak-wood or pitch-pine rods 7 to 12 inches square, in lengths of about 30 feet, connected by wrought iron strapping plates.

When water is met with during shaft or winze-sinking, it is either baled by hand from the sump into the buckets, kibbles or skips, or it is dealt with by Cameron or Evans pumps worked by compressed air. Worthington pumps actuated by compressed air are also employed. They are usually fixed for permanent work in those places where it is impossible or inconvenient to extend the Cornish lifts. Thus in Wallroth's shaft, Ooregum Mine, the water accumulating on the 1,060-foot level is dealt with by a Worthington high-lift duplex pump having 14-inch air-cylinders, 4½-inch plungers and a 10-inch stroke. By this pump the supply can be delivered to the Cornish lifts, which extend only to the 700-foot level.

Ventilation.—In those mines where connection has been made between two or more shafts, the ventilation by natural circulation of air is good. In long drives and rises where there is no natural circulation, the air from the exhaust of the machine drills, driven by compressed air, keeps up a supply of oxygen sufficient for working, if not always for comfort.

Illumination.—Candle-light is at present the usual method of illumination underground. When the electricity supplied to the mines by the Cauvery power scheme becomes available, no doubt electric light will be used for the lighting of main stations and main cross-cuts throughout the mines; at present only the Champion Reef has electric light underground. The cost of candles in the Mysore Mine during 1899 averaged 5½*d.* and in the Nundydroog Mine 6½*d.* per ton of ore milled.

DEVELOPMENT AND MINING COSTS.

Sinking.—The cost of sinking main shafts varies according to the size of the excavation, the hardness and breaking character of the ground, the amount of water met with, the rate of progress made, and many other factors. The rate of progress is very slow at Kolar; and there is little doubt that if the contracts for sinking were in the hands of expert shaft-sinkers like the Americans who have made such wonderful records on the Witwatersrand in South Africa, the cost per foot could be reduced very materially. The following are instructive examples of the cost of shaft-sinking at Kolar:—

1. *Vertical Shaft, Nundydroog Mine.*—Dimensions, within timbers, 12 x 6 feet. Depth at beginning of June 1900, 800 feet. Average rate of progress since the commencement of sinking, 15 feet per

month. Sunk at company's expense, by machine drills, actuated by compressed air. No pumping has been necessary. The following is the average cost per foot:—

	Shillings.	Per cent.
Labour	128·16	32·3
Timber	32·00	8·2 (*a*)
Explosives and general stores . .	54·94	13·8
Compressed air for three drills . .	134·6	33·9
Hoisting deads	44·8	11·3
Drill sharpening	2·0	·5
	396·5	100·00

or £19·8 per foot.

(*a*) The timber item is low on account of the small size of the shaft and the use of cheap Irul timber.

2. *Oakley's shaft.*—A new vertical shaft sunk in the Ooregum Mine at company's expense. Dimensions, within timbers, 16 × 8 feet (see Pl. 3). Depth to the end of June 1900, 437½ feet. Average rate of progress 25 feet per month, the greatest amount sunk in one month being 33 feet. The cost per foot during 18 months' work averaged £24·8. The following is the percentage ratio of the main items of cost approximately: (*b*)

Labour	27	per cent.
Timber	21	
Compressed air for three drills	17	,,
ditto for pump	11	,,
Explosives	10	,,
General stores	10	,,
Hoisting deads	4	,,
	100	

(*b*) Only an approximation could be obtained, as in the accounts kept the cost of running a main cross-cut was included.

3. *The new Vertical shaft at the Champion Reef Mine.*—Sunk at company's expense. Dimensions, within timbers, 16 × 8 feet (see Pl. 2). Depth at the end of July 1900, 1,112 feet. Rate of progress averaged 28 feet per month, and cost per foot £29·9.

4. *Edgar's shaft, Mysore Mine.*—Sunk at company's expense. Size of excavation, 20 feet. Diameter within the brick walling, 18 feet. Depth at the end of May was 409 feet. Average speed of sinking, 20

feet a month; but sinking is suspended during walling, which occupies more time than the sinking. The greatest speed obtained in one month was 39 feet. Four machine drills are used. The cost per foot sunk for sinking and walling averages £24·3 per foot; but the shaft has not yet been divided, nor has any pit work been put in.

Rising.—The following is a good example of the cost of rising. The rise, measuring 10 by 5 feet, was put up from the 1,060-foot level to meet Oakley's shaft. Two machine drills were used, the average rate of progress being 15·6 feet per month. The height reached at the end of July 1900 was 109 feet; and the cost per foot averaged £9; the main items of cost being—

	Shillings per foot.	Percentage.
White labour	33·28	18·3
Native labour	18·61	10·2
Explosives	25·34	14·0
General stores	19·88	11·0
Compressed air for two drills	84·39	46·5
Total	181·50	100·0

Driving—is done either by hand or machine-drilling, the rate of progress by machines being rather more than twice that by hand. The work is always by contract, with or without bonuses. Driving by hand-drilling costs the company, on the average, 36 shillings per foot, the rate of progress being about 15 feet per month. The cost of driving with machine drills, including the air supplied, is on the average 44 shillings per foot, and the average rate of progress is from 30 to 35 feet per month. The cost of tramming the deads from the heading and hoisting to the surface averages about 2 shillings and 8 pence per foot driven.

Stoping—is paid by the superficial fathom (6 ft. × 6 ft.) up to a stoping width of 6 ft. If over 6 ft. is stoped the contract is by the cubic fathom. The price per fathom in an ordinary stope, say, of 4 ft. 6 inches width, is about £3 per superficial fathom, contractors purchasing their own explosives, steel, lights, etc., but timbering being done by the company. Tramming the ore broken to the shaft costs about 12 shillings per cubic fathom, or say, 8½d. per ton.

The following tabulated statement gives the cost of mining, including development work, at two of the leading mines on the Kolar gold-field, reckoned on the tonnage milled:—

Heads of expenditure.	Mysore.		Nundydroog.	
	Cost per ton milled.	Per cent.	Cost per ton milled.	Per cent.
	s. *d.*		*s.* *d.*	
European labour	1 6·8	6·6	2 3·5	7·9
Native	8 1·9	34·3	10 1·1	35·1
Fuel	7 11·8	33·5	12 0·5	41·8
Explosives	2 2·0	9·1	1 8·1	6·1
Timber	1 11·6	8·3	0 7·2	2·1
Candles	0 5·5	1·9	0 6·4	1·8
Steel and iron	0 4·5	1·6	0 2·6	0·7
Oils and tallow	0 2·3	0·9	0 4·6	1·2
General stores	0 10·8	3·8	0 11·5	3·3
	23 9·2	100·0	28 9·5	100·0

CHAPTER IV.

SURFACE EQUIPMENT.

Power employed.—The power required on the Kolar field for pumping, winding, driving air-compressors, stamps, rock-breakers and for workshops and electric lighting is approximately 10,000 horse-power. The ratio in which it is utilized is as follows:—

Air-compressors	36	per cent.
Mills, rock-breakers, workshops, and electric lighting	28	,,
Winding	19	,,
Pumping	17	,,
	100	per cent.

The cost per horse-power varies in the different mines from £28 to £35 and averages about £31 per annum. The main item of this cost is the coal-bill which amounts to 84·5 per cent. of the total; next comes labour, 8 per cent; administration and supervision, 5 per cent.; and stores (comprising lubricants, waste, packing, kerosene, anti-friction metals, etc.), 2·5 per cent.

A scheme has been initiated by the Mysore Government to substitute for steam-power, water-power, transmitted by electricity. It is proposed to utilize for this purpose the falls on the Cauvery river at Sivasamudram, which are 95 miles distant from the Kolar gold-field. The Cauvery river at this place has a fall of 430 feet, of which an effective head of 350 feet can be obtained for power-generation. It has been planned to convey the water to the turbines in two channels each 19 feet wide by 5 feet deep, the distance from the intake to the pentstock being 3½ miles. Each channel, it is estimated, will convey 250 cubic feet of water per second. In case of a short-fall of water during the dry season it is proposed to supplement the power transmitted from Sivasamudram by steam-power generated at the central distributing station on the Kolar gold-field. The power will be taken by various companies to drive compressors, mill-engines, crushers and the machinery employed in workshops and electric lighting. It is estimated that the cost of the power employed in running this machinery can be reduced to £10 per horse-power per annum within 5 years by the substitution of water-power for steam-power.

Steaming plant.—The boilers employed on the field are chiefly of the Cornish type, but Lancashire, multitubular, vertical and Galloway boilers are also employed. The total number of boilers in use during 1899 was 198, having an aggregate grate-area of 3,393 square feet and a heating surface of 63,102 square feet. They were worked at a pressure of from 60 to 90 lbs. per square inch.

It is usual to group the steaming plant as far as practicable at the main hauling shafts, where steam is supplied to the hoisting, pumping and air-compressing machinery in use there. In addition, however, separate steaming plant is required to run the motors for the mill-stamps, rock-breakers, dynamos and the various machines employed in the workshops, which are not located near the shafts. At the Ribblesdale shaft of the Mysore Mine, there is a battery of eight 30 by 7 foot Lancashire boilers, supplying steam to the compressor, cage and skip-hoisting engines, a capstan-engine, and a Cornish Beam pumping engine. Similarly at the new vertical shaft of the Champion Reef Mine, there are ten 30 by 7 foot Lancashire boilers, steaming two compressors, two winding engines and the capstan and pumping engines.

The water in use on the field for steam-generation contains a rather large percentage of lime, thereby necessitating constant cleansing of boilers and condensers to get rid of "scale."

Feed-water heaters and economisers do not appear to have been introduced, the boiler feed being supplied, as a rule, direct from the condenser tanks.[1] Mechanical stokers are not used; but Wilton's and Meldrum's patent furnaces with forced draught are employed, enabling a large proportion of the waste ash-heaps to be burnt and thereby effecting a considerable economy in coal-consumption.

[1] A Green's Economiser is now being erected in connection with the steaming plant for the new mill at Champion Reef.

Of late Indian coals have practically superseded English, the result being a considerable saving, which varies, however, according to the prices ruling. Barakar coal from the Bengal Presidency has been used principally, but Singareni coal from Hyderabad is coming into favour. The Singareni coal has slightly less ash and less clinker than the Barakar. It is preferred by the native firemen because they find the work of firing is lighter. The cost of the three coals is at present as follows:—

	R	a.	
English	32	0	per ton.
Barakar	18	15	„
Singareni	15	8	„

The consumption of Indian coal per indicated horse-power in the most effective steaming plant, *e.g.*, that of the Mysore mill-engines, is about 4·7 lbs. per hour, boiler-pressure being maintained at 80 lbs. per square inch. The average throughout the field is, however, about 6 lbs. per hour.

Prime Motors.—The prime motors employed on the Kolar gold-field may be classified as follows:—

1. Air-compressing engines.
2. Engines for driving stamps, crushers, Wheeler pans, etc.
3. Hoisting engines.
4. Cornish pumping engines.

AIR-COMPRESSORS.—Power is transmitted by the medium of compressed air to the machinery employed underground. From the receivers the air is carried down the shafts in 8 or 6-inch wrought iron mains; and underground is distributed to the different points at which it is required by 4 and 2-inch pipes.

The air-compressors at present in use on the gold mines are 28 in number, having an aggregate indicated horse-power of 3,450. They are chiefly of Walker Brothers' manufacture. The air is compressed either in one or two stages. At the Mysore Mine there are two single-stage (20-inch air-cylinder) and three double-stage compressors, supplying air to 60 rock-drills (Climax pattern), of which an average of 55 are at work, 14 donkey-pumps (Cameron's) and three air-hoists.

The new double-stage compressor, just erected west of Ribblesdale shaft (see Pl. 18), is compound and condensing with steam-cylinders of 24 inches and 40 inches and air-cylinders of 22 inches and 34 inches diameter, respectively. It works with a 4-foot stroke, developing 301 indicated horse-power in the steam, and 268·8 in the air-cylinders, showing a loss of 10·7 per cent. The steam pressure is kept at 80 and the air pressure at 50 lbs. per square inch. The coal consumption is 3·8 lbs. per indicated horse-power per hour. This compressor drives 22 rock-drills (3½-inch) and one donkey-pump, but is not run at its full capacity, the steam being cut off at half stroke.

At the Champion Reef Mine there are in all 5 compressors at work. Of these one is of the Sandycroft pattern. It is a single-stage compound and condensing engine with a 20-inch air-cylinder, and steam-cylinders 18 and 32 inches, respectively. The other four are of Walker Brothers' patent. Two of them are similar to the one just described; and the other two are double-stage, compound and condensing engines with steam-cylinders 24 and 40 inches, and air-cylinders 34 and 20 inches, respectively, with a 4-foot stroke. The air is received in 2 egg-ended air-receivers 30 feet long by 7 feet diameter.

At this mine an average of 55 drills are kept at work, besides which there are several donkey-pumps and three air-hoists. The air pressure is maintained at 55 lbs. per square inch. The average monthly consumption of coal for the five compressors is 1,463 tons, and the total average cost of running them is £2,009 per month, which is at the rate of £33 per rock-drill per month, due allowance being made for pumps and air-hoists.

Mill-motors.—The mill-motors in use on the field are chiefly of Sandycroft manufacture. They are of the horizontal girder type, and are mostly compound and condensing. The majority of them have steam-cylinders of 16 and 30 inches diameter with a 3-foot stroke. The slide valves are usually fitted with Proell's Patent cut-off gear. The fly-wheels are about 14 feet diameter with 2-foot belt face, the power being transmitted to the mill shafting by cotton belting. The speed at which they are run varies from 50 to 75 revolutions per minute. To run the new 120-head Mysore mill, crushing 10,000 tons of ore per month, to pass 1,600 screening, there are two such engines each supplying power to 60 stamps. They are run at a speed of 65 revolutions per minute, and the two engines together indicate 340 horse-power with a boiler pressure of 80 lbs. The consumption of coal (Indian) is 4·7 lbs. per indicated horse-power per hour, the monthly consumption of coal being 500 tons.

HOISTING ENGINES.—Both direct-acting and geared engines are in use on the field. In all there are 56 winding engines having an aggregate indicated horse-power of 1,979. Hoisting is by round wire ropes of 1 to 1¼-inch diameter. Only in one case (at the Nundydroog Mine) is a flat rope employed. The engines are of Sandycroft make. The following are examples:—The cage-engine at Ribblesdale shaft (Mysore Mine) has 20-inch twin cylinders with a 4-foot stroke and is direct-acting; the skip-engine has 18-inch cylinders and is geared to 12-foot drums. At the new vertical shaft, Champion Reef Mine, the cage-engine is direct-acting and of the horizontal girder type, with 20-inch twin cylinders, 4-foot stroke and two 10-foot drums. The skip-engine is geared at 5 to 1 and is of the horizontal type with 20-inch twin cylinders and a 3-foot stroke. It is geared to double drums of 12 feet diameter.

At those shafts where a special compartment is reserved for lowering timber, etc., there is a capstan-engine fitted to work single or double purchase, and capable of handling up to 25 tons.

PUMPING ENGINES.—The engines in use on the Kolar gold-field for running Cornish pumps are 26 in number, having an aggregate indicated horse-power of 847. They are either single or compound cylinder and condensing engines. If compound, the arrangement of the cylinders is either tandem or twin. They are always geared down and are connected with the pump-rods by sweep-rods, the horizontal motion of the latter being converted to a vertical or inclined motion corresponding to the angle of the shaft by angle bobs. The weight of the pump-rods is also balanced at the surface by a balance bob fixed at the end of the horizontal arm. The sweep-rods are usually of teak-wood but occasionally of pitch-pine strapped together by iron plates. The intermediate rods, which have only a horizontal movement, run on rolls or are supported by small wheels running on rails. Different lengths of stroke are obtained, according to the requirements of the moment, by changing the attachment of the end sweep-rod to different points on the engine spur-wheel. A type of engine for Cornish pumps, much in favour on the field, is the Hathorn-Davy. One at the new vertical shaft of the Champion Reef Mine is a single cycle compound and condensing with a differential valve-gear and horizontal tandem cylinders of 30 and 60 inches diameter, respectively, and a 6-foot stroke. The only example of a Cornish Beam pumping engine is at the Ribblesdale shaft of the Mysore Mine. It has a vertical cylinder of 36 inches diameter with a stroke of 9 feet in the cylinder and 8 feet in the shaft, and the usual form of Cornish valve-gear with plug-rods and tappets. It is found to work with great economy.

Workshops.—The engineering workshops, comprising fitters, smiths, carpenters and moulding shops, are well equipped, as must needs be when one considers the isolation of the mines from other centres of engineering activity, by reason of which they are thrown on their own resources for repairs and alterations to machinery and for the construction and erection of new plant. Underground and side-tipping waggons, skips and cages are turned out in these shops.

The fitters' shops usually contain surface and screw cutting lathes, drilling, sharpening, planing, screwing, and slotting machines. They are also usually furnished with boiler-makers' punching and shearing machines and a set of rolls. The smiths' shops in the larger mines have 10 to 12 forges supplied with air from a Roots' Blower; and there is usually a small steam-hammer. Drill sharpening is generally by hand, but the Bradbury patent drill sharpener is also used. In the moulding shop there are at the Champion Reef, Mysore, and Ooregum Mines, cupola furnaces for castings and small furnaces for smelting brass. Castings are done twice a week, about 25 cwts. of metal being run down at a time. The carpenters' shops are fitted with band and circular saws and patent wood-boring machines for boring out mill-guides.

The skilled labour in the shops is entirely native and is most efficient, the native of Southern India being specially adept at such work as this, which requires considerable manual dexterity but no great muscular exertion.

Electric plant.—A few of the mines have the engine and boiler houses, as well as the mill, cyanide-works, shaft-tops and officers' quarters, lighted by electric light. At the Champion Reef Mine the electric power is supplied by a pair of 4-poled "S" type, shunt-wound dynamos making 500 revolutions per minute, and providing a current of 440 volts 120 amperes. This is run by two vertical 70 horse-power compound engines of the Mirless, Watson and Yarren type, with cylinders 11½ and 16 inches diameter and an 8-inch stroke. The installation is on the 3-wire system and is worked with an equalizer, reducing the current to 220 volts.

THE HANDLING OF THE ORE AT THE SURFACE.

The stone delivered at the shaft-head is either waste rock or ore. The former is trammed to and tipped on the waste-heaps. The latter is handled variously according to the arrangements of each individual mine. It may be trammed direct to the mill, or tipped over a screen at the shaft-head, the fines going to the mill and the coarse stuff to the sorting floors, or, if hoisted during the night, it may be taken temporarily to storage-bins, whence it is conveyed in the morning to the sorting floors.

It is obvious that the less the ore is handled on its way from the shaft-head to the mill bins, the greater will be the economy of its treatment. However cheap native labour may be, each transfer of ore from truck to ore-bin and *vice versâ*, must add something to the cost per ton. Labour-saving appliances such as self-dumping skips, transport by endless rope haulage, sorting belts and tables, which are in common use in South Africa and the United States, have hitherto not been employed at Kolar ; the reason given being the cheapness of native labour.

Headgears.—The headgears or poppet-heads are usually of wood and are of simple design ; but in the case of the New Vertical shaft at Champion Reef and the New Vertical at Nundydroog they are of steel lattice work (see Pl. 14). The headgears at Ribblesdale shaft, Mysore Mine (see Pl. 18), and the Champion Reef New Vertical are 50 and 54 feet high, respectively, and are provided with two pairs of pit-head pulleys of 10 feet diameter arranged one above the other, one pair being for the cage-ropes, the other for the skip-ropes. The cages in these shafts are double deckers and are chiefly used for raising and lowering men; the skips at Ribblesdale shaft have a capacity of from $1\frac{1}{4}$ tons and at Champion Reef of $2\frac{1}{4}$ tons, and are discharged by bringing them to rest on a moveable lip on the head-gear and then withdrawing a bolt which holds a hinged door on the bottom half of the front part of the skip. At the Nundydroog New Vertical there are no skips, the cages being arranged for the reception of the underground trucks, which are run out and tipped over screens at the shaft-head.

There are no storage-bins at the vertical shaft-heads, the ore being run from the skips through hoppers into the waggons which convey it to the sorting floors or to the storage-bins.

Transport.—From the shaft-top the ore is transported in waggons, drawn by hand, by bulls, or by locomotive power. The waggons are of steel and are either side-tipping or have a hinged bottom. Side-tipping waggons carry one ton while the larger size with bottom-discharge have a capacity of 4 tons. The ordinary tramlines for the smaller waggons are laid at a gauge of from 18 inches to 2 feet 6 inches, and the rails weigh 14 to 24 lbs. to the yard. The larger lines for locomotive transit are laid either at a 2 feet 6 inches or 3 feet 3 inches (metre) gauge, and the rails used weigh 36 lbs. to the yard.

The system in vogue at the Mysore Mine is as follows :— The ore hoisted (at night) at Ribblesdale shaft, which is at least 50 per cent. of the whole outturn, goes direct to storage-bins having a capacity of 1,000 tons (see Pl. 19), whence it is conveyed in 4-ton trucks, drawn by a locomotive, to Rouse's sorting floors. The ore hoisted at Tennant's shaft is also brought to Rouse's floors by the locomotive. That raised at Rouse's shaft is discharged direct from the skips over the grizzlys on to the sorting floor; while the trucks hauled up Crocker's incline shaft are brought up to the tipping platform by a small independent hoist. Only the ore delivered at McTaggart's shaft is screened at the shaft-head, the coarse stuff being brought to the sorting floors, while the fines are taken direct to the mill. After screening, sorting and breaking at Rouse's floors both fines and broken ore are trammed to the mill in one-ton trucks drawn by bulls. At the old mill they are hoisted up an incline, while at the new mill they are raised to the bin-floor by a vertical steam-elevator. The method of raising the ore to the top-floor of the mill by means of an inclined track is shewn on plate 17.

Screening, ore-sorting and preliminary crushing.—The amount of waste rock sorted out from the ore on the Kolar gold-field is comparatively small. As yet no labour-saving appliances have been introduced for that purpose. The mode of procedure in vogue at the Mysore Mine is briefly as follows. The ore brought to the sorting floors is tipped over a screen or grizzly, the bars of which are set at about 1½ inches apart. The heap of coarse ore is then picked over by natives, the pieces of clearly recognizable waste being thrown into waggons going to the waste-heaps; while the pay-ore is carried in baskets to the rock-breakers of which there are 4 (Blake-Marsden pattern). The sorting arrangements at the sorting floors are sketched in fig. 5. The floors are closed in and careful supervision by white overseers is exercised in order to prevent stealing of rich specimen-ore. The cost of sorting and tramming from the floors to the big mill is 2 annas 4 pies per ton of ore milled.

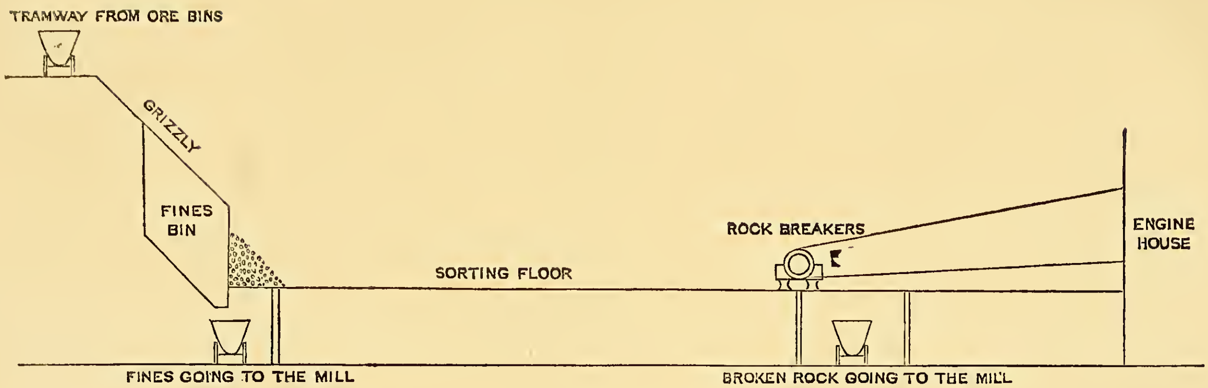


FIG. 5.—Diagram showing the arrangements for screening, sorting and preliminary breaking of the ore at the Mysore Mine.

Scale 1″ = 20 ft.

In the other mines where sorting is carried on, *e.g.*, Champion Reef, Ooregum, Nundydroog and Balaghat, the ore is picked over on floors situated in the immediate vicinity of the mills.

In connection with the new mill now being erected at the Champion Reef Mine, it is proposed to locate sorting floors and rock-breakers between the mill and the New Vertical shaft, where the bulk of the ore will be hoisted. Two circular sorting tables will be used, each having a diameter of 25 feet, with the waste-bin in the centre. The sorted ore will be delivered to two Blake-Marsden rock-breakers (see Pl. 6). A similar arrangement is in contemplation at the Ooregum Mine. The amount of waste sorted out at two of the leading mines during a year's work is as follows:—

Name of Mine.	Ore hoisted.	Quantity delivered at the mill.	Waste rock sorted out.	Percentage of waste sorted.
	Tons.	Tons.	Tons.	Per cent.
Mysore	100,973	93,757	7,216	7
Ooregum . . .	71,486	64,107	7,379	10

At the Champion Reef Mine about 10 per cent. of waste is rejected.

Since in most of the mines the vein is in many places made up of small seams of quartz intermixed with country rock, the whole of which has to be broken down in stoping, it is evident that by the adoption of efficient sorting appliances to eliminate the waste rock the grade of the ore sent to the mill could be raised, or, in other words, a larger quantity of gold could be recovered for the same expenditure of money. Sorting after breaking as well as before would probably be found profitable on account of the close admixture of pay-ore with valueless country rock.

WATER-SUPPLY AND STORAGE.

For the water required for milling and steam-generation, the mines are dependent on surface drainage during heavy rainfall and on the water pumped from the mines and from special water-shafts sunk for that purpose. The underground supplies are themselves of course regulated by the rainfall which is very variable both in quantity and as to the period in which it occurs. The registry of rainfall at the Nundydroog Mine during the last 4 years is as follows :—

Year.	Amount of rainfall in inches.
1896	28·63
1897	31·47
1898	44·01
1899	18·29

As a rule the wettest months are September and October (October being generally the time of the N. E. Monsoon) ; but April, May and June are also generally wet months (S. W. Monsoon). Practically no rain falls from December to March.

The water is stored in masonry tanks, the storage capacity of the larger mines being from three to nine million gallons. At the Mysore Mine, the water required for milling purposes is stored in a tank having a capacity of 4½ million gallons, and the water from the mill is returned from the slimes catch-pits to this tank. There are two other large storage tanks having a combined capacity of 3½ million gallons, and several small condensing tanks at the compressor and mill-houses. These tanks store water from surface drainage, also that pumped from the mines and that pumped from the water-shafts, situated three miles distant from the mine.

During average years, the supply is quite adequate for the requirements of the mines, but to cope with the short-fall occasioned by years of drought, the construction of a large dam in the neighbourhood of the mines to catch and conserve the surplus surface drainage during exceptionally heavy rains, which now runs to waste, would be advisable. The Mysore Government has recently proposed a scheme to provide a water-supply for the rapidly growing population of the Kolar gold-field and at the same time to meet the increased requirements of the mines.

CHAPTER V.

METALLURGICAL PRACTICE.

Milling.—Since the Champion lode yields when properly sorted a clean quartz with practically no admixture of clayey matter, there is no tendency to the formation of intractable slimes, even when comminution is carried to a considerable degree of fineness. Taking this fact in connection with the high grade of the ore as to gold-contents, it is not surprising to find that the practice at the bigger and richer mines of the Kolar gold-field aims at a good mill extraction rather than a high stamp duty. Inside amalgamation is practised at the two leading mines (the screening in use having 1,600 holes to the square inch at Mysore and 1,200 at Champion Reef, and the depth of discharge being 7 inches at Mysore, 6 at Champion Reef), the object being to liberate and amalgamate as much of the gold as possible in the battery boxes in order to prevent amalgam-stealing.

A high mill extraction necessitates a low stamp duty. At the Mysore Mine it averages 2·27 and at the Champion Reef only 2 tons per stamp per diem, with stamps weighing at Mysore 1,050lbs. (120-head) and 750 lbs. (30-head) and 850lbs. at the Champion Reef. The highest duty on the field, namely, 2·7, is that performed by the Balaghat mill with 1,150 and 1,050lb. stamps and a depth of discharge of only two inches. The average of the whole field is 2·22 tons per diem.

The number of stamps at present dropping on the field is 585. In addition to these there are 60 lying idle, pending further development of the mines, and 120 in course of erection at the new Champion

Reef mill. The following table summarizes the milling practice at the Kolar mines:—

Name of Mine.	Number of stamps in use.	Weight of stamps in lbs.	Average stamp duty per diem (24 hours).	Drop in inches.	Speed per minute.	Depth of discharge.	Mesh of screening (number of holes per square inch.)	Nature of screening.
Mysore Mine	{ 120 30	1,050 750 }	2·27	8	85	7	1,600	Woven wire.
Champion Reef	150	850	2·00	7	90	6	900-1,200	ditto.
Ooregum	110	850	2·26	7-8	70-90	5	1,000-1,200	ditto.
Nundydroog	40	900	2·62	8	90	2	No. 6 needle= 900.	Punched copper.
Balaghat	15	1,050	2·70	8½	85	2	No. 6 needle= 900.	ditto.
Tank Block	30	950	2·60	7	88	1½	840	Woven wire.
Coromandel	40	950	2·20	7½	85	3	900-1,200	ditto.
Nine Reefs	20	950	1·80	7½	85	3		Punched iron.
Road Block	20	1,050	2·02	7½	85	3	No. 6 needle= 900.	ditto.

The mercury consumed per ton of ore crushed varies from ·37 ounce to 2 ounces (avoirdupois), the latter extraordinarily large amount being the result of the use of Wheeler pans. Challenge feeders are in use in all the mills except in two at Champion Reef and those of the Ooregum company where hand-feeding is still practised. Hand-feeding is theoretically good, but with native labour, requiring most constant and watchful supervision, does not give in practice as good results as automatic feeding. No concentration is practised, except to a very small extent on the Ooregum Mine where black sands and pyritic material are collected on riffle-strakes below the amalgamating plates. These are ground with mercury in Wheeler pans.

The striking feature of the milling practice on the field is the multiplicity of small mills on some of the properties. Thus the Champion Reef company has three independent mills each of 50 stamps. The Ooregum company has also three mills, two of forty stamps and one of thirty. This condition of things is the result of the gradual development of the mines and the wish of the management to be sure of their mine before committing themselves to a big capital expenditure. It affects the cost of milling unfavourably, as the supervision and labour required to run several independent mills is of course more than would be required for one large mill. The decentralization of steaming and motive plant is also undesirable.

On the Mysore property, where a few years ago there were three stamp mills and three Wheeler pan mills for the treatment of tailings, there has recently been a complete and successful reorganisation; two of the stamp mills and the three tailings mills have been discarded and a new 120-stamp mill of modern design erected, while the third stamp mill has been remodelled. The same process of reorganisation is now taking place on the Champion Reef property, where a new stamp mill with 120 heads of 1,250lbs. is in course of erection, and on the Ooregum property a similar scheme is in contemplation.

The Mysore 120-head mill has 1,050lb. stamps in two lines of 60 arranged face to face and each operated by an independent engine (see Pl. 4). The stamps are in batteries of five, each battery having a separate cam-shaft and pulley, with a gang-way between every set of 10 stamps. The pattern of mortar-boxes in use is shown in fig. 6.

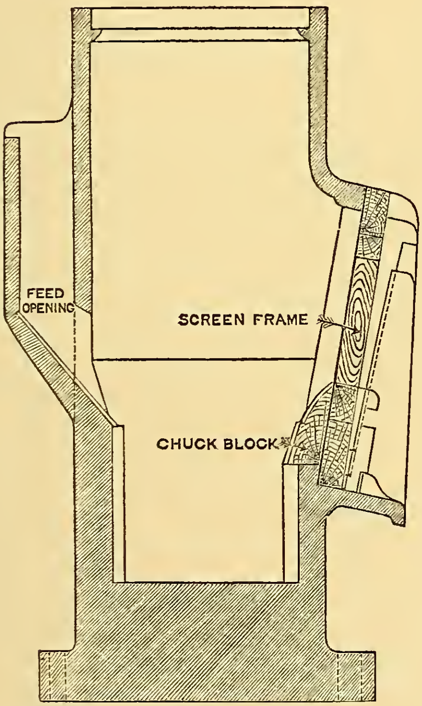


FIG. 6.—Mortar-box, Mysore mill (1,050 lb. stamps). Scale 1½″=2 ft.

The plates are in three tiers, each 3 feet long and 4½ feet wide, except the lower portion of the third plate which is narrowed off to 3 feet. Below the lowest plate there are two riffles which serve as mercury traps. The plates are cleaned up daily; but the chief clean-up is once a week when the chuck-blocks[1] are removed from the boxes and scraped or chipped on an amalgamating table. The amalgam is carefully worked up with mercury, the iron chips derived from the abrasion of the shoes and dies being picked out or removed by the magnet. It is then taken to the silver-room where it is ground up in a mortar with more mercury and finally squeezed in chamois leather. The amalgam thus obtained contains about 43 per cent. of gold. It is weighed and locked up in the office safe pending the monthly or bi-monthly consignments to England. Once a month a general clean-up takes place, when the mortar-boxes are thoroughly cleaned out, the worn dies and shoes replaced and any other necessary repairs made. The staff employed in the Mysore mills comprises a chief and two assistant reduction-officers, whose duties consist in superintending the milling operations besides cleaning-up, retorting and smelting the gold and general assay work; 15 mill-men, who work four in each shift of eight hours in the 120-stamp mill and one per shift in the 30-stamp mill; six oilers and one fitter. With the exception of the four assistants to the fitter, who are employed in making repairs, no natives are, under ordinary circumstances, allowed inside the mills. This regulation has been made in order to prevent amalgam-stealing which is very prevalent on the field.

A section of the new mill now being erected on the Champion Reef property is shown on plate 5. It is similar to the Mysore mill, and consists of 120 stamps, in two lines of 60, face to face. The stamps are heavier than at Mysore, being of 1,250 lbs., and the feed-openings to the mortar-boxes are smaller in order

[1] The chuck-blocks are blocks of wood fixed under the screen frame, with a curved inner surface to which an amalgamated copper plate is fixed. Most of the gold is caught on this plate when inside amalgamation is practised.

to prevent amalgam-thefts (see fig. 7). The plates are in two tiers, each 5 feet square, the lower one tapering to 3 feet.

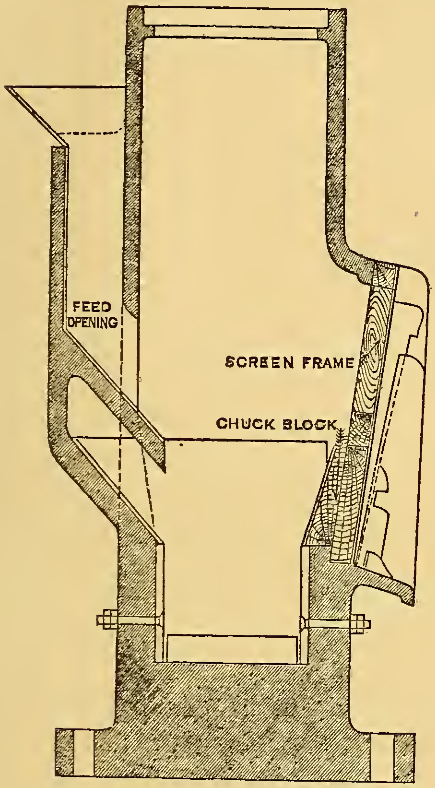


FIG. 7.—Mortar-box, Champion Reef New mill (1,250lb. stamps). Scale $1\frac{1}{2}''=2$ ft.

The tailings from the mills run into settling pits whence the sands are discharged by hand-labour, and stacked for exposure to the atmosphere before being submitted to the cyanide treatment. Priestman dregers were tried, but on account of the waste of water, which is not too abundant on the field, their use had to be abandoned. With hand-labour the sands pack better and the waste of water is obviated. The cost of emptying the settling pits is charged to milling.

The practice of grinding mill-tailings with mercury in Wheeler pans, which till recently was in favour at Kolar, has been practically abandoned since the introduction of the cyanide treatment on a large scale; although it still lingers to some extent at the Ooregum Mine.

According to the returns published by the Mysore company 92,343 tons of ore were milled during the year 1899, producing 156,128 ounces of standard gold, having a value of £606,947. This is equivalent to a yield from all sources of 31 dwts. of fine gold to the ton of ore. According to the Superintendent's report the gold recovered by amalgamation averaged 29·3 dwts. of fine gold per ton. Consequently of the total amount of gold won from mill and cyanide works, that recovered by amalgamation amounted to 94 per cent. The ore sent to the mill is estimated by the management to have had an assay value on the average of 33·8 dwts. of fine gold to the ton. On this estimate, therefore, the extraction by amalgamation amounted to 86·6 and the total extraction to 91·7 per cent., of the total value of the ore. It would be profitless to make calculations on the relative proportion obtained by amalgamation and cyaniding as the company is still engaged in treating old accumulations of tailings.

The cost of milling in three of the leading mines, as shown by the published accounts of the companies, was during 1899 as follows:—

Name of Mine.	Mill costs.	Wheeler pan costs.	Total amalgamation costs.
	s. *d.*	*s.* *d.*	*s.* *d.*
Mysore	5 1·6	*nil.*	5 1·6
Champion Reef	6 7·9	2 10·1	9 6
Nundydroog	5 9·5	0 10·5 [1]	6 8

The disadvantages of conducting milling operations in a number of small mills with light stamps is apparent in the high working cost of the Champion Reef. There is no doubt that, when the new mill starts work there, and Wheeler pans are discarded, these costs will be brought down to a level with, if not lower than, those obtaining in the Mysore mill. The following tabulated statement gives some details of the expenditure on milling for the Mysore and Nundydroog companies:—

Heads of expenditure.	Mysore.		Nundydroog.	
	Per ton.	Per cent.	Per ton.	Per cent.
	s. *d.*		*s.* *d.*	
European labour	0 7·5	12·1	0 7·2	10·4
Native labour	0 11·4	18·4	1 0·4	17·8
Fuel	2 2·3	42·6	3 5·3	59·4
Shoes and dies	0 4·9	8·0	0 3·4	4·9
Quicksilver	0 1·6	2·6	0 0·5	0·7
Oils and tallow	0 0·9	1·5	0 0·7	1·0
Timber	0 0·9	1·5	...	...
General stores	0 8·2	13·3	0 4·0	5·8
	5 1·7	100·0	5 9·5	100·0

[1] Only 800 tons were treated in Wheeler pans and that only for six months.

Treatment of the tailings.—The tailings from the mill are run into settling pits immediately outside the mill. Here the sands and the greater portion of the slimes are caught. The overflow goes to the catch-pits, where during three weeks the remainder of the slimes is allowed to settle, after which the water is pumped back to the mill reservoir.

As soon as the pits are full they are emptied by coolies who scrape the wet sand up into baskets which they carry on their heads to the decomposition heaps (see Pls. 15 and 16). The stacked tailings are there left exposed to the action of the atmosphere for three months, during which time the percentage of moisture is reduced from 16 or 17 per cent. to 7 or 8 per cent., and the gold contained in the sands is said to be rendered more easily amenable to the cyanide treatment. They are then filled into the percolating vats and submitted to the MacArthur process of treatment. The strength of the cyanide solution used is 0·26 for mill-tailings and 0·15 for slimes. After a three-days' treatment the solutions are drawn off and conducted through the extractor boxes where the gold is precipitated by zinc shavings. When sufficient gold has been accumulated, the boxes are opened and cleaned up, and the gold recovered from the zinc slimes by the usual method of reduction with borax and alkaline carbonates, the bullion thus obtained having a fineness of 650 to 820 per 1,000.

The above is a brief outline of the process as carried on, with few variations, at the mines. The drawback to the method is the amount of handling the tailings undergo from the time they leave the mill to the moment of their final deposition on the residue heaps; and one cannot help comparing it with the almost automatic process in use in the Transvaal. There the pulp from the mill is elevated by a tailings-wheel, or some form of sand-pump, to the height required for the automatic conduct of the subsequent operations. By means of launders and Spitzkasten (pointed boxes) the sands are classified into two or more grades of fineness, which are run direct into the treatment tanks, the final overflow carrying the finely suspended slimes being mixed with lime and run into vats where the slimes are settled and the excess water is drawn off. Cyanide solution is then added and the slimes agitated by a centrifugal pump or other mechanical means for a short time; they are then allowed to settle and the clear solution carrying about 80 per cent. of the gold is drawn off.

It is stated on the Kolar field that the direct process would not be a success, as exposure to the atmosphere for a considerable time is essential to successful leaching. This of course is a matter for experiment, which I hope will be made, as the successful initiation of the direct method would lower working costs.

The following details of the plant in use and of the materials consumed at some of the mines were collected:—

At the Mysore Mine there are separate plants for the treatment of the mill-tailings and of the old accumulations of tailings and slimes that have been through the Wheeler pans. The plant for mill-tailings from the 120-stamp mill (see Pl. 19) has a nominal capacity of 10,000 tons per month. It consists of nine steel percolating vats of 30 feet diameter by 6 feet deep; four masonry sumps of 28 feet diameter and 8 feet deep; and one steel reservoir of 30 feet diameter by 8 feet deep. The average charge assay is 3 dwts. 17 grains per ton; and the average discharge assay 1 dwt. 8 grains per ton, the extraction being 64 per cent. The strength of the strong liquor is 0·28 per cent. Consumption of cyanide, 1·7lbs. and of zinc, ·15 lbs. per ton treated. The other plant has a nominal capacity of 4,000 tons per month. It consists of 12 circular wooden percolating vats of 21 feet 6 inches diameter by 4 feet deep: three sumps and two reservoirs of 22 feet 6 inches diameter by 6 feet deep. The average charge assay is 2 dwts. 8 grains, and the average discharge assay 1 dwt. and 20 grains per ton; the extraction being also 64 per cent. The strength of the strong liquor is 0·12 per cent. Cyanide consumption, 1·2lbs., zinc consumption, 0·14lb. per ton treated. On the average 0·68lb. of mercury are recovered from each ton of slimes treated. During the year 1899, 57,815 tons of tailings were treated, yielding 7,290 ounces of bullion and 23,743 tons of slimes (old accumulations from Wheeler pans) yielding 2,032 ounces of bullion.

At the Champion Reef Mine the capacity of the plant is 9,000 tons. There are 18 wooden vats each having a capacity of 54 tons. Of these 6 vats are reserved for the treatment of slimes (old accumulations from the Wheeler pans) the remainder being for mill-tailings. The treatment lasts three days, 6 vats being filled and discharged every day. During the year ending 30th September 1899, 77,330 tons of mill-tailings were treated, producing 16,543 ounces of bullion, and 22,476 tons of slimes from the pan process. The extraction of tailings averages 58·6 per cent. The strength of the strong solution is 0·25 per cent; the consumption of cyanide, 1·4 lbs. and of zinc, 0·1 lb. per ton treated.

At the Ooregum Mine the capacity of the plant is 9,000 tons per month. The percolators are open air masonry vats, measuring 55 by 25 feet with a depth of 5 feet. Hitherto the plant has only been used for the treatment of slimes from the Wheeler pan process; the average extraction being 71 per cent.

At the Nundydroog Mine there are nine percolators, *viz.*, three steel vats of 25 feet diameter by 4 feet 6 inches deep and six wooden vats of diameter 21 feet by 4 feet 9 inches deep. The treatment is similar to that of the other mines. During the year 1899, 46,047 tons of tailings were treated, yielding 5,163 ounces of bullion or an average of 2 dwts. 6 grains per ton.

With regard to working costs the following particulars for the year 1899 have been compiled from statements published by three of the leading companies:—

Name of company.	Quantity of tailings and slimes treated.	Cost of treatment.	Cost of treatment per ton.
	Tons.	£	*s.* *d.*
Mysore . . .	81,558	13,264	3 3
Champion Reef . .	99,806	17,089	3 5·5
Nundydroog . .	46,047	5,458	2 4·4

Costs were higher during 1899 than they are now, owing to a scarcity of labour produced by plague scares. The Mysore plant for instance was only worked at about half its capacity, and the cost per ton treated has since been reduced to 2 shillings and 6 pence per ton, as will be seen in the following detailed statements. At Nundydroog the cost has been reduced to 1*s*. 11*d*. per ton treated.

During April of this year the expenditure at the Mysore Mine on cyanide works No. 2 and No. 3 of the Mysore Mine for the treatment of 3,700 tons of old accumulated slimes and 9,583 tons of mill-tailings was as follows:—

Heads of expenditure.	Cost per ton treated.		Percentage cost.
	s.	*d.*	
European pay	0	2·02	6·7
Native pay	0	5·02	16·7
Repairing gang	0	0·46	1·5
Fuel	0	1·90	6·3
Cyanide	1	6·75	62·3
Zinc	0	0·85	2·8
Other items	0	1·10	3·7
TOTAL	2	6·10	100·0

European pay includes all supervision charges. Native pay includes the cost of filling and discharging the vats. The item repairing gang comprises the pay of the blacksmiths, carpenters and fitters employed on repairs and general up-keep of the plant. The details of expenditure at the Ooregum Mine during the six months ending September 30th, 1900 are as follows:—

Heads of expenditure.	Cost per ton treated.		Percentage cost.
	s.	*d.*	
European pay	0	1·55	4·8
Native labour	0	·72	2·2
Filling and discharging contract	0	3·79	11·8
Fuel	0	1·06	3·3
Cyanide	1	11·21	72·5
Zinc	0	·35	1·1
Other items	0	1·36	4·3
TOTAL	2	8·04	100·0

The cost at Nundydroog has been still further reduced, as is shown by the following statement of the average cost per ton for the eight months ending 31st August 1900:—

Heads of expenditure.	Cost per ton treated.		Percentage cost.
	s.	d.	
European pay	0	1·66	7·6
Native labour (including filling and discharging)	0	5·05	23·3
Maintenance	0	·55	2·5
Fuel	0	1·52	7·0
Cyanide	1	0·06	55·5
Zinc	0	·43	2·0
Other items	0	·45	2·1
TOTAL .	1	9·72	100·0

CHAPTER VI.

MINE ECONOMICS.

I.—MATERIALS AND SUPPLIES.

THE base of supplies for the Kolar gold-field is the port of Madras, 183½ miles by rail from Ooregum, which may be taken as the centre of the field. The mines are connected with the Madras Railway by a branch line which joins the main line at Bowringpet, 175½ miles from Madras.

From Bowringpet to Ooregum is 8 miles and to Marikuppam (Mysore Gold Mine), 10 miles.

Railway Rates.—The railway rate from Bowringpet to Ooregum is 9 annas per ton on all classes of goods; but from Madras to Bowringpet the rates vary according to the class of goods and is different for large and small lots. In the following table the rates from Madras to Ooregum are given for some of the principal supplies required by the mines[1]:—

Class of goods.	Rate per maund to Bowringpet.	Rate per ton to Bowringpet.	Rate per ton to Ooregum.
	R a. p.	R a. p.	R a. p.
Coal, in waggon loads	0 2 2	3 10 6	4 3 6
Timber, in waggon loads not exceeding 17 feet in length	0 3 1	5 3 3	5 12 3
Timber, in waggon loads exceeding 17 feet in length	0 3 8	6 3 0	6 12 0
Steel and iron rails, cast iron pipes, machinery in large lots, cement, kerosene	0 5 9	9 11 3	10 4 3
Wire ropes, galvanized iron pipes	0 7 9	13 1 3	13 10 3
Machinery in small lots	0 10 1	17 0 3	17 9 3
Explosives	1 13 4	49 7 0	50 0 0

[1] For information regarding railway rates I am indebted to the Traffic Superintendent of the Madras Railway.

These rates are on the whole moderate: thus, for example, the carrying rate for coal averages for whole distance from Madras to Ooregum, 0·367 pence per ton per mile.

Fuel.—Of the fuel used in the mines, 83 per cent. consists of Indian coal, 3 per cent. is English coal and 14 per cent. is fire-wood. The quantities consumed during the year 1899 and the average prices paid were as follows:—

Nature of fuel.	Tons.	Average price per ton.
		s. *d.*
Indian coal	144,950	26 4
English "	4,970	39 7
Fire-wood	25,273	10 6

Until recently, the Indian coal was entirely derived from Bengal collieries; but of late Hyderabad coal from Singareni has been successfully tried, and since it is 15 to 20 per cent. cheaper, while at least equally efficient, will probably supersede the Bengal coal if the good quality of the Singareni coal is maintained. The comparative merits of the two coals was recently tested by the Chief Engineer of the Mysore Mine. The period of the test was in each case 240 hours, the indicated horse-power being 340. The amount of Barakar coal used was 159·3 tons and of Singareni 148·5 tons, being 4·3lbs. per indicated horse-power per hour in the case of the Barakar and 4·0lbs. in the case of the Singareni. The amount of ash produced from the Barakar was 10 per cent. and from the Singareni 11 per cent. The cost per ton of the Barakar was R18½ and of Singareni R15½. English coal is now only imported for smithy work, for which Indian coal is not so suitable.

Timber.—The timber used on the Kolar gold-field, both for underground timbering and construction purposes on the surface, amounts to over half a million cubic feet per annum, the average price paid working out at 2 shillings and 1 penny per cubic foot. This timber is entirely of native origin and is derived chiefly from the forests on the Western Ghats, being imported to the field from Calicut in logs, scantlings and planks.

The timbers chiefly in use are the following :—

Teak or Sagwani, Kan. (*Tectona grandis*, Linn.) imported in logs, scantlings and planks, being used for pump-rods, runners and flooring. The price of logs up to 35 feet in length is about R3-8-0 per cubic foot, while the price of the scantlings and planking is R4-8-0 and R4 per cubic foot, respectively.

Urupu or Irubogam (*Hopea parviflora*, Bedd.) imported in logs, scantlings and planks and used for underground timbering. The price of the logs up to 17 feet is about R1-11-0 per cubic foot and above 17 feet, R1-13-0. The scantlings are from 6 to 12 inches square and cost R2-5-0 per cubic foot. The planks are from R1-12-0 to R2-5-0 per cubic foot.

Irul (*Xylia dolabriformis*, Benth.) imported in 1½ to 2-inch planks at R1-6-0 per cubic foot; and in poles for underground timbering from 10-inch diameter upwards, the price ranging from 12 annas per cubic foot to R1-3-0 up to 20-inch diameter and above 20-inch diameter at R1-9-0 per cubic foot.

Casuarina or Sura, Kan. (*Casuarina equisetifolia*, Forst.) imported in poles for underground and surface work at 7 to 12 annas per cubic foot.

Black Matti or Malabar walnut. (*Terminalia tomentosa*, Bedd.) imported in logs for poppet-head construction at R1-12-0 per cubic foot.

White Matti (*Terminalia arjuna*, Bedd.) imported in one-inch planks for casings, at R1-12-0 per cubic foot.

White Cedar or Toon wood, Tundu, Kan. (*Cedrela Toona*, Roxb.) in one-inch planks for casings at R2-4-0 per cubic foot and in logs for construction work at R1-12-0, up to 22 feet in length, and above 22 feet at R2-14-0.

Indian Red-wood or Bastard Cedar, Suami, Kan. (*Soymida febrifuga*, Adr.) in logs, up to 22 feet, at R1-10-0 per cubic foot, and above 22 feet at R2-4-0; used for mill pulley-wheels, screens, etc.

Sago-palm or Bhyni (*Caryota urens*, Linn.) in beams at R2-0-0 per cubic foot, used for mill-guides.

Benteak, Tam or Bandura, Kan. (*Lagerstroemia lanceolata*, Wall.) in logs and planks. The logs are used for roofing, door-frames, etc., and cost R1-12-0 per cubic foot, up to 22 feet, and above 22 feet R1-14-0 per cubic foot. The planks are used for doors and windows and cost from R1-12-0 to R2-4-0 per cubic foot.

Pillamaradu or Pallumurdu (*Terminalia paniculata*, Roxb.) in logs at 15 annas per cubic foot and in scantlings and planks at R1-6-0 per cubic foot; used underground for shoots, sollars and ladder-sides, and on surface in construction work where not exposed to the sun.

Other woods in use for general purposes are Ayni (*Artocarpus hirsuta*, Lamk.), Honne (*Pterocarpus Marsupium*, Roxb.), Tamarind (*Tamarindus indica*, Linn.), Dinduga (*Anogeissus latifolia*, Wall.), Kull-ponné, Kan. (*Calophyllum Wightianum*, Wall.).

About 75 per cent. of the timber used underground is Urupu and Irul, the remainder being Casuarina, White Cedar, Ayni and Black Matti. Urupu and Irul are preferred for sets, lagging, mine-props and stull-pieces on account of their tough and durable qualities and resistance to damp. Of the two Urupu possesses greater density, strength, and stiffness, but both are somewhat deficient in elasticity when subjected to heavy strain. Black Matti is a strong and useful timber, but is said to be subject to dry rot, and Ayni, though light, possesses toughness and elasticity, owing to its stringy texture. Casuarina is a cheap wood which is tough and elastic but has no lasting quality owing to its liability to dry rot; it is consequently not used much underground. White Cedar is used for sets and lagging.

The woods in use for construction purposes are Teak, White Cedar, Pallumurdu, Benteak, Black Matti, and Honne. Of these the Teak, White Cedar, and Pallumurdu are the most serviceable. Malabar Teak is a close and even-grained timber of glossy texture and great strength. It is not attacked by white ants or by weather. White Cedar and Pallumurdu are favourite woods for building purposes, being tough and durable if not in exposed situations.

Dynamite.—The explosives used on the Kolar gold-field consist of blasting gelatine and gelignite which with fuse and detonators are manufactured and imported by the Nobel Company. The imports for the past three years were—

	Dynamite (gelignite).	Blasting gelatine.
1897	120 tons	300 tons
1898	90 "	225 "
1899	30 "	225 "

In the mines, blasting gelatine (93 per cent. nitro-glycerine) is used almost exclusively. According to returns made by the mining companies to the Mining Inspector for last year (1899) 8,968 cases of 50lbs. were consumed in underground work, and the average price paid by the mines under the control of Messrs. John Taylor and Sons was 71*s*. per case; while the only company not under their management (the amalgamated Mysore West and Mysore Wynaad) paid 80*s*. per case. Gelignite costs the Taylor companies 54*s*. 6*d*. per case of 50 lbs.

General Stores.—Having dealt with fuel, timber, and dynamite, which are the most costly items in the list of materials used in mining, there remain the numerous stores of which a supply has to be kept up in any well-conducted mine. Of these the bulk are imported by the companies direct from England. The principal items are machine spares, shoes, dies, cams, cam-shafts, mortar-boxes, screening, bolts and nuts, pipes and pipe-fittings, steel, bar-iron rails, truck-wheels, wire ropes, belting, candles, oils, grease, kerosene, cement, quicksilver, cyanide, zinc, and assay chemicals.

The following are one or two selected examples of consumption and cost for the whole field during 1899:—

Material.	Quantity consumed in lbs.	Cost. £
Candles	547,012	10,537
Mercury	24,127	2,864
Cyanide	414,553	19,909
Zinc	43,242	602

2.—LABOUR.

The labour employed in the field comprises Europeans (chiefly Cornishmen and Italians), Eurasians and Natives, in the following proportions :—

Europeans	2·2 per cent.
Eurasians	1·6 „
Natives	96·2 „

The total number of employés is approximately 21,000. The native miners are chiefly drawn from the Madras Presidency, the best of them (Moplahs and Tyahs) coming from the Malabar Coast. The Canarese of the Mysore State are also capital miners.[1] Both Hindoos (of the Pariah class) and Mahomedans work underground. They are employed in all the different branches of mining work, such as hand and machine drilling, blasting and pit-work, timbering, shifting stuff, tramming, engine-driving, stoping, drill-sharpening, carpentering and machine-shop work. Their wages range from 4 annas to R1-8-0 per day, according to skill and individual fitness. The following is a list of the wages paid by the companies to natives. It must, however, be

[1] Mr. R. Bullen, Superintendent of the Ooregum Mine, has given me the following memorandum on the comparative quality of the native labour employed in the mines :—

Moplahs.—For underground work where there is any difficulty to be encountered such as hard ground or water, in sinking shafts, Moplahs are far better than any other coolies I have ever employed. In underhand stoping, too, they also hold their own with any of the natives.

Canarese—Coolies are excellent underground men, and are second only to the Moplahs.

Tamils.—Some of the Tamil coolies are excellent men, but, on the whole, they do not compare favourably for hand labour work with either of the above ; as machinemen they are superior.

Wudders.—These men seldom go underground, but for surface work (earth excavations to a depth of 20 feet) there are no men to compare with them in this country.

Telegus.—Some of these are excellent underground men, and they run the Canarese coolies fairly close for second place ; some of them also make good machinemen.

remembered that a very large proportion of the work is done by contract; the contractors paying the men employed on a scale fixed by themselves:—

Carpenters	6 annas	to	R 1-8	per day.
Smiths	4 "	"	" 1-7	"
Timbermen	8 "	"	" 1-5	"
Engine-drivers	10 "	"	" 1	"
Plate-layers	10 "	"	" 1-4	"
Mistries[1]	12 "	"	" 1	"
Machine-drill men	10 "	"	" 1	"
Miners	8 "	"	ans. 12	"
Blasters	8 "	"	" 12	"
Landers	8 "	"	" 10	"
Trammers	8 "	"	" 9	"
Underground coolies (muckers)	7 "	"	" 8	"
Firemen	6 "	"	" 8	"
Surface coolies	4 "	"	" 6	"

Natives are neither fed nor housed at the expense of the companies. They live in lines belonging to the company and pay a small rent for their huts.

With regard to the wages paid to Europeans, there is naturally considerable variation according to position, abilities, length of service, etc. The following is a list of the wages paid to Europeans:—

	Per month.
Underground Agents	£ 22 to £ 50
Reduction-officers	" 18 " " 40
Cyanide Chemists	" 20 " " 50
Assistant Engineers	" 18 " " 24
Smiths	" 18 " " 22
Fitters	" 16 " " 20
Mill-men	" 11 " " 15
Pitmen	" 16 " " 17
Engine-drivers	" 15
Timbermen (English)	" 13 " " 18
Do. (Italian)	" 6 " " 11
Machine-drill men (Italians)	" 6 " " 10

The appointments are made in England and the men are under contract for a term of years (generally three): a system which does

[1] The word *mistri* corresponds to *ganger* and signifies a man in charge of a working party.

not always give the best results. Quarters, furniture, fuel, lights and servants are provided by the companies. Medical attendance is free, and the men who are laid up by sickness continue to draw full pay. There is a well-equipped hospital, a good club for the officers, and reading and recreation rooms for the men.

Altogether the condition of living in the Kolar gold-fields compares favourably with most other mining centres.

13.—ADMINISTRATION AND WORKING COSTS.

The Kolar gold mines are the property of London companies and are controlled by boards of directors with headquarters in London. The technical management of the mines now working is, with one exception (the Tank Block), in the hands of the London firm of John Taylor and Sons, and the Superintendents and the other officers of the companies are appointed in London. Locally the mines are managed by the Superintendent with or without an Assistant Superintendent. The following are the natural divisions into which the local administration falls: *office,* under the Chief Cashier; *underground work,* under the Chief Mine-agent; *surface work,* under the Chief Engineer; *mill,* under the Chief Reduction-officer; *cyanide works,* under the Cyanide Chemist. In each department the chief officer has one or more assistants. The mine plans are kept up to date by the *Survey Department* which acts for the whole group of mines; but in most cases a special Survey Officer is also attached permanently to the mine. The assay work is divided between the Reduction-officers and the Cyanide Chemists. The duties of the different departments are as follows:—The Office receives the bullion won, pays the salaries of the officials and the wages of the men, keeps the stores and controls their distribution. The Underground Department is concerned with the development and mining of the ore; the Engineering Department with the erection and maintenance of the plant and machinery; the Milling Department with the crushing of the ore and the extraction of the gold by amalgamation; and the Cyanide Department with the extraction of the gold from the mill-tailings and slimes.

The following table shows some details of the working expenses, per ton milled, of six leading mines during 1899:—

Heads of expenditure.	Mysore.	Champion Reef.	Ooregum.	Nundydroog.	Balaghat.[1]	Coromandel.
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
Mine costs . . .	23 9·1	29 3·7	38 9·7 (Mine costs, Mill, Wheeler pans, Cyanide)	28 9·5	48 10·4	19 11·9
Mill . . .	5 3·0	6 11·2		5 9·6	5 9·6	6 6·8
Wheeler pans . .	...	2 10·1		0 10·5	...	...
Cyanide . . .	2 10·5	3 7·9		3 1·2	2 0·9	1 11·4
Administration . .	1 2 0	1 1·9	1 9·8	2 1·2	3 3·2	3 1·5
General charges . .	3 1·2	2 6·3	2 0·1	2 0·0	1 3·6	2 0·3
Total of the above .	36 1·8	46 5 1	42 7·6	42 8·0	61 3·7	33 8·4
Royalty on gold won .	6 6·2	6 2 5	3 6·5	4 7·5	2 7·5	0 10·7
Depreciation of plant and machinery.	1 8·6	1 1·1	0 7·3	1 8·3	9 0·6	2 0·9
London office . .	1 7·8	1 3·0	1 4·3	2 8·4	3 7·4	3 0·8
GRAND TOTAL .	46 0·4	54 11·7	48 1·7	51 8·2	76 7·2	39 9·8

The average total working cost for these six mines works out 50*s.* 6·5*d.* per ton. "Administration" in the above table comprises the salaries of the superintendent, mine-agents, cashier, accountant, storekeeper, clerks, engineers and reduction-officers. "General charges" comprises transport of ore, pumping of surface water, transport and insurance of the bullion,[2] medical establishment, survey department, passages and travelling expenses of employés between London and India, agency at Madras, law charges, telegrams,

[1] The high working cost of the Balaghat Mine is due to the mine being still in the developing stage, so that the cost of a large amount of development work has to be distributed over a small amount of ore milled.

[2] The bullion is sent to England for realization and is subject to the following charges: freight to Bombay R10 per 1,000 ounces; insurance at the rate of ¼ per cent. of the declared value. From Bombay to London it is carried and insured by the P. and O. Company for ½ per cent. of the declared value. The London bank charge for refining amounts to 2¾*d.* per ounce.

postage, and fire insurance. "London office" comprises directors' fees, salaries of managers, secretary, accountant and clerks, office rent, etc., auditors' fee, printing and stationery, telegrams, postage and sundries.

"Depreciation of plant and machinery" is an arbitrary amount annually written off the cost price of machinery and plant. "Royalty on gold won" is the amount paid to the Mysore Government at the rate of 5 per cent. of the gold produced, being the condition of the leases on which the properties are held.[1] The mines are not subject to any further rent, license or other tax. Five per cent. of the output amounts to no mean sum in the case of the richer mines, as will be seen by the following statement of the royalties paid during the past four years by the four leading mines :—

	1896.	1897.	1898.	1899.
Mysore . . .	£ 21,036	£ 24,737	£ 30,885	£ 30,080
Champion Reef . .	„ 14,984	„ 22,168	„ 25,331	„ 28,920
Ooregum . . .	„ 12,224	„ 10,325	„ 9,737	„ 11,352
Nundydroog . .	„ 8,327	„ 10,570	„ 7,704	„ 8,143

The variation in working expenses during the past four years is given for the four leading mines in the following table, in which the costs are expressed in shillings and pence per ton milled, London office and depreciation being included, but royalty given separately :—

	1896.		1897.		1898.		1899.	
	Working expenses.	Royalty.	Working expenses.	Royalty.	Working expenses.	Royalty.	Working expenses.	Royalty.
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
Mysore . . .	43 6·1	6 6·5	41 10·6	6 7·9	38 7·2	7 1·0	39 6·2	6 6·2
Champion Reef .	41 5·6	4 9·0	45 9·0	5 0·6	49 4·3	5 8·1	48 9·2	6 2·5
Ooregum . .	39 8·7	3 9·9	40 1·9	2 11·9	39 5·9	2 10·4	44 7·2	3 6·5
Nundydroog . .	34 6·8	4 2·6	32 6·0	4 3·1	45 1·1	4 0·7	47 0·7	4 7·5

[1] The present leases expire 10 years hence when a new arrangement will have to be made.

The working costs are high, but it is not difficult to account for this. First, the nature of the ore-deposit dictates a high cost of working, as, for instance, the occurrence of the pay-ore in chutes, which, though of high grade, are of comparatively limited extent. This leads to a heavy expenditure in development, as much sinking, driving and cross-cutting have to be done in waste rock in order to open up pay or chute-ore. The cost of this development work is included in the figures for working costs given above. Then again the heaviness or instability of the ground in parts of the mines necessitates a big expenditure on timber to secure the stopes, shafts, and levels. Further, it must not be forgotten that the cost of working a high-grade ore is of necessity greater than that of a low-grade ore, and the reason for this is plain. In mining low-grade stuff, the main object is to obtain a large tonnage at a low cost; consequently the stopes are carried as wide as possible and the whole mass of the ore-body is, as a rule, exploited, the exploratory or dead work being at a minimum. With high-grade stuff, on the other hand, the stopes are kept as narrow as possible and great care is exercised only to extract the payable portions of the ore-body. Much exploratory work on waste rock is, therefore, necessary in order to locate the pay-ore. Similar factors influence the metallurgical treatment. With low-grade stuff the ore is passed quickly through the mill, a high stamp-duty being maintained by the use of coarse screening and a low discharge, and the cyanide process is relied upon to catch the gold that escapes amalgamation. Whereas with high-grade ore the usual practice is to crush fine and to catch as high a percentage of the gold as possible by amalgamation.

For these reasons it is impossible to compare the working costs of high-grade mines, such as those at Kolar, with the low-grade mines of other countries, as, for instance, those of the Witwatersrand in the Transvaal. At the same time, it must be admitted that a reduction in working expenses at Kolar could no doubt be effected by improvements in milling plant, and by the substitution of automatic mechanical means for native labour in the handling of the ore delivered at the shaft-top, and of the tailings leaving the mill. The substitution of a large centrally-placed mill with heavy stamps for several small and scattered mills with light stamps, which at the present moment is being carried out on the Champion Reef, and is in anticipation at Ooregum, will decrease the cost of milling at these mines. The introduction of mechanical haulage, automatic sorting tables, tailings-wheels for elevating the tailings, and pointed boxes for classifying and filling them direct into the cyanide-vats, all these improvements would no doubt have a similar effect. So also will the introduction of water power transmitted by electricity, as it is proposed to do by the Cauvery power scheme.

CHAPTER VII.

GOLD PRODUCTION AND DIVIDENDS.

THE following statistics have been compiled from the published statements of the companies to show the gold produced and dividends paid since the commencement of operations down to the present year:—

Table No. I shows the tonnage of ore crushed per annum by the producing mines.

Table No. II shows the realized value of the gold won from the producing mines.

Table No. III shows the dividends paid per annum by the four dividend paying mines.

Table No. IV shows the revenue, disbursements, profits and dividends of the four leading mines.

The field has, as a whole,[1] since the commencement of mining operations in 1882 down to the end of June 1900, crushed 2,308,695 tons of ore, recovering 2,746,130 ounces of fine gold, realizing £11,533,757, being an average yield of 23½ dwts. of fine gold to the ton of ore crushed. The total sum distributed in dividends by the Mysore, Champion Reef, Ooregum and Nundydroog Mines was, to the end of 1899, £4,590,360.

With regard to the life of the mines it is impossible, owing to the well-known capriciousness of quartz mines, to make any reliable estimates, such as can be made in the case of the auriferous conglomerates of the Witwatersrand in the Transvaal, where the average gold-contents are fairly constant. As to ore-reserves, the larger producing mines have about two years' mill-supply in sight, and development proceeds *pari passu* with extraction.

[1] The crushings of ore of unimportant companies, which have ceased to work, such as the Kempinkote and the Yerrakonda, are not included, as complete returns of these companies are not available. The amounts recovered are so trifling as not to affect the total to any appreciable extent.

TABLE No. I.

Tonnage of ore crushed.

Year.	I Mysore.	II Champion Reef.	III Ooregum.	IV Nundydroog.	V Balaghat.	VI Coromandel.	VII Nine Reefs.	VIII Mysore Wynaad and Mysore West.	IX Road Block.	X Gold-fields.	Totals.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1882	...	...	...	132	...	...	...	...	...	...	132
1883	...	...	...	335	...	...	...	...	...	...	335
1884	454	...	...	...	...	...	...	...	...	...	454
1885	1,616	...	...	...	...	...	...	...	...	...	1,616
1886	6,077	...	...	152	83	...	...	...	...	...	6,312
1887	14,061	...	...	890	70	...	...	...	...	...	15,021
1888	20,191	...	2,119	3,887	1,278	...	...	...	...	...	27,475
1889	32,567	...	7,839	3,781	1,800	...	...	...	...	...	45,987
1890	38,812	...	12,929	9,495	5,702	...	...	...	...	...	66,938
1891	40,353	...	15,673	11,750	7,784	...	...	...	...	...	75,560
1892	44,548	2,800	24,041	18,176	8,005	...	...	...	...	...	97,570
1893	49,822	19,165	37,821	25,760	7,822	...	...	...	...	...	140,390
1894	60,957	31,604	44,754	29,750	1,776	...	...	495	...	...	169,336
1895	60,654	49,705	53,420	32,975	675	600	3,170[n]	4,275	...	...	205,474
1896	64,297	63,157	63,888	39,490	...	7,250	175[m]	14,610	...	...	252,867
1897	74,272	87,772	68,889	49,675	...	15,226	1,643[p]	16,200	...	...	313,677
1898	87,155	89,271	67,942	37,930	680[m]	15,500	11,900	17,600	...	...	327,978
1899	92,343	93,121	64,107	35,200	11,070	13,100	11,290	19,000	...	3,960†	343,191
1900 to June 30	58,276[t]	70,126[s]	27,669[t]	18,220[t]	7,030[t]	8,776[s]	9,250[t]	11,500[t]	7,240[o]	295‡	218,382
Total	746,455	506,721	491,091	317,598	53,775	60,452	37,428	83,680	7,240	4,255	2,308,695

m = 1 month
n = 10 months
p = 3 "

o = 7 months ending June 30.
s = 9 " " "
t = 6 " " "

† = Oriental lode (mill and cyanide).
‡ = Crushing W. Balaghat lode.

TABLE No. II.

Value of gold won.

YEAR.	I Mysore.	II Champion Reef.	III Ooregum.	IV Nundydroog.	V Balaghat.	VI Coromandel.	VII Nine Reefs.	VIII Mysore Wynaad and Mysore West.	IX Road Block.	X Gold-fields.	TOTALS.
	£	£	£	£	£	£	£	£	£	£	£
1882	...	...	...	37·6	...	...	...	...	...	...	37·6
1883	...	...	...	95·9	...	...	...	...	...	...	95·9
1884	1,732·5 *	...	...	...	...	...	...	...	...	...	1,732·5
1885	14,675·2 *	...	...	...	...	...	...	...	...	...	14,675·2
1886	61,953·0 *	...	...	505·3	81·3	...	...	...	...	...	62,539·6
1887	63,400·6 †	...	...	5,737·9	633·1	...	551·0	...	...	...	70,322·6
1888	73,349·6	...	15,126·3	26,230·5	10,232·2	...	3,071·0	...	...	...	128,009·6
1889	193,535·5	...	62,096·1	22,773·3	13,957·4	...	5,273·0	...	...	...	297,635·3
1890	229,966·8	...	104,047·2	58,911·9	14,068·3	...	868·0	...	...	...	407,862·2
1891	261,485·0	.	132,481·9	89,084·1	20,270·0	...	...	...	...	...	503,321·0
1892	249,331·7	10,267·1 *	202,249·7	117,635·2	27,155·1	...	...	...	...	...	606,638·8
1893	254,311·5	100,521·9 *	280,040·5	103,107·6	27,788·0	...	...	...	...	...	765,769·5
1894	203,087·3	173,844·0 *	255,273·3	110,304·4	21,909·6	... §	...	976·0	...	...	765,394·6
1895	270,911·0	264,459·7 *	263,461·7	144,079·7	1,123·8	889·0 *	4,654·5	14,125·0	...	...	963,704·4
1896	425,586·3	302,500·1 *	246,645·4	168,166·9	10,175·0	14,907·6 *	216·2	23,432·0	...	...	1,191,629·5
1897	498,292·3	448,521·4 *	208,707·7	211,396·6	636·0	46,169·8 *	856·1	39,895·0	...	...	1,454,474·9
1898	623,269·6	512,708·2 *	196,600·1	156,196·4	1,571·8 ‡	38,225·0 *	9,403·7	20,031·0	...	3,572·0 t	1,561,577·8
1899	606,947·3	584,048·2 *	229,028·9	164,114·7	29,122·5	12,056·2 *	17,841·5	16,728·0	407·3 f	884·0 g	1,661,178·6
1900	323,533·3 w	460,205·6 h	137,035·6 w	87,646·2 w	26,596·3 w	18,500·0 †	10,843·6 w	9,399·4	2,524·5 w	873·0 z	1,077,157·5
TOTAL	4,355,368·5	2,857,076·2	2,332,794·4	1,466,024·2	205,320·4	130,747·6	53,578·6	124,586·4	2,931·8	5,329·0	11,533,757·1

* Year ending September 30.
† 15 months.
‡ One month's crushing.
§ Mill tests.

w 6 months ending June 30.
h 9 months ending June 30.
f Month of December.
t 6 months (Oriental lode).

z Trial Crushing West Balaghat lode.
g Cyanide treatment of tailings from Crushing of Oriental lode.

TABLE No. III.

Dividends paid.

Year.	I Mysore (Nom. Cap. £250,000.) Number of Dividends.	I Mysore Amount paid. £ s. d.	II Nundydroog (Nom. Cap. £242,000.)	II Nundydroog Number of Dividends.	II Nundydroog Amount paid. £ s. d.	III Ooregum (Nom. Cap. £145,000 Ord., 120,000 Pref.) Number of Dividends.	III Ooregum Amount paid. £ s. d.	IV Champion Reef (Nom. Cap. £220,000.) Number of Dividends.	IV Champion Reef Amount paid. £ s. d.	Total dividends paid by the 4 companies per annum. £ s. d.
1886	1—2	30,000 0 0	Nundydroog Gold Mining Company.	...	...	...	...	...	...	30,000 0 0
1887	3	15,000 0 0		...	...	...	...	...	...	15,000 0 0
1888	4—5	31,209 10 0		1	5,112 15 0	...	...	...	...	36,322 5 0
1889	6—8	130,842 0 0		2	5,260 8 4	...	...	...	...	136,102 8 4
1890	10—11	142,142 17 0		3, 4, 5	27,719 13 8	...	...	...	...	169,862 10 8
1891	13—15	140,472 13 6		6, 7, 8	45,431 12 5	1—2	49,500 0 0	...	...	235,404 5 11
1892	16—18	112,489 10 0		9, 10, 11	57,128 10 5	3—5	104,750 0 0	...	...	274,368 0 5
1893	19—21	117,456 4 8	Nundydroog Company.	1—2	25,840 5 10	6—8	137,875 0 0	...	...	281,171 10 6
1894	22—24	62 235 0 0		3—4	32,920 10 0	9—11	131,250 0 0	1—3	70,000 0 0	296,405 10 0
1895	25—27	118,246 10 0		5, 6, 7	54,960 5 0	12—14	111,375 0 0	4—6	135,000 0 0	419,581 15 0
1896	28—30	249,311 0 0		8, 9, 10	71,500 0 0	15—17	98,125 0 0	7—9	148,500 0 0	567,436 0 0
1897	31—33	275,000 0 0		11, 12, 13	03,500 0 0	18—20	58,375 0 0	10—12	220,000 0 0	646,875 0 0
1898	34—36	375,000 0 0		14, 15, 16	63,731 0 0	21—23	45,125 0 0	13—15	242,000 0 0	725,856 4 8
1899	37—39	350,000 0 0		17, 18, 19	72,600 0 0	24—26	58,375 0 0	16—18	275,000 0 0	755,975 0 0
Total	39	2,149,405 5 2		30	555,705 4 4	26	794,750 0 0	18	1,090,500 0 0	4,590,360 10 6

TABLE No. IV.

Revenue, disbursements, profits and dividends.

	Year.	Revenue from sale of gold won.	Amount spent in winning same.	Royalty paid to Mysore Government.	Amount spent on Capital account for new works and machinery.	Total disbursements.	Profit, equals difference between Revenue and Disbursements.	Dividends paid.	Ratio of Dividend to Revenue (per cent.).
		£	£	£	£	£	£	£	%
Mysore	1896 .	425,506·0	139,887·9	21,036·1	9,306·6	170,230·6	255,275·4	249,311	55·59
	1897 .	498,292·4	155,542·9	24,737·2	10,233·7	190,513·8	307,778·6	275,000	55·60
	1898 .	623,269·7	168,226·1	30,885·7	13,547·5	212,659·3	410,610·4	375,000	60·16
	1899 .	606,947·3	182,008·8	30,080·8	3,516·6	215,606·2	391,341·1	350,000	57·66
Champion Reef . . .	1896 .	302,500·1	130,949·8	14,983·8	25,700·4	171,634·0	130,866·1	148,500	49·09
	1897 .	448,521·4	200,783·5	22,168·1	18,642·3	241,593·9	206,927·5	220,000	49·05
	1898 .	512,708·2	220,329·0	25,330·7	37,021·0	282,680·7	230,027·5	242,000	47·20
	1899 .	584,048·2	225,920·6	28,919·7	42,089·0	296,929·3	287,118·9	275,000	47·08
Ooregum	1896 .	246,645·4	126,898·4	12,223·9	412·5	139,534·8	107,110·6	98,125	30·97
	1897 .	208,707·8	138,342·9	10,325·1	543·7	149·211·7	59,496·1	58,375	20·79
	1898 .	196,600·1	134,175·5	9,737·1	4,215·7	148,128·3	48,471·8	45,125	20·29
	1899 .	229,028·9	142,989·6	11,352·6	18,864·2	173,206·4	55,822·5	58,375	20·54
Nundydroog	1896 .	168,167·0	68,251·2	8,327·0	18,644·4	95,222·6	72,944·4	71,500	42·51
	1897 .	211,396·6	80,725·1	10,569·8	25,795·3	117,090·2	94,306·4	93,500	40·42
	1898 .	156,196·4	85,509·2	7,704·3	26,286·7	119,500·2	36,696·2	63,731	40·08
	1899 .	164,114·7	82,865·8	8,143·4	16,202·7	107,211·9	56,902·8	72,600	40·42

APPENDIX.

Notes on Rock-specimens collected by Dr. F. H. Hatch on the Kolar Gold-field,

by

T. H. HOLLAND,

Officiating Superintendent, Geological Survey of India.

Notes on Rock-specimens collected by Dr. F. H. Hatch on the Kolar Gold-field,

By T. H. Holland, *Officiating Superintendent, Geological Survey of India.*

The specimens sent to represent the petrology of the Kolar gold-field and described in this note are grouped in accordance with the "stratigraphical" order—which for want of evidence to the contrary, is taken to correspond with the order of age—adopted by Mr. Foote [1] in his first description of the area, namely, (1) Granitoid Gneiss, (2) Kolar schist band, (3) Intrusive basic dykes.

In a subsequent paper, Mr. Foote [2] grouped the Kolar schist band with other similarly occurring schists in South India under the name "Dharwar" system.

(1) GRANITE-GNEISS.

The specimens of granite-gneiss agree in general characters with the type which forms the prominent tors of the Hosur and Krishnagiri taluks of the Salem district. The rock is essentially hornblende-biotite granite in composition and generally contains some epidote with brown pleochroic and frequently zoned sphene as characteristic accessories. The biotite has frequently a green colour and is occasionally altered to chlorite. The felspars include a small amount of oligoclase, whilst the potash-felspars are frequently microperthitic and in the form of microcline. The felspars often contain brightly polarising minute bodies of presumably secondary origin. Opaque black iron-ores, apatite and zircon occur as casual and irregular accessories.

The constituents often show peripheral granulation; but otherwise there are no signs of severe crushing since consolidation, and it is unlikely that these granites have been seriously deformed since their solidification, which is difficult to reconcile with the assumption that the associated highly folded schists are younger and were laid down as sediments on the denuded surface of this granite.

In addition to the specimens sent to represent the main granitic mass, two specimens obtained near the edge of the Kolar schist band, and thus not far from the visible base of the Dharwar series, are essentially granite-gneisses in composition. They differ, however, from the prevalent granite-gneiss in containing much muscovite, in being highly crushed, in the more complete destruction of the dark-coloured ferro-magnesian silicates with formation of chlorite, and in the absence of sphene. So far as they go—it would of course be dangerous to generalize from two specimens—these characters are in agreement with those which I have described in connection with the older biotite-gneisses of South India

[1] "Notes on a traverse across some gold-fields of Mysore." Rec. Geol. Surv. Ind., Vol. XV (1882), p. 199.

[2] "The Dharwar System, the chief auriferous rock series in South India." Rec. Geol. Surv. Ind., Vol. XXI (1888), p. 40.

(*Mem. Geol. Surv. Ind.*, Vol. XXX, pt. 2), for instance, those which are foliated in conformity with the hornblendic schists of the Dharwar type near Salem.

The differences between these two specimens and the prevalent form of granite-gneiss previously mentioned are not necessarily primary; they may be due to mere local secondary changes, but in view of the fact that two distinct biotite-gneisses occur elsewhere in South India, the relationship of these two varieties should be checked in the field.

(2) DHARWARIAN.

According to Mr. Foote's account of the Kolar gold-field, the Dharwar rocks are arranged in the following order on the west side of the syncline:—

f. Hornblendic schists with auriferous reefs.
e. Chloritic schists.
d. Quartzites and quartz-iron-ore rocks.
c. Micaceous schist.
b. Chloritic gneiss.
a. Micaceous gneiss (resting on granitoid gneiss.)

The specimens representing stage *a* so completely agree in all essential characters with the granitoid gneiss that I have separated them from the Dharwars in this description. The rock appears to be only a highly crushed form of granitoid gneiss, and quite different in characters to the mica schist of stage *c*. Stages *b* and *e* are not represented in the specimens sent by Dr. Hatch.

The auriferous quartz rocks are associated with the hornblende schists, and were presumably formed after the latter.

c. Mica Schist.

Only one specimen of a true mica schist has been obtained, namely, from near the base of the Dharwars, north-west of Wallagamathaconda and near the Champion Reef Mine pumping station. The specimen of micaceous and schistose rock found associated with the mica schist contains much felspar and in all essential respects its composition agrees with that of a granitoid gneiss (*q.v.*), merely differing from the latter in being more highly crushed and altered.

The mica schist (No. $\frac{14}{829}$) is a well foliated rock in which silvery mica and a dark-greenish or dark-grey variety are associated. Microscopic examination showed the colourless and the green pleochroic mica intimately interleaved. Scales separated from the rock give sometimes a wide optic axial angle, as wide as that of muscovite, and sometimes a confused figure which is due to the disturbed condition of each crystal. An occasional stout prism of a colourless mineral, probably apatite, with high refractive index and weak double refraction, appears in thin section; but the main mass of the rock is composed of mica and water-clear quartz without any discoverable trace of felspar.

A rock of this kind might very well be derived from a felspathic type by metamorphism of the felspar into quartz and colourless mica, and it is not impossible therefore that it is genetically related to No. $\frac{14}{828}$, the highly foliated gneiss from the same locality (see p. 75). It is placed here as it is reported to be within the Dharwar boundary, and the other is placed with the gneiss out of respect to its petrological similarity to the latter rocks. These two types, therefore, give us stages in a petrological transition from the quartzites to the gneiss; but the actual relationship is not probably so simple. Had the underlying granite-gneiss presented an intrusive relation with regard to the Dharwar schists, this transition band might be regarded as an example of the contact phenomena. But all the field workers agree unanimously in regarding the Dharwar schists of Kolar as younger than the granite-gneiss, and besides recounting the unmistakable nature of the evidence at Kolar, Mr. R. Bruce Foote has cited numerous instances from other areas to show that Newbold was mistaken in supposing that the granitoid gneiss in South India intruded into his "hypogene schists" (Dharwar).[1]

The apparent transition of the mica schist into the gneiss must be due, therefore, to the alteration of both classes of rocks—a kind of welding process—during the subsequent metamorphism which affected both, but to which the granite-gneiss yielded only at its marginal portions. The instance here of a mica schist and a highly crushed (schistose) mica-gneiss near the base of the Dharwars, resembles to a certain extent the Nemkal section in the Bellary district described by Mr. Foote,[2] who does not appear to suspect in it any indications of the granite-gneiss being intrusive.

It would be interesting to find out if the occurrence of mica schist is always limited to a lower stage in the Dharwars; it is frequently the case, and it is this petrographical contrast—hornblendic schists on the one hand and mica schist on the other—which serves to distinguish the Dharwar series from the so-called "upper gneisses" of Peninsular India. The contrast is one which holds elsewhere, particularly in America, between the corresponding series, for instance, the Keewatins and the Coutchichings of Canada. Because of the remarkable quiet which has been enjoyed by Peninsular India for so many geological ages every fact of this kind in connection with our azoic rocks will have more than local value.

d. Quartzites and Quartz-iron-ore Rocks.

The term quartzite is applied to the rocks composed largely of granular quartz, but none of the Kolar specimens shows the slightest structural evidence of detrital origin. They agree in all essentials with the ferruginous quartzites which so frequently form prominent ridges amongst the so-called Transition Rocks of South India.

[1] *Cf.* R. Bruce Foote, "Geology of the Bellary District." Mem Geol. Surv. Ind., Vol. XXV, pp. 22, 28, 137 and 139. [Since the above was written I have been informed that the Mysore Geological Department has recently distinguished three types of granite-gneiss in the neighbourhood of the Kolar field, and one of these appears to be younger than the Dharwars. From specimens, however, sent to represent the three different types (whose relations are shown on the geological map), I am unable to detect any essential petrological distinctions. The divisions of the granite-gneiss presumably, therefore, rest on field evidence.]

[2] Mem. Geol. Surv. Ind., Vol. XXV, p. 147 and plate vi.

The cleanest specimens are composed of interlocking granules of quartz, generally very small, but sometimes large and irregular, with elongation in the direction of the banding. The cystals do not show independent inclusions; but small needles and plates of black and brown minerals are embedded in the quartz, striking irregularly across the boundaries of adjacent cystals. Cloudy bands of very minute inclusions also traverse the rock.

The iron-ore is generally concentrated along bands which are frequently crumpled. The grains are often isometric in outline and consist of a mixture of magnetite and hematite as in the case of the more coarsely crystallized quartz-iron-ore rocks associated with the crystalline rocks further south in the Madras Presidency. Chemical examination of a specimen (No. $\frac{14}{846}$) from near the base of the Dharwars on the eastern margin of the Kolar gold-field gave the following result:—

Ferrous oxide (FeO)	11·67 per cent.	
Ferric oxide ($Fe_2 O_3$)	36·03 „	
Equal to *Iron* (Fe)	34·27 „	and
Magnetite ($FeO. Fe_2O_3$) . . .	37·61 „	
Hematite (Fe_2O_3)	10·06 „	

Plates and needles of a brown colour are associated in this rock with colourless needles of a mineral undetermined. The mineral grünerite, so common in the quartz-iron-ore rocks in the Madras Presidency (Salem district, for instance) has not been identified in these Kolar rocks.

Mr. Foote especially refers to these rocks as *hematitic* quartzites, and so distinguishes them from the *magnetic* iron-ore beds amongst the gneisses further south in the Carnatic.[1] The distinction is not, however, very satisfactory, being merely a matter of degree and that not always a noticeable one. In a paper just published, I have pointed out that the so-called magnetic ore-beds occurring amongst the gneisses of Salem, Malabar, and other districts, the magnetite is always accompanied by a large proportion of hematite, sometimes exceeding the magnetite in quantity, and on an average forming about 46 per cent. of the total ore. In the one specimen from the Dharwars of Kolar the magnetite, it is seen, greatly exceeds the hematite in quantity, and the relative abundance of the two ores is thus the reverse of what would be expected if the distinction drawn by Mr. Foote were universal.[2]

f. Hornblende schists.

The hornblende schists are generally tough, dark greenish-grey rocks, with a specific gravity 3·03—3·09. They show a distinctly foliated structure in hand-specimen, and this is sometimes accentuated by banding with coarse-grained pyroxene layers or thin lenticles of brown mica. Effervescence with acid reveals the presence of calcite in nearly every specimen, sometimes in thin films along joint planes, sometimes as distinct crystals, especially in the pyroxenic bands. A

[1] Foote. Rec. Geol. Surv. Ind., Vol. XV, p. 202.

[2] *Cf.* Holland, "Geology of the neighbourhood of Salem." Mem. Geol. Surv. Ind., Vol. XXX, p. 112.

handsome specimen (No. $\frac{14}{815}$ from the Ooregum Mine) photographed for the frontispiece, contains an abundance of calcite filling in small "pockets" produced by the folding of the schist, which shows the usual coarse-grained pyroxenic bands and brown-mica films near the auriferous lode.

Under the microscope, the hornblende schists are seen to be composed very largely, almost wholly in many cases, of green hornblende, which characteristically forms distorted, sheaf-like crystals presenting the following pleochroism :—

$\mathfrak{a}$ = straw-yellow.
$\mathfrak{b}$ = dark-green.
$\mathfrak{c}$ = blue-green.

Extinction ($c : \mathfrak{c}$) = 16°. Twins parallel to (100) not uncommon.

Brown mica, almost uniaxial, is commonly associated with the hornblende in a way which suggests its secondary development from the latter. Occasionally in radiating bundles of hornblende some of the radia consist for a part of their length of brown mica and the association is one which from previous experience might be expected as an alteration product of hornblende in rocks which have been subjected to the action of deep-seated vapours.[1] The sections of the hornblende schists are generally spotted with numerous granules of *opaque iron-ores*, more frequently pyritous than black. Rounded granules of *sphene* are common in most sections and sometimes in large grains show a distinct pleochroism. The colourless minerals are generally very irregular in their distribution and seldom abundant over a large area. Granular quartz, plagioclase-felspar and a white mica, formed by secondary alteration of the felspar, are the usual constituents of the colourless patches.

A noteworthy feature frequently seen in specimens of these hornblende schists is the occurrence of bands, half an inch wide or less, of pale-green augite, which shows the characters of *malacolite* and occurs in irregularly-shaped crystals, often intergrown in a pegmatoidal fashion with calcite. These bands show no signs of crushing and do not strictly conform with the foliation planes, but cut them obliquely as is also the case with the associated quartz veins, and they not improbably originated under similar circumstances. The malacolite has in its turn undergone a partial change into actinolitic hornblende, and field observations may possibly show that the bands are old enough to have suffered from the folding movements which are known to have disturbed the associated auriferous quartz lodes. Fragments of the same kind of pyroxene are frequently found isolated in the quartz veins, the ragged, spongy crystals of malacolite sometimes enveloping numerous granules of clear quartz.

Zoisite is a frequent constituent of the hornblende schists; but is apparently quite irregular in its distribution.

Only a few of the specimens from Kolar show unmistakable diabasic structure' the felspars retaining their ordinary elongated character with ragged outline, and sometimes with the hornblende around showing an ophitic disposition. Such rocks one might safely refer to epidiorites, and there are one or two others, now in a

[1] *Cf.*—Parsons on "The development of brown mica." Geol. Mag., July 1900, pp. 316-319. and literature therein quoted; also Van Hise, "Principles of North American Pre-Cambrian Geology," p. 690.

completely granulitic condition, which may also, from the abundance and even distribution of the felspathic constituents, be referred to the class of altered diabases; but the larger number of specimens are of doubtful origin, retaining no peculiarity of structure or of composition sufficiently well marked to definitely refer to any known more recent type. The general composition, judging from microscopic examination, is about the same as one would expect as the result of the metamorphism of a basic ash, but without chemical analyses it would be unsafe to refer the hornblende schists to such an origin. The presence of undoubted basic igneous types amongst the schists, however, settles the origin of some of the bands, and it is highly probable that they were originally basic flows accompanied by ash beds whose metamorphism would then account for the remainder of the hornblende schists.

Pseudo-conglomerates.

Specimens from one locality, Pedpalli, contain numerous isolated lumps of gneiss, not generally rounded but more often lens-shaped, and firmly cemented in the matrix by marginal intercrystallization. The fragments of gneiss are embedded in bands which are of a more felspathic and gneissose character than the average hornblende schists, and occasionally angular fragments of the latter, as well as of quartz-iron-ore rocks, are included in these gneissose bands. These rocks present many of the characters described by different authors—C. R. Van Hise, H. L. Smyth, A. E. Barlow, and others—as due to the autoclastic (Smyth) deformation of some similar types amongst the American pre-Cambrian rocks. The fragments of granite-gneiss and the gneissoid bands are probably related to one another, and due to the brecciation of an old granitic intrusion together with the hornblende schist, which it invaded. Basing his estimate on Prof. Hoskins' experiments on the flow and fracture of solid rocks, Van Hise[1] assumes that the zone in which autoclastic rocks may be produced is confined to the outer 10,000 metres of the earth's crust, and that the formation of widespread autoclastic rocks is probably limited to the outer 5,000 metres. The preservation of the individuality of the fragments in this Kolar autoclastic conglomerate shows that deformation occurred above the "rock-flowage" level, whilst the complete crystalline cementation of the whole points to deformation under great pressure. In essential points these rocks differ from true conglomerates, though it might be difficult to distinguish this kind of material from conglomerates which have been mutilated by dynamic action: the real criteria must be checked in the field, for which purpose the subjoined notes on the rock fragments constituting one of the large specimens may be of service:—

Sections from different parts of the pseudo-conglomerate:—(1) Areas of coarsely granular clear quartz in a matrix of fine granulitic quartz and felspar, with numerous shreds of green-brown biotite and colourless muscovite. Large felspars much damaged on their borders and with numerous secondary brightly polarising inclusions. The section is not essentially unlike some of the supposed older biotite gneisses of South India; but in other sections this granite-gneiss shows sphene and epidote as is the case with the prevalent granite-gneiss of the area.

(2) Section across the junction of a piece of granitoid gneiss and a thin hornblende schist streak separating the granitoid gneiss from a quartz-iron-ore band. The hornblende schist

[1] Principles of North American Pre-Cambrian Geology, p. 679.

streak thins down from half an inch to a mere film, and cuts obliquely across the foliation planes of the quartz-iron-ore fragment.

(3) Mica schist (brown mica) with band of cleaner granular quartz (? vein quartz), both types containing calcite.

(4) Quartz-iron-ore rock, very fine-grained but comparatively rich in iron-ore, cemented along a sharp junction line with a quartzose hornblendic schist, with a little brown mica and calcite, but without recognisable felspar.

(5) Quartz-felspar rock, comparatively coarse in grain and with much calcite in irregular, ragged crystals, joined, with a ragged ill-defined junction line, to mica schist, which is about ¼ inch thick and passes on the other side into a granular quartz rock with a little opaque black iron-ore.

(6) Fragment of comparatively coarse granite-gneiss containing sphene and apatite like the ordinary granite-gneiss, but with signs of considerable alteration with formation of calcite, etc. This is joined, with a fairly clean junction line, to a schist composed largely of brown-green mica, much opaque black iron-ore, quartz, sphene, and epidote.

(7) A schist composing apparently most of the material which in hand-specimen looks like the matrix holding the "pebbles." In this rock a greenish-brown mica predominates over blue-green hornblende, and the rock contains much epidote and quartz; opaque black ores being comparatively sparse and in well defined granules. The junction between this and the granite-gneiss "pebble" is never sharp and is apparently a zone of intergrowth and reaction.

The above description shows what a great variety of rocks are represented in one large specimen, and I am inclined to regard this pseudo-conglomerate as the result of the deformation of a Dharwar schist into which granitic material has intruded, and would then look upon the variations in the schist and the so-called granite-gneiss pebbles as the result of reaction under pressure. The quartz-iron-ore rock fragments have preserved their individuality more completely than any of the other types.

(3) POST-DHARWAR DIABASE DYKES.

The basic dykes cutting the Dharwars, and not themselves disturbed by subsequent earth movements, belong to the diabase (augite-plagioclase) class, and, like many others of the same type traversing the crystalline schists of South India, generally contain small quantities of micropegmatite. These rocks were described in detail by me in 1897,[1] and the Kolar specimens do not differ essentially from those previously described under Cole's term "augite-diorite." These rocks are generally composed of a pale pyroxene (augite predominating), a plagioclase felspar, near labradorite in composition, a small quantity of micropegmatite, and the usual amount of iron-ore, which is generally titaniferous and sometimes pyritous. As minerals of secondary origin, hornblende often fringes the augite crystals, whilst biotite, chlorite, and secondary quartz are often found in, or in the neighbourhood of, the micropegmatitic patches. Epidote occurs also in much altered specimens.

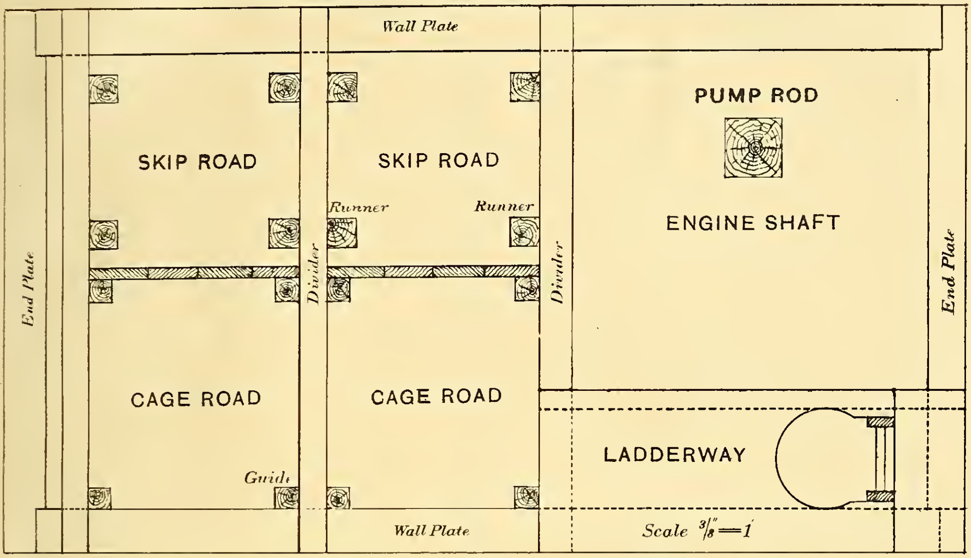
The Kolar diabases vary in texture from the coarse-grained central portions of the large north and south dyke, which cuts through the Mysore, Nundydroog, and

[1] "On some Norite and associated basic dykes and lava-flows in Southern India." Rec. Geol. Surv. Ind., Vol. XXX, p. 16, and "On Augite-diorites with micropegmatite in Southern India." Quart. Journ. Geol. Soc., Vol. liii, p. 405.

Balaghat Mines, to the compact augite-prophyrite forming 2 to 3-inch veins with tachylytic selvages in the Ooregum Mine.

On account of their geographical distribution these post-Dharwar dykes in South India are generally regarded as the underground representatives of the Cuddapah trap-flows.

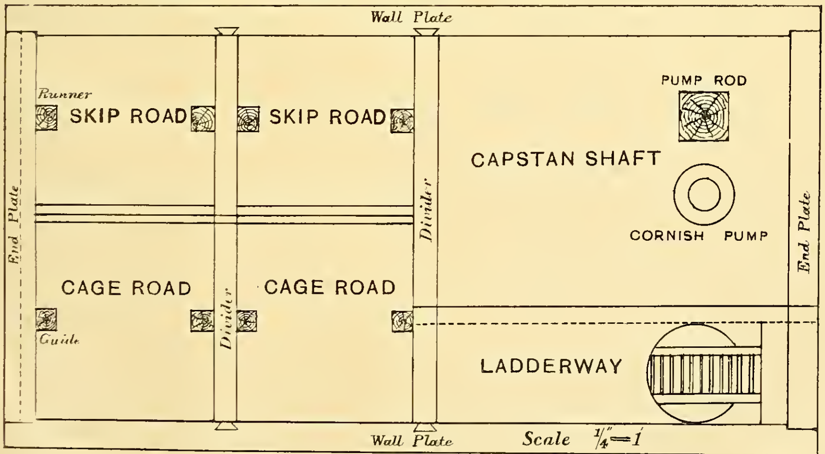
Plan of Ribblesdale's shaft, vertical part, Mysore Mine.



Dimensions of Compartments:

2 SKIP ROADS	3′ × 3′	ENGINE SHAFT	5′ × 4′-8″
2 CAGE ROADS	3′-4″ × 3′	LADDERWAY	5′ × 1′-6″
PUMP ROD	10″ × 10″		

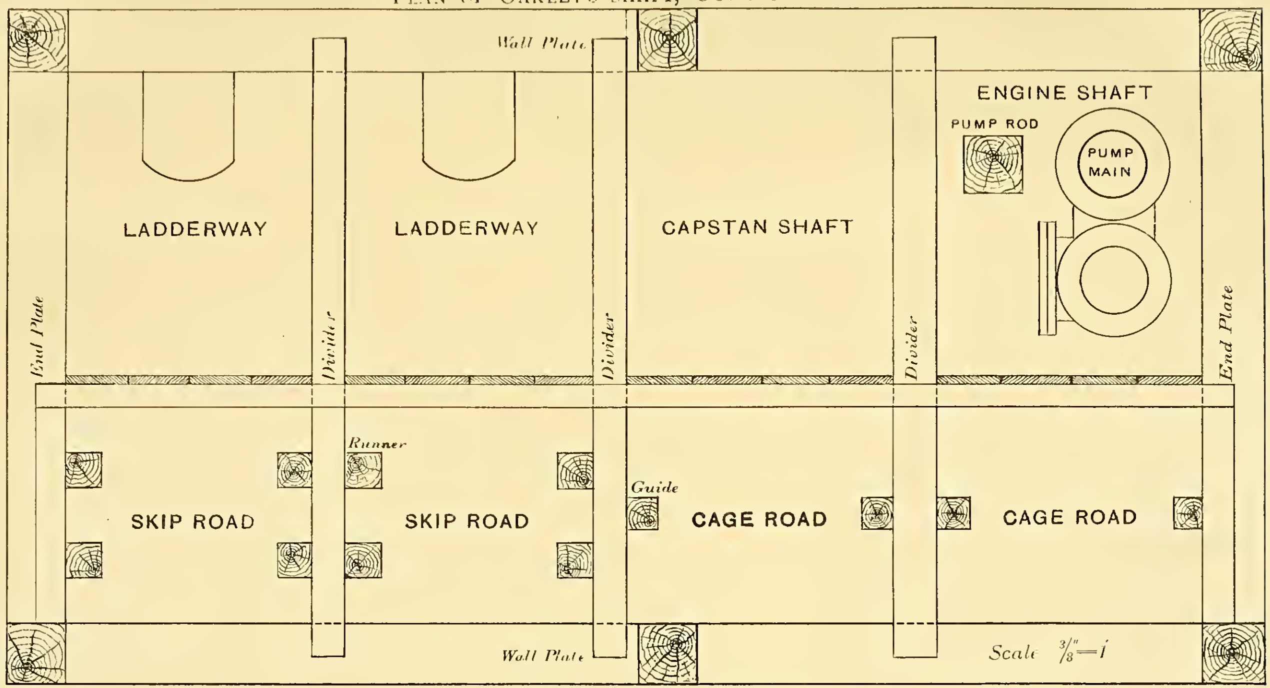
Plan of Champion Reef new vertical shaft.



Dimensions of Compartments:

2 SKIP ROADS	3′-9″ × 3′-6″	CAPSTAN SHAFT	7′-6″ × 5′-6″
2 CAGE ROADS	3′-9″ × 4′-2″	LADDERWAY	7′-6″ × 2′-1″
PUMP ROD	12″ × 12″	CORNISH PUMP	8″ IN DIAMETER

PLAN OF OAKLEY'S SHAFT, OOREGUM MINE.



DIMENSIONS OF COMPARTMENTS

2 SKIP ROADS .... 3′–5¾″ × 3′–1½″

2 CAGE ROADS .... 3′–8¾″ × 3′–1½″

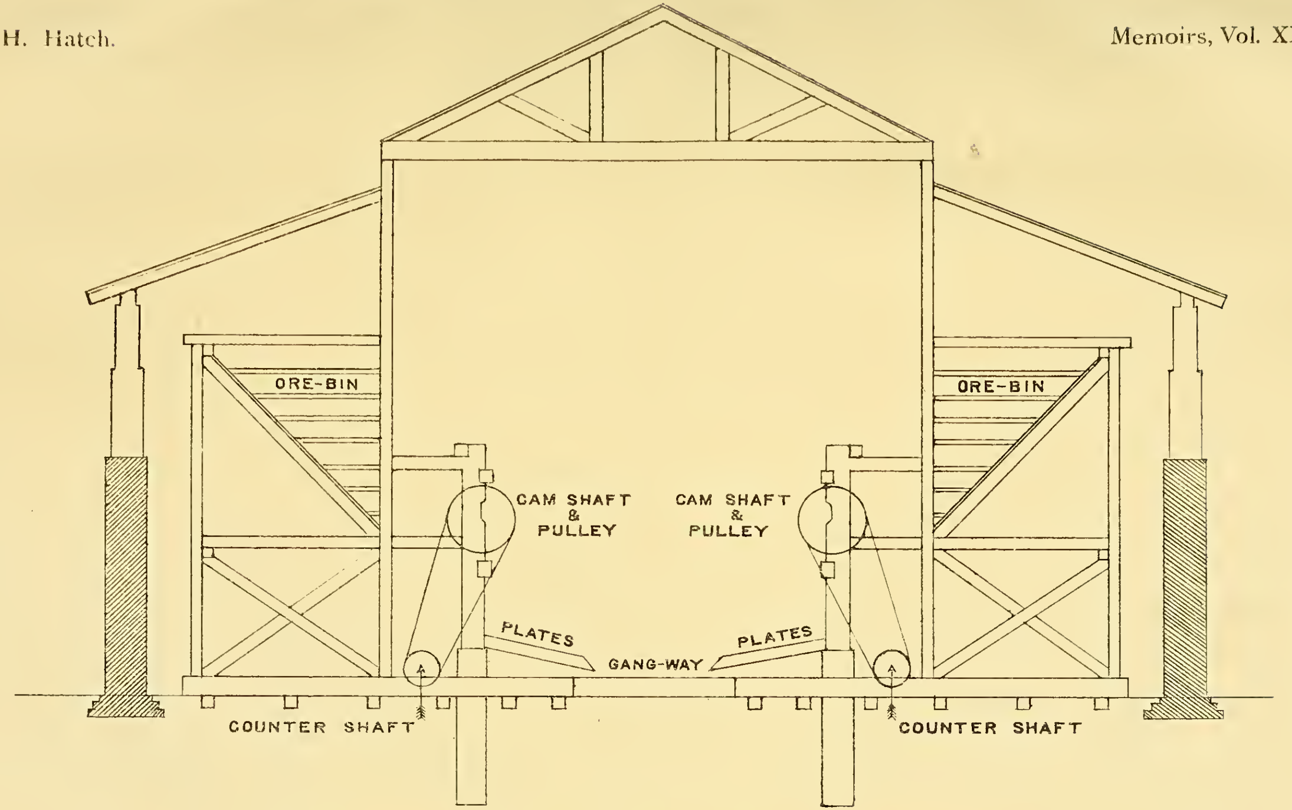
PUMP ROD .... 10″ × 10″

LADDERWAY .... 4′–6″ × 3′–5⅓″

CAPSTAN SHAFT .... 4′–6″ × 3′–8¾″

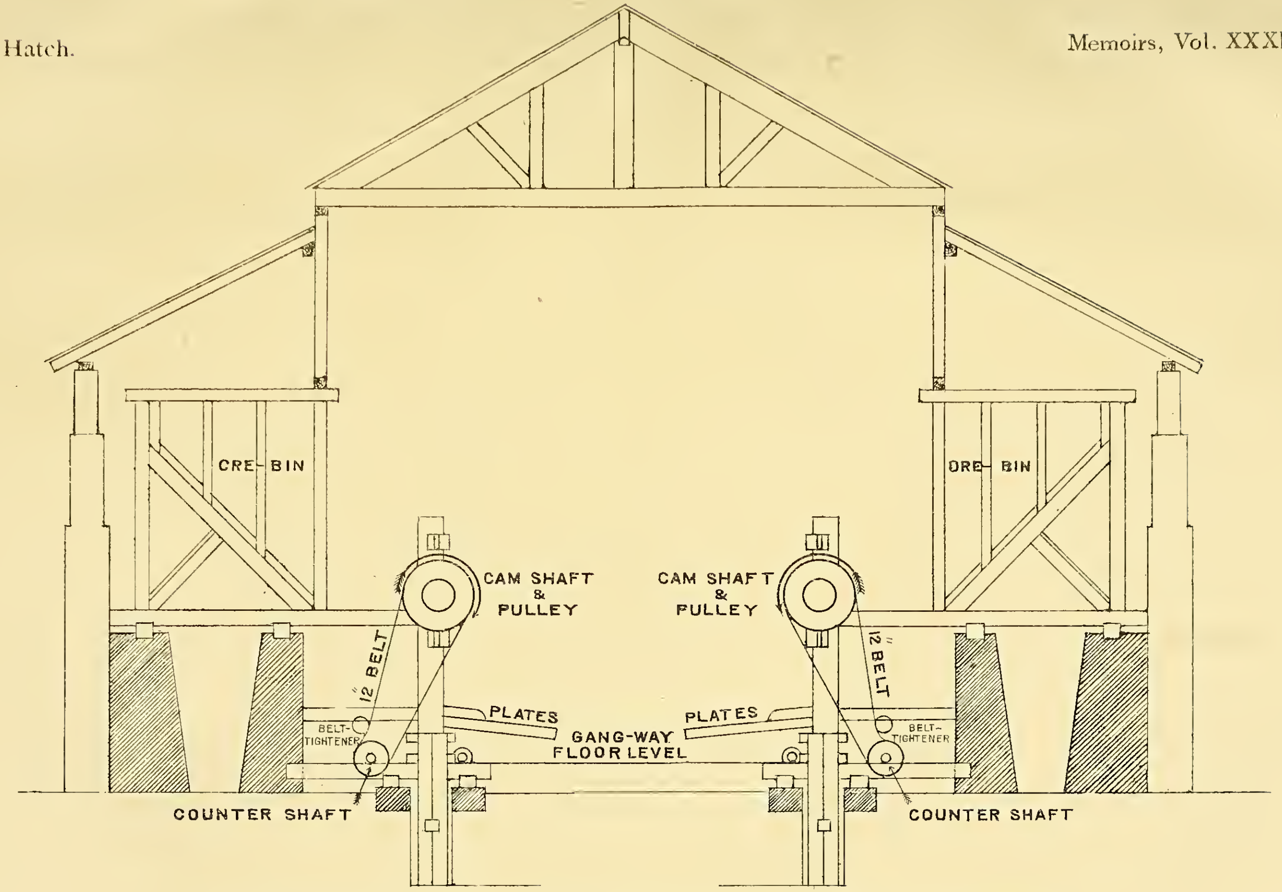
ENGINE SHAFT .... 4′–6″ × 3′–8¾″

PUMP MAIN .... 12″ IN DIAMETER



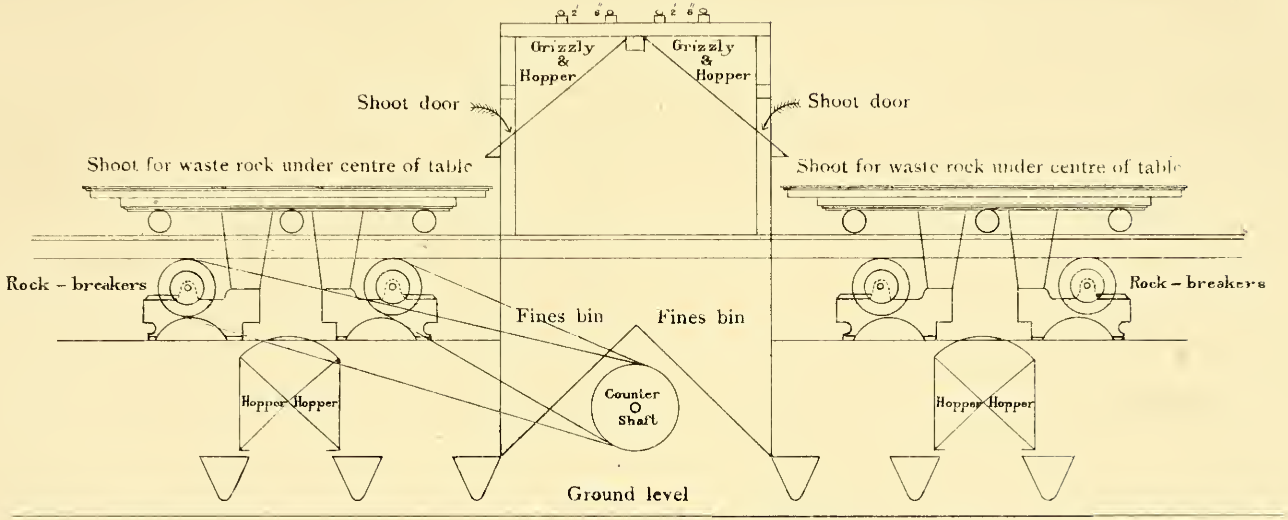
TRANSVERSE SECTION 120 STAMP MILL, MYSORE MINE.

Scale 1 inch = 16 feet.



TRANSVERSE SECTION CHAMPION REEF NEW MILL (120HEAD)

Scale 1 inch = 16 feet.

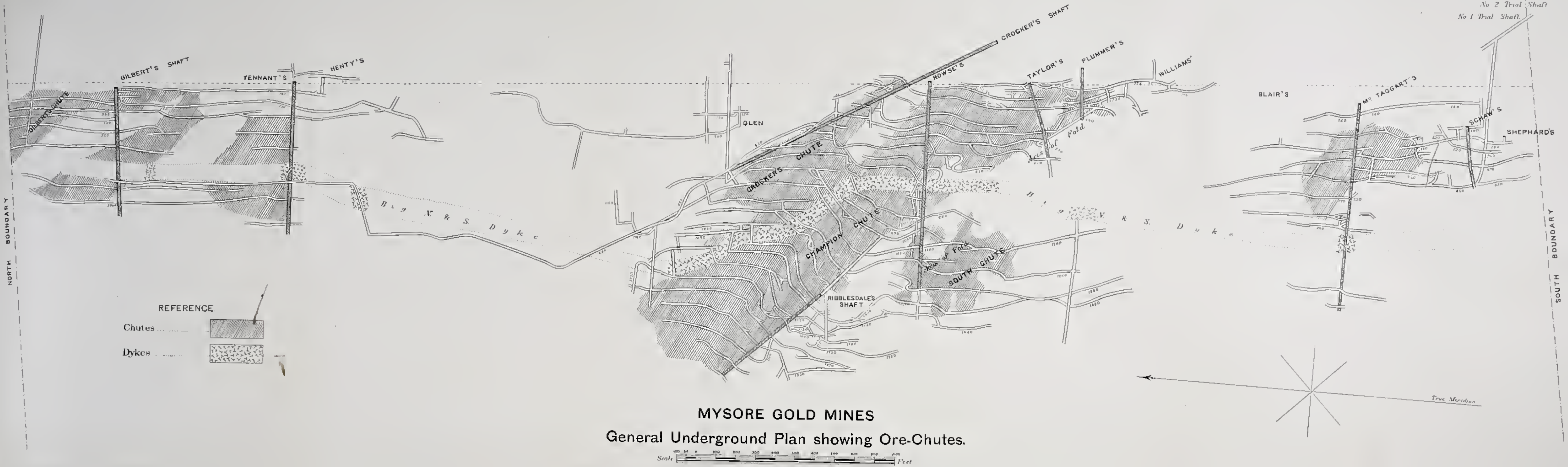


PROPOSED ARRANGEMENT OF SORTING-FLOORS & ROCK-BREAKERS AT THE CHAMPION REEF MINE.

Scale 1 inch = 12 feet.


WILLIAMS'
773
D y k e

Dr. F. H. Hatch.

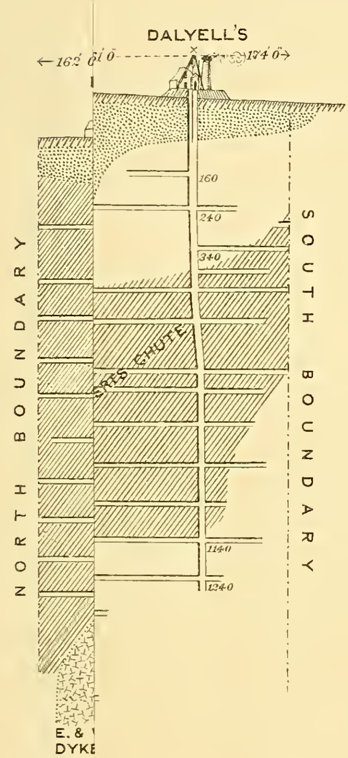


MYSORE GOLD MINES

General Underground Plan showing Ore-Chutes.

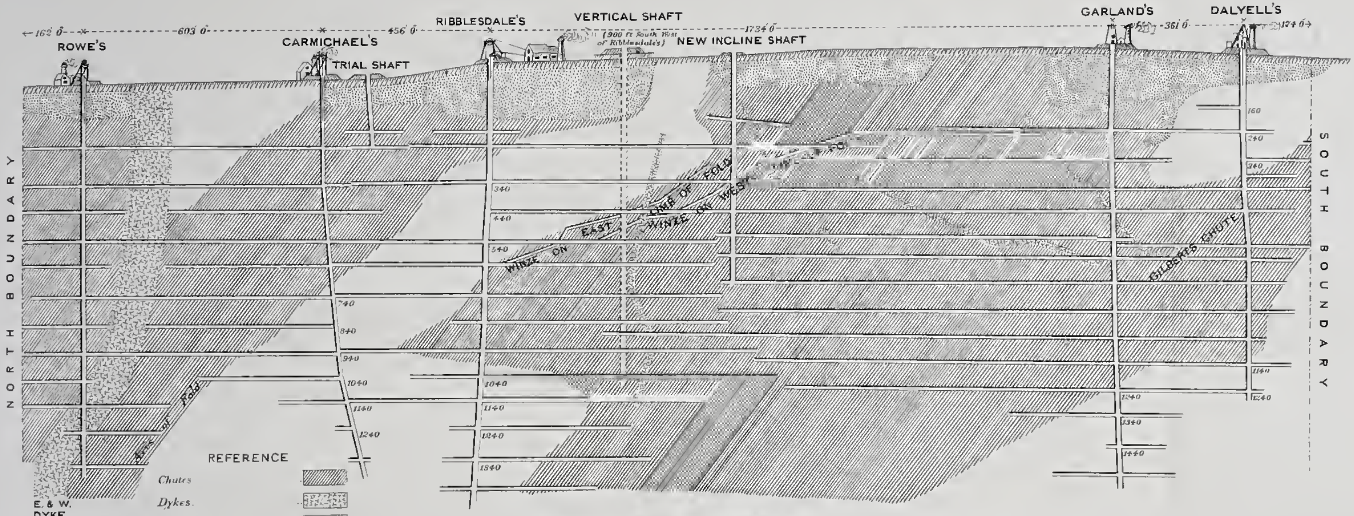
Scale — Feet

Drs, Vol. XXXIII, Pl. 8.



Dr. F. H. Hatch.

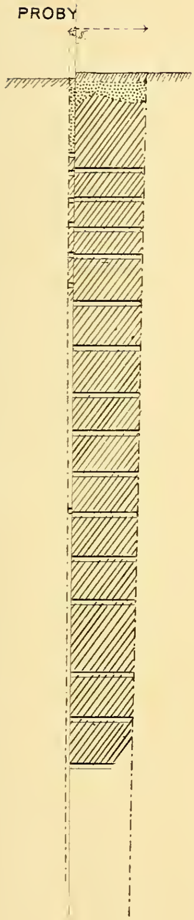
Memoirs, Vol. XXXIII, Pl. 8.



CHAMPION REEF GOLD MINE.

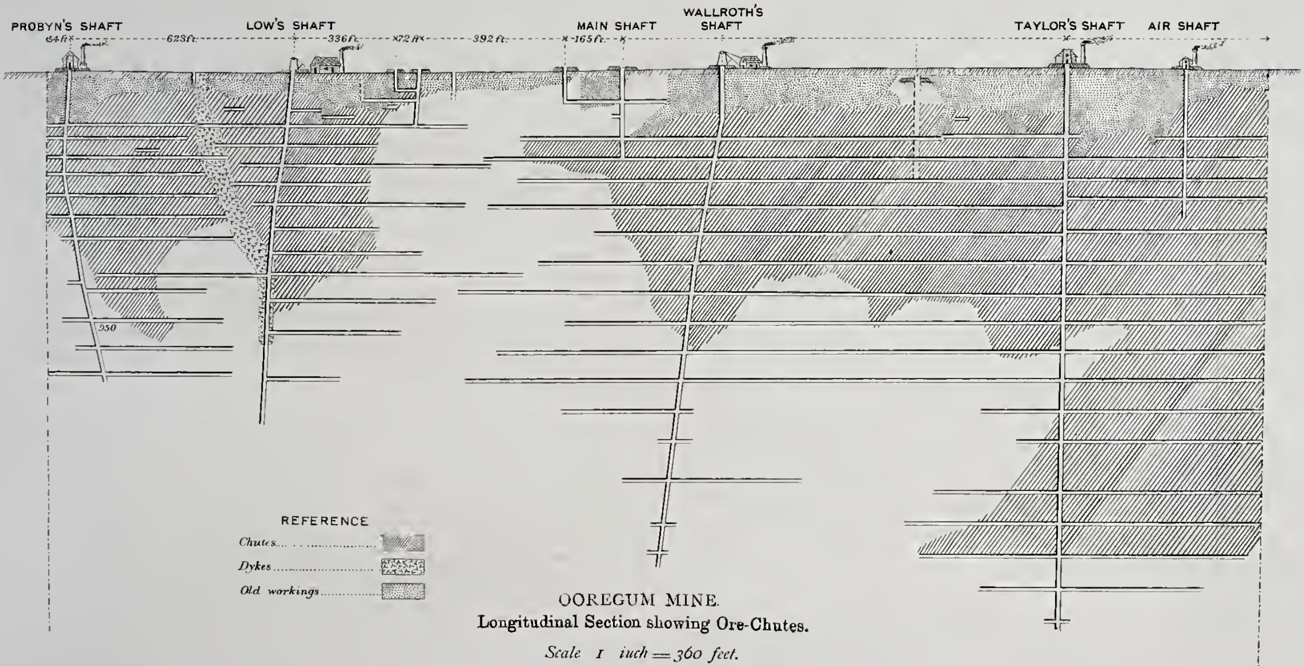
Longitudinal Section showing Ore-Chutes.

Scale 100 50 0 100 200 300 400 500 Feet


PROBY

Dr. F. H. Hatch.

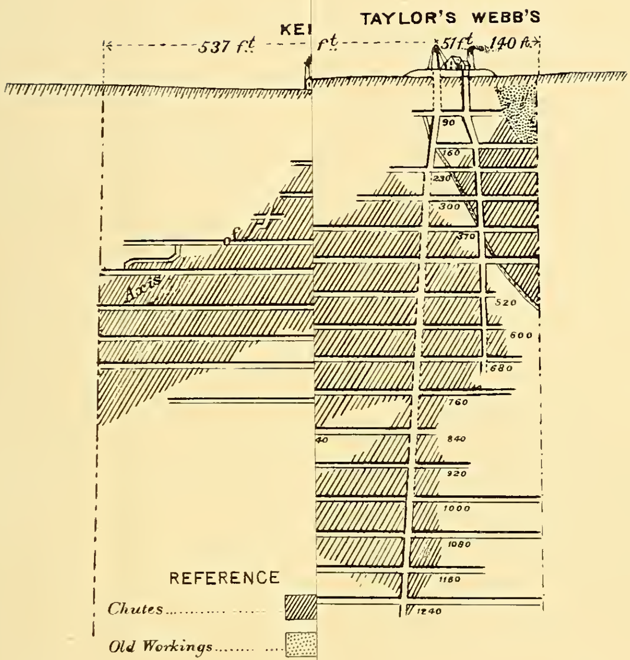
Memoirs, Vol. XXXIII, Pl. 9.

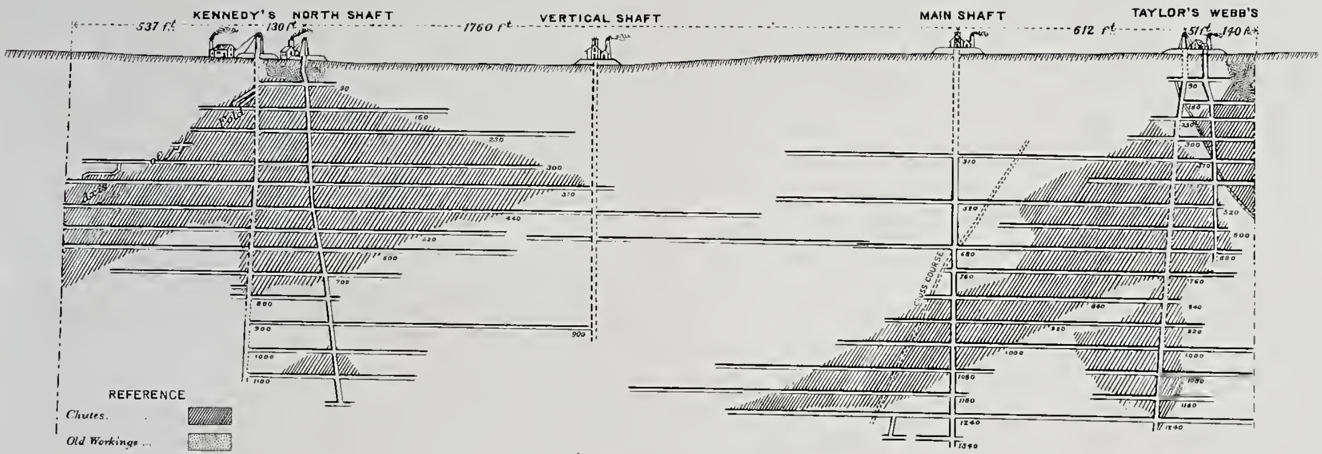


OOREGUM MINE.

Longitudinal Section showing Ore-Chutes.

Scale 1 inch = 360 feet.


TAYLOR'S WEBB'S
KEI
537 ft
ft
51 ft
140 ft
Axis
90
160
230
300
370
520
600
680
760
840
920
1000
1080
1160
1240
REFERENCE
Chutes
Old Workings

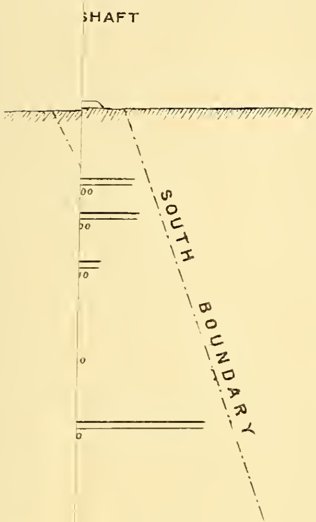


NUNDYDROOG GOLD MINE.

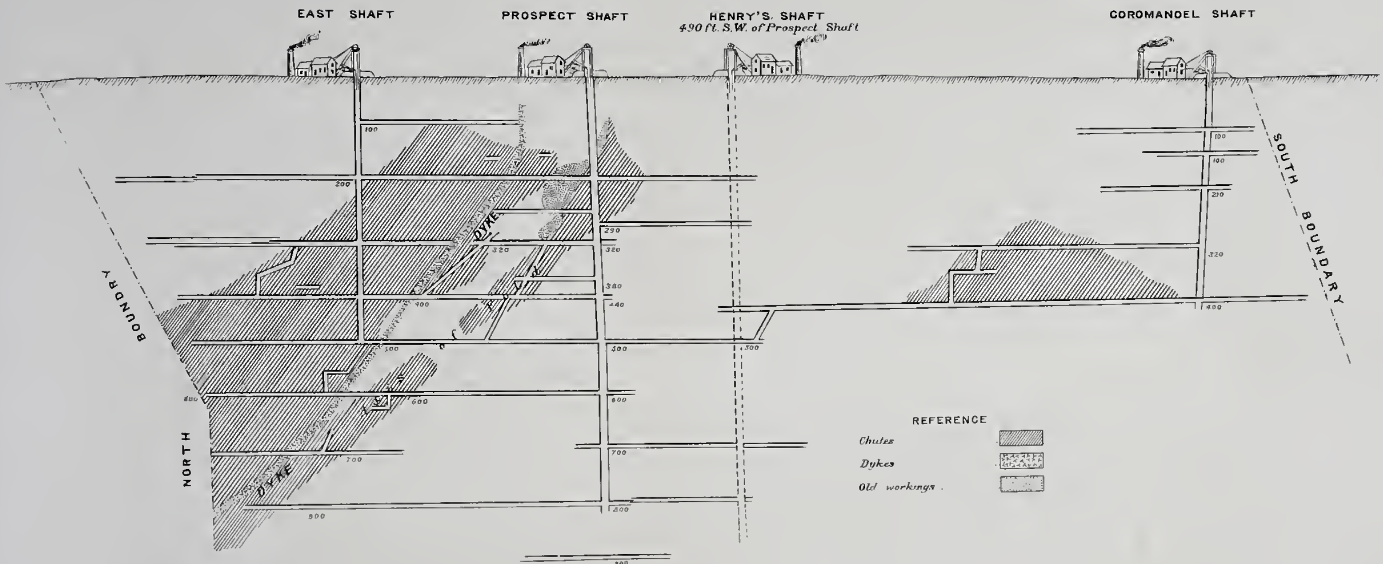
Longitudinal Section showing Ore-Chutes.

Scale Feet

XIII, Pl. II.

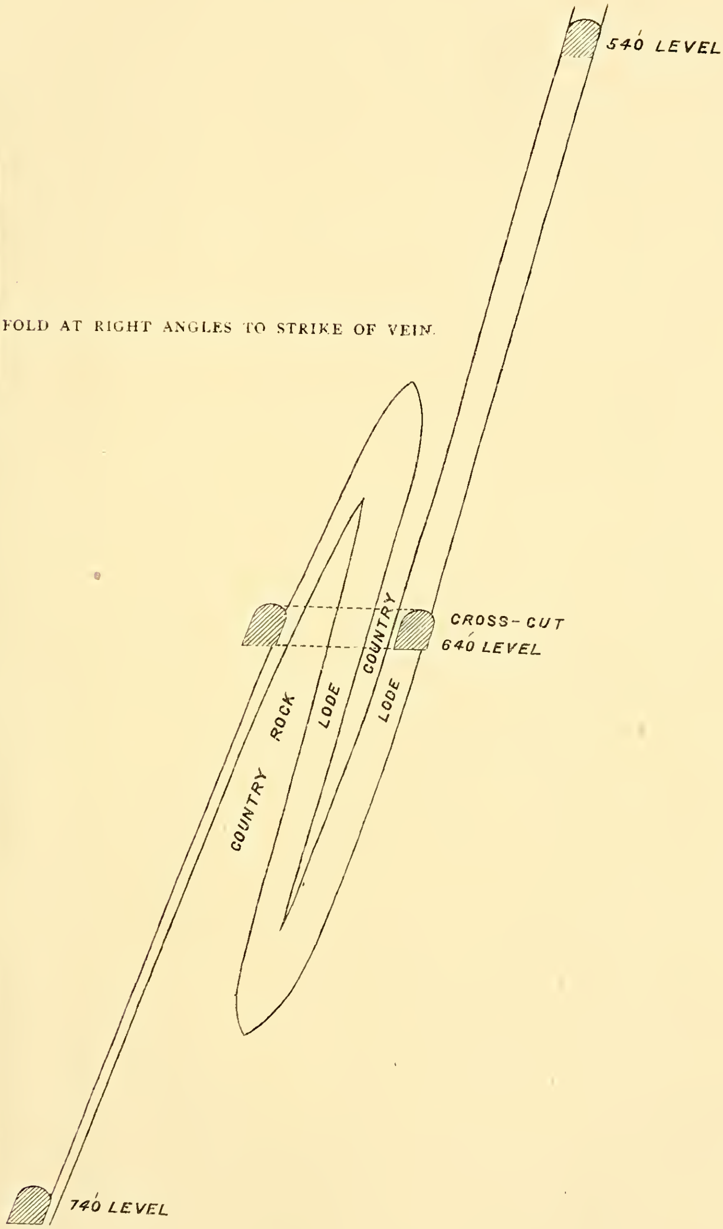


Dr. F. H. Hatch.



THE COROMANDEL GOLD MINE.

Longitudinal Section showing Ore-Chutes.

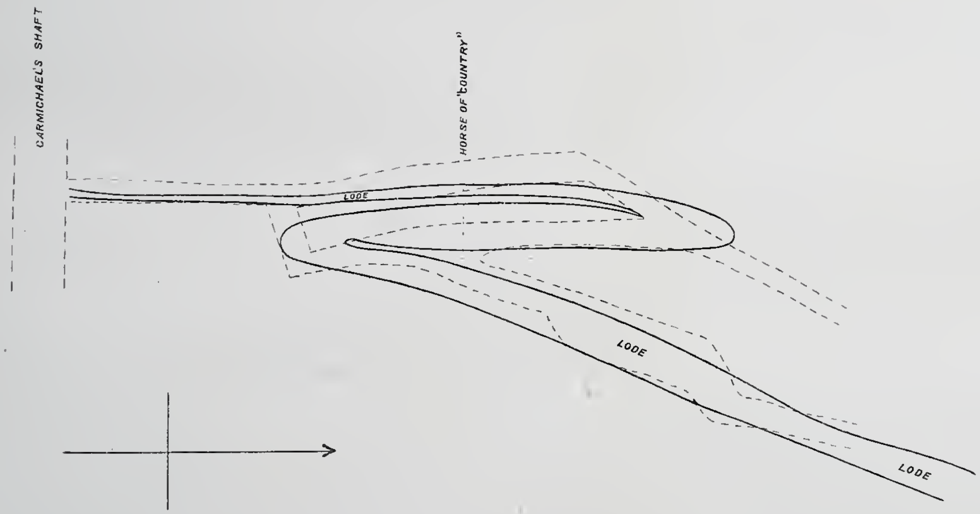


CARMICHAEL'S SHAFT.

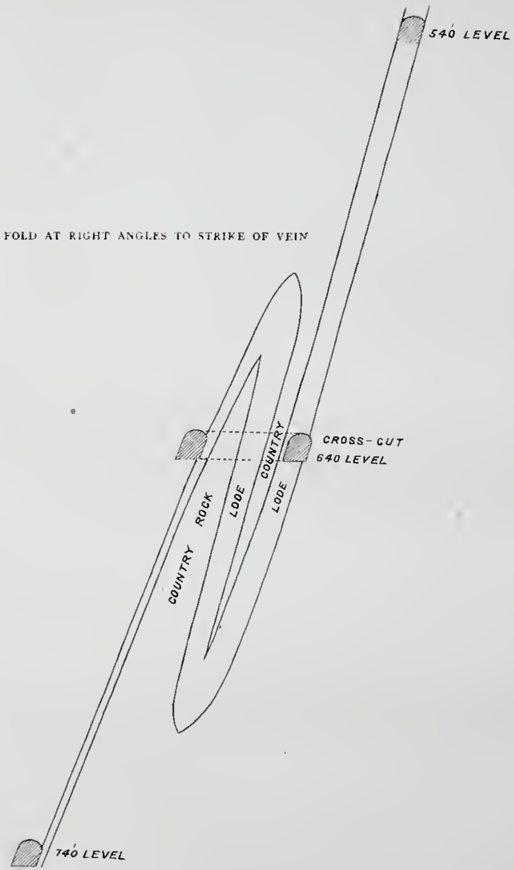
Dr. F. H. Hatch.

Memoirs Vol. XXXIII Pl. 12.

Plan of workings on 640 level.

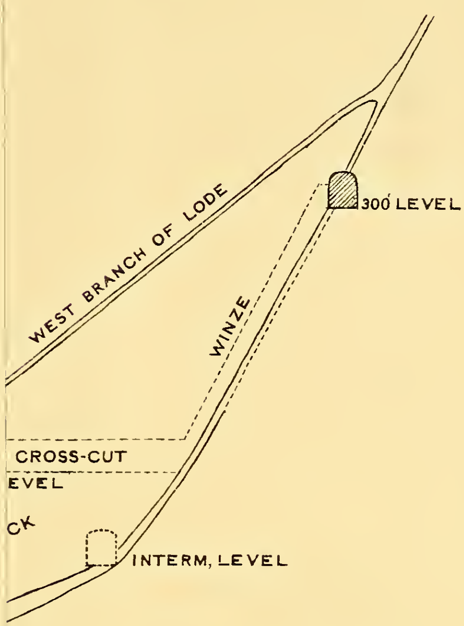


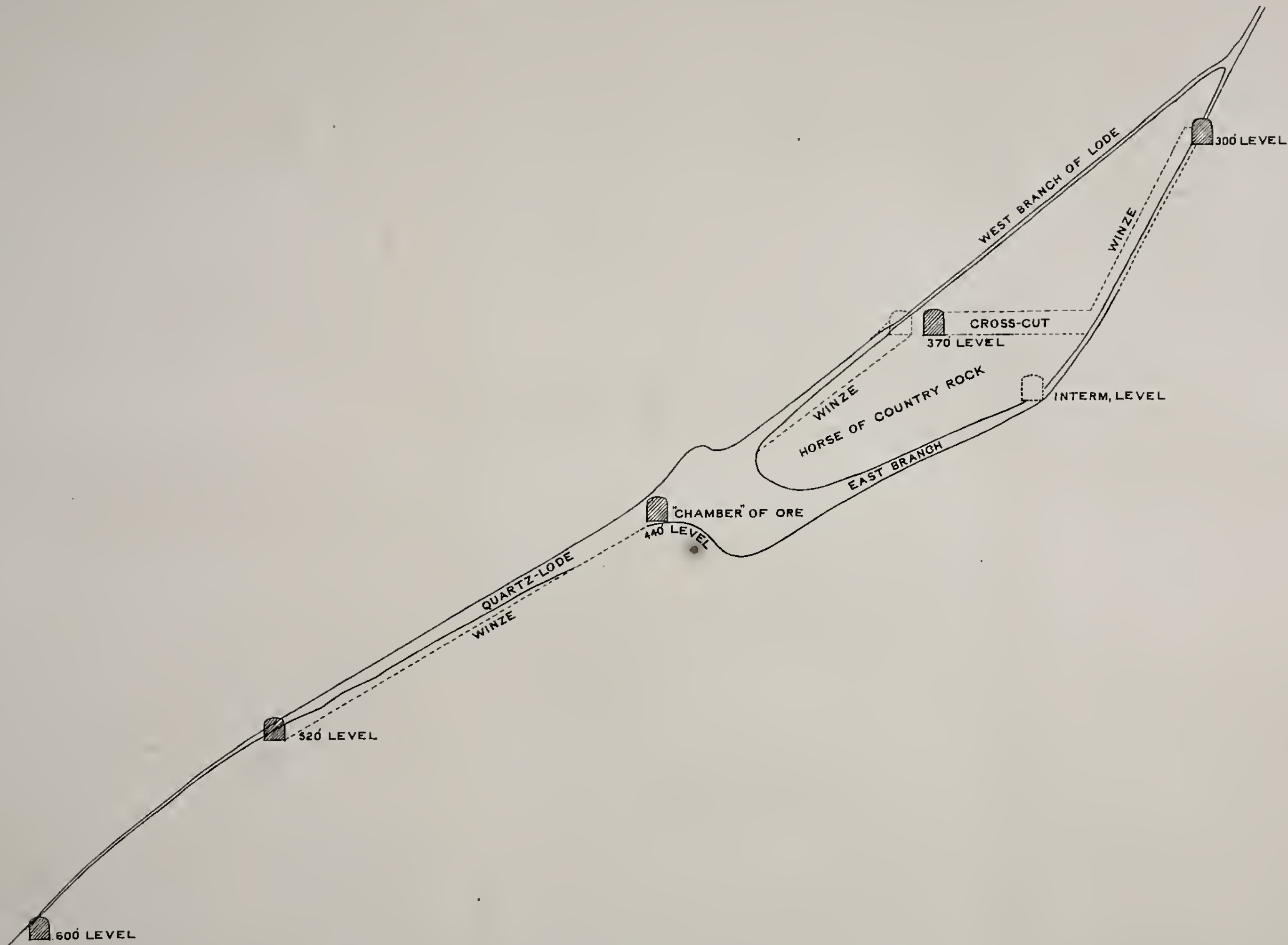
Transverse Section through fold at right angles to strike of vein



PLAN & SECTION OF FOLDED PORTION OF LODE IN CHAMPION REEF MINE NORTH OF CARMICHAEL'S SHAFT.

Scale 1 inch = 30 feet.


WEST BRANCH OF LODE
300' LEVEL
WINZE
CROSS-CUT
EVEL
CK
INTERM, LEVEL



TRANSVERSE SECTION THROUGH FOLDED PORTION OF LODE.

North end of Nundydroog Property, near the Boundary with the Tank Block.

Scale 1 inch=40 feet.

Dr F. H. Hatch.

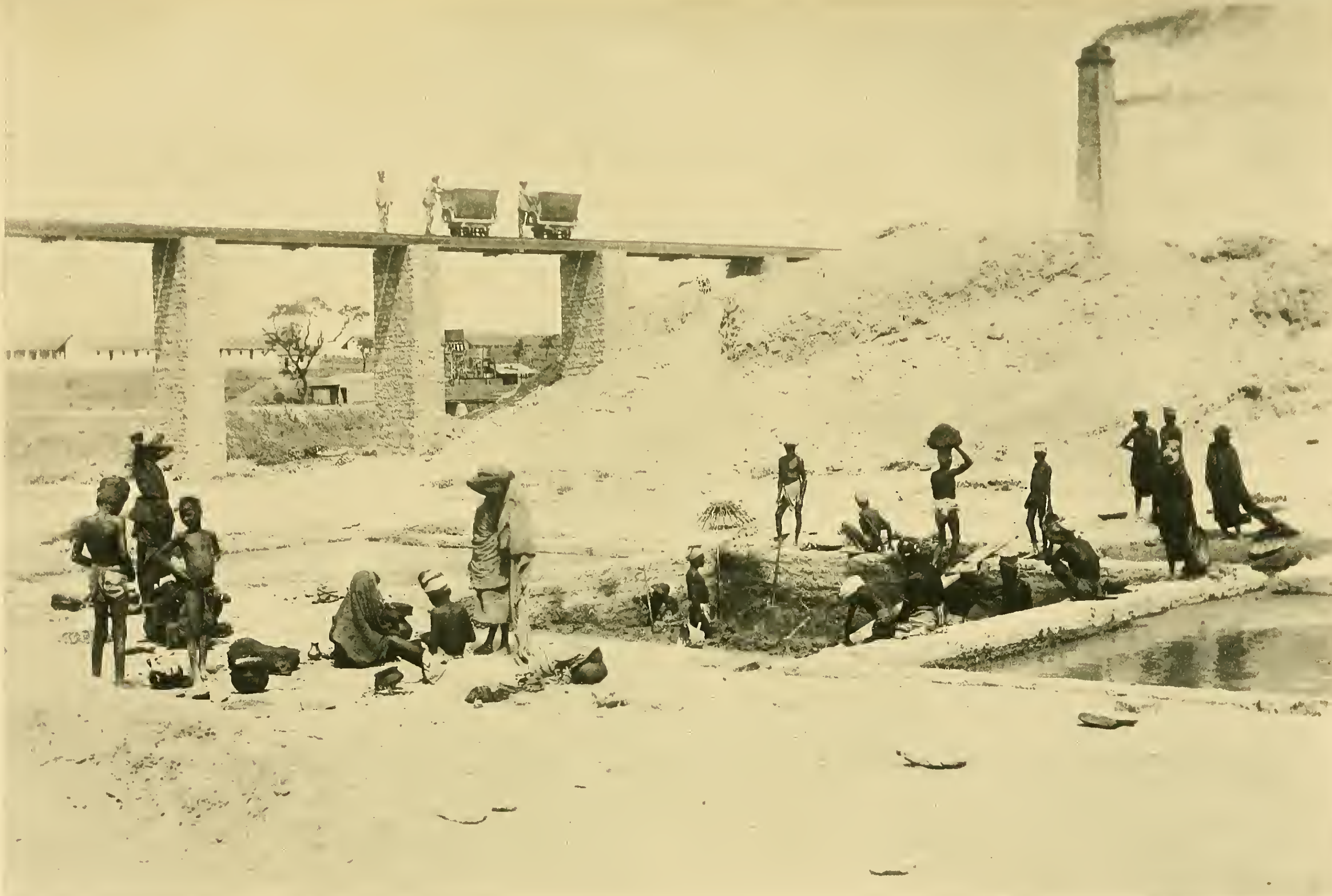
Memoirs, Vol XXXIII, Pl. 14.

Photogravure.

Survey of India Offices, Calcutta, January 1901.

CHAMPION REEF, STEEL HEADGEAR.

Photographed by Mr Del Tufo.

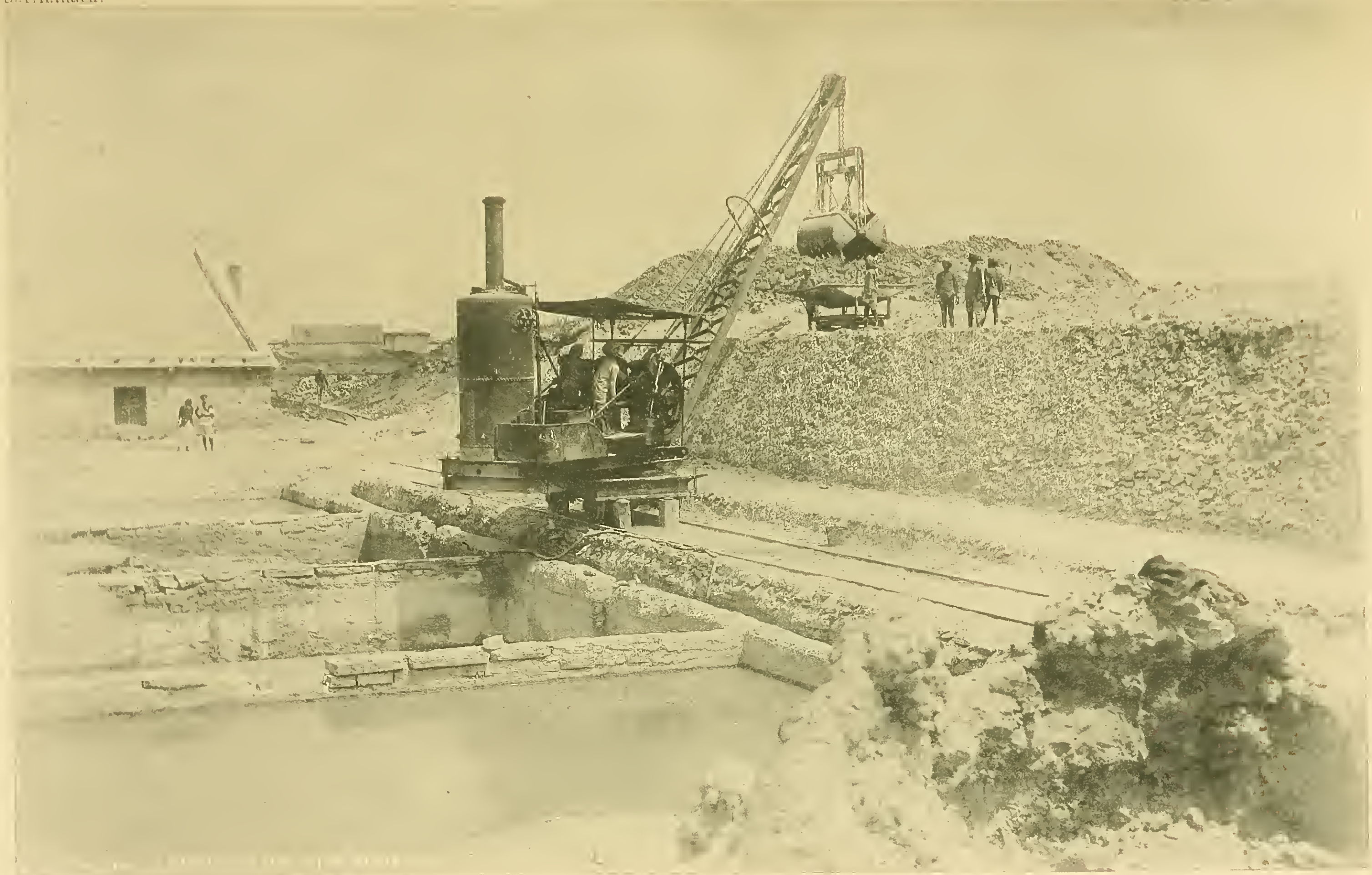


Photogravure. Survey of India Offices, Calcutta, January 1901.

EMPTYING TAILINGS PITS BY COOLY LABOUR.

Photographed by Mr. Del Tufo.

Dr. F. H. Hatch.



Photogravure.

Survey of India Offices, Calcutta, January 1901.

EMPTYING TAILINGS PITS BY AID OF A CRANE.

Photographed by Mr. Del Tufo.

Photogravure.

Survey of India Offices, Calcutta, January 1901.

INCLINE TO MILLHOUSE AT THE NUNDYDROOG MINE.

Photographed by Mr Del Tufo.

Dr. F. H. Hatch. Memoirs, Vol. XXXIII. Pl. 18.

THE NEW COMPRESSOR-HOUSE,
MYSORE MINE.

Photogravure. Survey of India Offices, Calcutta, December, 1900.

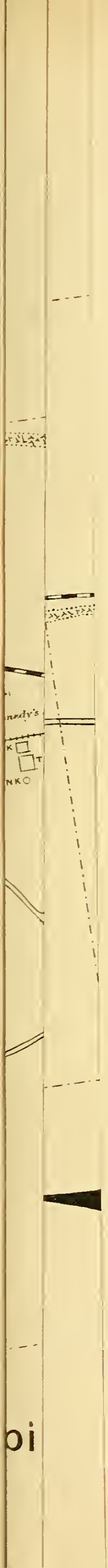
HEAD GEAR AND ENGINE-HOUSE AT RIBBLESDALE SHAFT,
MYSORE MINE.

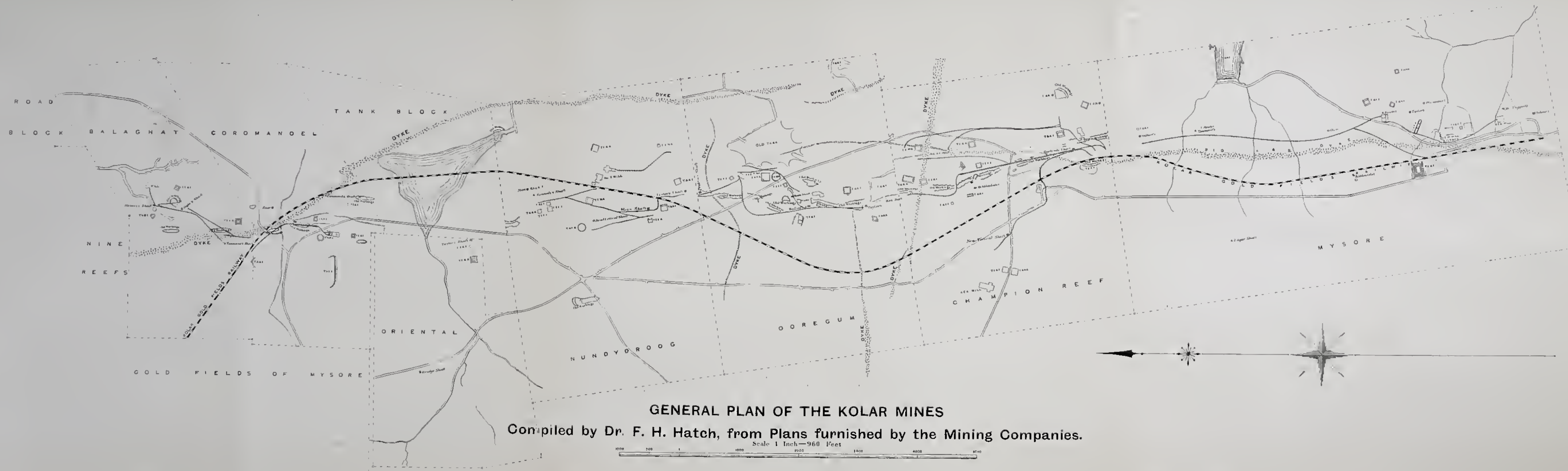
Dr F. H. Hatch. Memoirs, Vol. XXXIII. Pl. 19.

THE NEW ORE-BINS NEAR RIBBLESDALE SHAFT, MYSORE MINE.

Photogravure. Survey of India Offices, Calcutta, December, 1900.

CYANIDE WORKS WITH THE 120-STAMP MILL IN THE DISTANCE, MYSORE MINE.



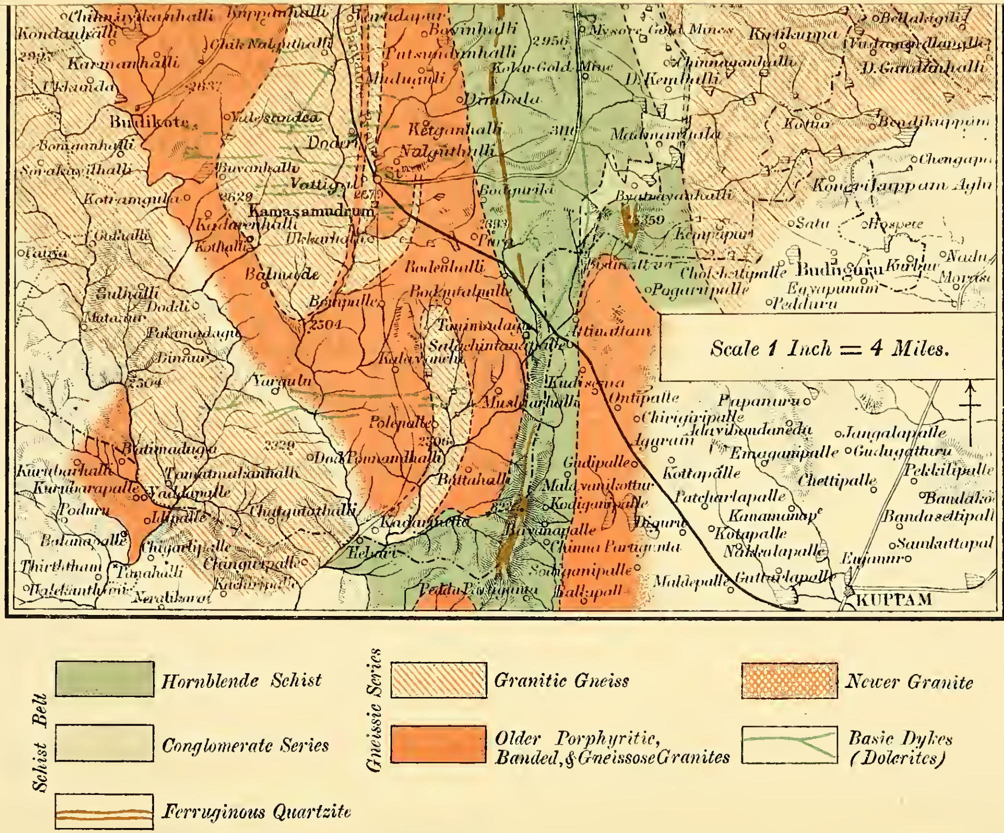


GENERAL PLAN OF THE KOLAR MINES

Compiled by Dr. F. H. Hatch, from Plans furnished by the Mining Companies.

GEOLOGICAL MAP

OF THE



GEOLOGICAL MAP
OF THE
KOLAR GOLD FIELDS AND ADJOINING COUNTRY,
SURVEYED BY THE MYSORE GEOLOGICAL DEPARTMENT.

Dr. F. H. Hatch. Memoirs Vol. XXXIII, Plate 21.

MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

INSTRUCTION TO BINDER.

1. Please substitute the new title page, table of contents, etc., in place of the former one.

2. Through a printer's error the explanations to plates 2 and 3 have been inserted between pages 48 and 53; they should be opposite their respective plates.

CONTENTS of Part 2.

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

VOL. XXXIII, PART 2.

REPORTS ON SOME AURIFEROUS LOCALITIES IN INDIA, *by*
H. H. HAYDEN, B.A., B.E., F.G.S., *Officiating Deputy Superintendent, Geological Survey of India*, AND F. H. HATCH, PH.D., F.G.S., ASSOC. M. INST. C.E., *Mining Specialist, Geological Survey of India.*

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8, HASTINGS STREET.

MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

I.—THE GOLD-FIELDS OF WAINÁD, *by* H. H. HAYDEN, B.A., B.E., F.G.S., *Officiating Deputy Superintendent, Geological Survey of India,* AND F. H. HATCH, PH.D., F.G.S., ASSOC. M. INST. C.E., *Mining Specialist, Geological Survey of India.* (With Plates I to VII.)

CONTENTS.

Part I.—H. H. HAYDEN: Historical, geological and economic aspects.

A.—INTRODUCTION.

Early history.

The early history of the gold mining industry in Wainád taluk is largely conjectural, but it would seem probable from the local traditions that the auriferous reefs were known to, and worked by, the natives at least two centuries ago: claims of a far greater antiquity for the industry have been made by numerous writers, who would identify Wainád with the Ophir of II Chron. viii. 18 and ix. 10; but the evidence in favour of this identification is far from convincing.

First official recognition.

The official history of Wainád as a gold-producing area appears to begin at the end of the century before last, when in 1798, the Governor of Bombay[1] applied to the local officials for information on the subject of gold washing and mining. The matter was again taken up in 1828, since when it has never wholly been allowed to drop, many attempts having been made, with but indifferent success, to establish the industry on a remunerative basis.

"Boom" of 1880.

Of these attempts, the most important was that which began some twenty-five years ago, and resulted in the great "boom" of 1880, when numerous companies,[2] having an aggregate capital of over four millions, were floated on the London market. A reference to the "Mining Journal" and similar papers[3] of the years 1880 and 1881 will show how

[1] "Correspondence regarding Gold Mines in Wynaad, Malabar District." Madras, 1874.

[2] See Handbook of the Indian Gold-mining Companies, 1881.

[3] See also "The Indian Gold-mining Industry," by D. E. W. Leighton, Madras, 1883.

completely the public was carried away by the tales of reefs said to carry anything from a few pennyweights to over two hundred ounces of gold per ton, a modest estimate being one ounce of gold per ton of ore! On the strength of such reports, much expensive machinery was sent out, but frequently nothing further was done, some of the machinery not being even erected, while most of the crushings that were made gave results so much smaller than had been anticipated, that the boom was followed by an equally severe "slump" from which the mines still suffer. Of the numerous companies in existence in 1880 and 1881, only three still retain their properties, but no work has been done even by them for many years, the old batteries and other machinery having been in most cases left where they stood and being now completely overrun by jungle.

Recent attempts.

An attempt, however, is now being made by a local syndicate to revive the industry, and some of the old mines, such as "Richmond" and "Dingley Dell" are being reopened, in the hope that improved modern methods, such as the cyanide process, may render it possible to work the Wainád ores at a profit.

Of the many reports on the Wainád gold-fields, the majority are merely short notes written by mining experts employed by the various companies. In most cases, the reefs had not been proved to any appreciable extent nor had any development or serious prospecting been undertaken, consequently the experts were compelled to base their conclusions on a few surface observations, and would appear, in some cases, to have been led by excess of zeal into giving opinions more favourable than were warranted by the facts.

Bibliography.

The following bibliography includes the more important papers and reports that have been published on the subject of gold-mining in Wainád:—

AINSLIE (*Whitelaw*).—Materia Medica of Hindoostan. Madras, 1813.

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Reports. King.

In 1875, attention was drawn to the reefs in south-east Wainâd, and in the same year Dr. W. King of this department visited the locality and made a report, which was published in the *Records* (Vol. VIII, p. 29): unfortunately at the time of his visit, none of the reefs had been exploited sufficiently to allow of extensive sampling, and he was consequently compelled to take samples for assay from isolated exposures of reef, often too from points which had been proved to be exceptionally rich in gold, and his estimate of the value of the reefs was, therefore, probably higher than it would have been had he been able to obtain a more extensive series of samples. In a subsequent and fuller report published in 1878,[1] this fact was recognised by Dr. King, and the results of more extensive crushing made by some of the companies then at work were given, the average yield of nearly 1,200 tons of ore being at the rate of a little over 4½ dwts. per ton, over half of this quantity having yielded less than 2½ dwts. per ton.

Brough Smyth.

In the following year, Mr. Brough Smyth was employed by the Government of India to examine the reefs of Wainád and his report was published in 1880.[2] He appears to have examined all the localities in which gold was known to occur and his conclusions were on the whole favourable. Basing his calculations on the results obtained in Victoria, he estimated that low grade ores, running even as low as 3 dwts. to the ton, could be worked at a profit. At the end of his report will be found a table of assays made by himself and others: the results obtained range from *nil* to 204 oz. of gold per ton of ore; but in very few cases is it stated how or from what parts of the reefs the samples were taken, and it is consequently impossible to base any estimate of the true value of the reefs on the above results.

Darlington.

In the year 1883, the services of Mr. John Darlington were obtained by the Indian Consolidated Gold Company to report on six properties, covering a large area in south-east Wainád. The general conclusions at which he arrived were that the reefs were not sufficiently thick and continuous to afford even a moderate amount of ore, and that the ore was

[1] Rec. Geol. Surv. Ind., Vol. XI, p. 235.

[2] "The Gold-mines of the south-east Wynaad and Carcoor Ghát."

of such a low grade as to render remunerative mining impossible. He recommended, however, that certain trial crushings should be made, but should these fail to yield satisfactory results, he was of opinion that it would be better to cease all mining operations.

Charleton.

In the following year, Mr. A. G. Charleton reported for the same company on the properties which had previously been examined by Mr. Darlington, and also on the Phœnix property at Pandalur. His conclusions were similar to those arrived at by Mr. Darlington in the previous year. With regard to the Phœnix property, owing to the fact that the ore did not promise a yield of more than 3 dwts. to the ton, he recommended the complete abandonment of the works, unless further tests, then about to be made, gave substantial reasons for continuing.

With regard to the properties previously reported on by Mr. Darlington, he advised that average samples be taken from certain points, and should these prove satisfactory he recommended the milling of a large quantity of ore from each of those points. "If", he continues, "on the other hand, these tests should turn out unsatisfactorily, looking at the general result that has attended mining almost throughout the district, *or even now*, it becomes a question whether all thought of mining in the neighbourhood had not better be abandoned."

The results obtained up to this time throughout Wainád were so poor that mining operations were gradually suspended; the Phœnix mine, however, was kept open for some time longer, and is said to have yielded sufficient gold to pay working expenses, but was eventually shut down, by order of the Government, owing to the frequency of accidents. Work is also said to have been carried on in a desultory way on the Alpha Gold Mining Company's property, near Devála, till about the year 1893, when all further attempts were abandoned.

Reasons for re-examination.

It having been decided by the Government of India that a re-examination by this department of the chief auriferous localities of India was desirable, the old mines in south-east and south Wainád were visited during the camping season of 1899-1900, and a preliminary note on the subject was published in the General Report for 1899-1900.[1] The extraordinary discrepancy between the reports, made on the various properties of Wainád by mining experts, and the actual results subsequently obtained made it desirable that a careful investigation of the reefs should be made in order to ascertain how far improved modern methods might render it possible to revive, with some prospect of success, the gold-mining industry in this area: for the belief is undoubtedly still current in many quarters that the previous failures were in large part due to unsuitable appliances as well as to inefficient supervision. It was, therefore, arranged that Dr. F. H. Hatch, whose services had been temporarily retained by the Secretary of State for India, should include the Wainád mines among those to be examined by him while in India.

Preliminary examination of south and south-east Wainád.

A preliminary visit was, therefore, paid to south and south-east Wainád with a view to examining as far as possible all the old mines and ascertaining how far it would be practicable to make a detailed investigation of the characters and value of the quartz reefs. Most of the tunnels and shafts had, during the last ten years, become to a great extent filled with débris and water, and it was considered advisable to open up one or more of the most important mines. The preliminary examination showed that the "Phœnix" mine, near Pandalur, and the "Alpha," near Devála, were the most suitable for this purpose, having been developed to a greater extent than any other mines in Wainád.

Preparations for sampling.

Between the months of July and November 1900, the work of clearing and opening up the old drives was carried out, for the greater part of the time, under the superintendence of Mr. Stonier, Mining Specialist, assisted

[1] General Report, Geol. Surv. Ind., 1899-1900, p. 53.

by Lala Kishen Singh, Sub-Assistant of this department. Considerable difficulties were met with in carrying out this work, chiefly owing to the season and the abnormal rainfall: Mr. Stonier had completed the greater portion of the work when he handed over charge to me in October. By the end of November, we had succeeded in opening over 3,500 feet of drives, and the sampling of the reef was then undertaken by Dr. Hatch.

B.—GEOLOGICAL FEATURES.

The chief topographical and geological features of Wainád have already been described by Dr. King (Rec. Geol. Surv. Ind., Vol. VIII) who included most of the rocks found in the area visited by him in the archæan system (crystalline or gneissic series).

Dr. King's classification.

He describes four different varieties of gneiss: of these three have certain points of resemblance to one another, but the fourth, which he calls a "syenitoid and quartzose gneiss" is quite distinct and was formerly placed in the Upper (Bengal) division of the gneisses. The great advances recently made in our knowledge of the petrological characters of the rocks of Southern India, and especially the work of Mr. Holland, have now proved that this rock, to which in 1893 Mr. Holland gave the name of *charnockite*, is not only younger than the majority of the biotite gneisses, but is intrusive in them.[1]

The rocks then in south-east Wainád fall into five classes:—

1. Gneisses.
2. Members of the *charnockite* series.
3. Ferruginous quartzites.
4. Intrusive rocks, including older and younger basic intrusives, biotite granite, and mica-bearing pegmatites.
5. Quartz reefs.

[1] Holland. Mem. Geol. Surv. Ind., Vol. XXVIII, Pt. 2, 1900.

(1) *Gneiss.*

The rocks which fall under this head are typically *biotite gneisses* and show but slight variation from a common type; they form the greater part of the "country" rock in south-east Waïnád, and extend over almost the whole area from Nadugani to Cherambádi. They are always well foliated, the strike of foliation being almost invariably from east-north-east to west-south-west. Intrusions of charnockite and of a basic hornblendic rock are not uncommon.

Constituent minerals.

The chief constituents of the gneiss are *quartz*, *felspar*, *biotite garnet* (Pl. 2, fig. 1). These are almost invariably present, while a few other minerals, viz., *zoisite*, *epidote*, *chlorite*, *muscovite*, *rutile*, *iron ores* (*magnetite*, *pyrite*, *ilmenite*), *sphene* and *calcite* are accessory, many of these being of secondary origin. *Actinolite* is found in the more basic bands occurring in the gneiss, and is particularly common at its junctions with the charnockites and with certain hornblendic rocks (*epidiorite*) found at the Phœnix mine on the southern flank of Hadiabetta and on Hamsluck estate, near Devála.

Quartz.

The *quartz*, which occurs in considerable quantity, is usually clear and granular, but occasionally contains numerous hair-like inclusions, too small to be determined definitely.

Felspar.

The *felspar* includes both monoclinic and triclinic varieties: the latter represented by small crystals of oligoclase albite, and a form approaching labradorite; they are at times fairly fresh but are frequently decomposed with the formation of epidote and muscovite, which in some instances completely replace the original felspar.

Biotite.

The *biotite* is of the common brown variety and is seldom, if ever, absent.

Garnet.

Garnet has been found in almost every specimen examined and is a characteristic constituent of the gneiss: the crystals are usually cracked and broken and often decomposed, the resulting minerals being as a rule chlorite and iron ores. The chlorite is formed at first in thin bands along the cracks (Pl. 2, fig. 2), whence it gradually extends till nothing remains but a few minute grains of garnet in a confused mass of chlorite (Pl. 2, fig. 3). Where the garnet has been more than usually ferruginous, it is decomposed into a mass of limonite containing some chlorite and a few still unaltered fragments of garnet. The alteration is always most strongly marked in the neighbourhood of the charnockite intrusions.

Accessory constituents.

The remaining minerals found in the gneiss may be regarded merely as accessory constituents, though a few, such as chlorite, zoisite, epidote,—all probably of secondary origin—are rarely absent. Calcite occurs in the biotite gneiss of Hadiabetta, in the neighbourhood of the quartz reefs.

Intrusives in the gneiss: charnockite.

As already stated, intrusions of charnockite are found at several points in south and south-east Wainád: where these occur, the biotite gneiss has undergone considerable alteration (Pl. 3, fig. 1); the felspars are decomposed and contain much epidote, rutile and kyanite (Pl. 3, fig. 2); the quartz is full of microscopic granules and rods—possibly rutile—and actinolite is common but is usually altered into chlorite. An exactly similar rock has been described by Mr. Holland from the neighbourhood of Salem,[1] as the result probably of alteration of the biotite gneiss by charnockite: throughout south-east Wainád it has invariably been found between these two rock-series where they approach one another closely, nor has it been found except when those conditions prevail, and it would, therefore, seem safe to assume that it is a product of contact action between the two series.

Other phenomena, similar to those already noticed in Salem by Mr. Holland (*loc. cit.*), and pointing to an intrusive origin for the charnockite, occur also in Wainád: these are—

(*a*) the presence of irregular masses and bands of charnockite

[1] Geology of the neighbourhood of Salem. Mem. Geol. Surv. Ind., Vol. XXX, Pt. 2, p. 122.

which extend from the main mass into the gneiss, frequently running across the foliation planes of that rock:

(*b*) the absence in these bands or tongues of any foliation, although the surrounding gneiss is well foliated.

These phenomena may be observed on the ghát road from Nadugani to Carcoor and on the Marpanmudi ridge between Deväla and Pandalur, and leave little room for doubt that Mr. Holland's theory of the igneous origin of the charnockites is the true one.

West of Pandalur, the gneisses become much more hornblendic, and biotite is to a great extent replaced by actinolite, the prevailing type being composed of quartz, felspar—with much plagioclase—actinolite and large quantities of zoisite and epidote. Garnet, though rarely absent, occurs in much smaller quantity, while chlorite is common.

Epidiorite.

This change is due to the prevalence in this area of a basic felspar-hornblende rock, which occurs in great masses on the southern flank of Hadiabetta and elsewhere between Pandalur and Cherambádi. A band occurs also at the waterfall on Hamsluck estate near Deväla and was described by Dr. King [1] as a compact diorite. This rock will be referred to subsequently (p. 16).

Age of the gneiss.

It has already been stated that the gneiss of south-east Wainád belongs probably to the upper (Bengal) division of the gneisses: these rocks, as seen elsewhere in India, are characterised by the presence of many accessory minerals, amongst which garnet is always prominent, while the members of the lower (Bundelkhand) division are usually of a much simpler and more granitic type and contain but few accessory minerals, which have never yet been found to include garnet. Although the Wainád gneisses show many signs of secondary change, such as the alteration of the felspars into muscovite and epidote, and of garnet into chlorite, yet the abundance of garnet throughout the gneiss points rather to the upper division than to the lower,

[1] Rec. Geol. Surv. Ind., Vol. VIII, Pt. 2, p. 38.

and the advanced state of alteration of the constituent minerals is only such as might be expected on the borders of the great intrusive mass of the Nilgiri charnockite.

At some period, probably anterior to the intrusion of this latter rock, earth-movements of great intensity must have taken place in south-east Wainád: these resulted in the formation of a series of fissures and of innumerable faults, of varying throw, in the gneiss: the fault planes are still indicated by bands of hard, black mylonitic material, resembling the bands so common in the so-called *trap-shotten* gneiss found in so many parts of the Madras Presidency and in Bengal, the true explanation of the origin of which,—*viz.*, rise of temperature and consequent fritting of the material along the fault planes—has recently been given by Mr. Holland.[1]

(2) *Charnockite.*

The chief charnockite masses in south-east Wainád are found in the Ouchterlony valley and on the Marpanmudi ridge—between Devála and Gudalur on the east and Nellakota and Pandalur on the west. Other smaller exposures occur between Pandalur and Cherambádi and on the ghát road from Nadugani to Carcoor.

Ouchterlony valley.

The charnockite of the Ouchterlony valley is merely the western fringe of the Nilgiri mass already described by Mr. Holland:[2] it belongs to the intermediate variety and is highly garnetiferous and hornblendic: it is well seen on the ghát road between Naduvatam and Gudalur.

Between Devála and Pandalur.

Much of the Marpanmudi ridge also is composed of charnockite, which forms the north-eastern end of the ridge. Further south, where it is crossed by the road from Devála to Pandalur, numerous intrusions of acid and intermediate forms, but chiefly the latter (Pl. 3, fig. 3), occur in the gneiss; and it would seem that the ridge has a core of charnockite

[1] Mem. Geol. Surv. Ind., Vol. XXVIII, Pt. 2, p. 200.
[2] Mem. Geol. Surv. Ind., Vol. XXVIII, Pt. 2, p. 184.

throughout : similar conditions probably prevail in almost all the more striking hill ranges in south and south-east Wainád, with the exception of the granite masses at Sultan's Battery and Kalpeta near Meppadi. The whole range of Velliramalai in south Wainád and most of the hills to the north of Vayitri are composed of charnockite. The intrusion of these great masses, when the rocks were probably at great depths below the surface, would amply account for the degree of alteration of the constituents of the gneiss.

(3) *Dharwars.*

Ferruginous quartz schist.

To the north of Devála and south-west from Needle-rock peak the crest of the Marpanmudi ridge is formed of a band of rock, composed of granular quartz, iron ores and garnet, standing up in hard vertical wall-like masses and forming a striking contrast to the majority of the rocks, which are usually decomposed to a depth of a hundred feet or more from the surface. This rock was described by Dr. King [1] as "a very hard . . . highly quartzose and ferruginous gneiss, containing laminæ of grey hæmatite": [2] it has not been found elsewhere in south-east Wainád, and occurring as it does in the form of a small band in the archæan gneiss would naturally have been included with them as a more siliceous and ferruginous variety of that series.

Under the microscope, however, it is at once seen to be entirely different to the gneisses; the granular character of the quartz, the absence of felspar and other minerals characteristic of the gneiss, and the presence of much hæmatite and magnetite are all features which serve to distinguish it from the surrounding rocks. It has in fact the usual characters of the quartz-iron-ore schists of the Dharwars and is now referred to that system.

[1] Rec. Geol. Surv. Ind., Vol. VIII, Pt. 2, p. 28.
[2] *Loc. cit.*, p. 37.

In addition to the minerals already enumerated, garnets also are occasionally found. They are, however, greatly decomposed, and in many cases consist merely of minute fragments of garnet lying in a confused mass of chlorite or limonite (Pl. 2, fig. 4), or a mixture of both. This secondary alteration of the garnet is not improbably due to the charnockite which, as previously stated, is found in many places on this ridge. No actual contact between it and the quartzite has been observed, but it is probable that if sufficient time could be devoted to a careful search along the ridge, such a contact would be found. This, however, would involve a post-Dharwar age for the charnockite, and in view of the absence of direct evidence bearing on this question, we are not at present in a position to assume this. Yet the advanced state of alteration of the garnets in both the gneiss and the quartzite, taken in conjunction with the absence of alteration of those of the charnockite, would tend to show that such alteration was not produced subsequently to the intrusion of the latter rock. The similarity in the products and degree of alteration of the garnets of both the gneiss and the quartzite on the Marpanmudi ridge is favourable to the supposition that the alteration was in both cases due to the same or a similar cause, while the fact, that in the neighbourhood of the charnockite intrusions the alteration of the garnets is much more complete than elsewhere, points to the charnockite as being that cause.

Decomposition of the garnet.

The presence of such a small isolated strip of Dharwar rocks in the midst of the gneissic area of south-east Wainád is somewhat surprising, the nearest known outliers of that age occurring far to the north-east in Mysore and also in North Coimbatore.

(4) *Intrusives other than the charnockites.*

These include four series of intrusives, *viz.*,—

(*a*) Older basic.
(*b*) Younger basic.
(*c*) Biotite granite.
(*d*) Pegmatite veins.

(*a*) The older basic intrusives have already been mentioned as occurring in the gneiss near Devála and Pandalur. These may be classed as *epidiorites* (Pl. 3, fig. 4). They are composed of felspar and hornblende, with few accessory minerals.

Older basic.

The *felspar* is always much altered and is full of grains of epidote: when sufficiently unaltered to be determined it is found to have been originally a plagioclase probably oligoclase.

Felspar.

Hornblende.

The *hornblende* is a common green actinolite.

Other minerals present are *sphene*, *rutile*, *zoisite*, *garnet* (rare), and chlorite. *Biotite* is common in the intrusive mass on the southern flank of Hadiabetta.

Accessory minerals.

Portions of the rock as seen on Hadiabetta are composed entirely of dark green hornblende with a little calcite: these appear to be merely more basic portions or *schlieren* enclosed in the main mass.

The band of this rock seen at the waterfall on Hamsluck estate, near Devála, runs apparently parallel to the strike of the gneiss, but there is little room for doubt that Dr. King was correct in supposing it to be intrusive, and Mr. Holland informs me that a very similar rock was found by himself and by Dr. Walker intrusive in his "Mercara group" of schists and gneisses in Coorg.

(*b*) The younger basic dykes are not seen in south-east Wainád, but a broad dyke occurs near Vayitri in south Wainád and below Naduvatam on the road from Ootacamund to Gudalur. The rock is in each case a dolerite composed of broadly twinned plagioclase felspar—labradorite—and augite. The felspar is fresh, but the crystals are often deformed and slightly granulated by pressure. The augite is full of black ferruginous dust and is usually surrounded by a border of green secondary hornblende. In both localities the dykes have suffered from pressure, and fracture, accompanied by the formation of mylonite, has taken place in various directions through the rock.

Younger basic dykes.

(c) Intrusive masses of biotite granite occur at Sultan's Battery and Kalpeta or Mottumalai, a prominent hill near Meppadi. These granite masses were described by Dr. King[1] as "great rocky cores, around and over which the foliated gneisses were laid down." The granite of Kalpeta strongly resembles, both in its composition and in its relation to the surrounding rocks, the so-called "dome gneiss" of the Házaribágh district of Bengal,[2] and in the light of more recent researches by Mr. Holland and the present writer, in Bengal, and by the writer, in Wainád, it seems more probable that this rock is in reality younger than the surrounding gneisses and is intrusive in them.

Biotite granite.

(d) Pegmatite veins are very common throughout south-east and south Wainád, and occur in both the gneiss and the charnockite: in the former, they run parallel to the strike of foliation of the gneiss. They are composed of quartz and felspar with muscovite and occasionally biotite and garnet—no other minerals have been identified in them.

Pegmatite.

The *quartz* occurs in great masses, and has in some cases been mistaken for reef quartz: but its granular and sugary character is almost invariably a safe means of distinguishing it from the clear uncrushed quartz of the true reefs.

The *felspar* is always decomposed to kaolin, usually free from impurities.

Muscovite occurs in large crystals of very fine quality (best ruby mica) and of fair size, and is of considerable economic value. Mining is being carried on at Cherambádi, and offers every prospect of success. The other minerals, biotite and garnet, are merely accessory, and are both somewhat rare.

The presence of great masses of quartz in the pegmatites led to this being confounded with the auriferous reefs, and mining operations were in some instances carried on for a considerable time before it was realised that they were not auriferous. The fact that these

[1] Rec. Geol. Surv. Ind., Vol. VIII, p. 38.

[2] General Report, Geological Survey of India, 1898-99, p. 29.

pegmatite veins were in reality intrusive had, however, been recognised by Dr. King, who drew attention to their frequent occurrence as also to the peculiarities, *viz.*, the granular and saccharoid character of quartz and the presence of mica—by which they differ from the auriferous reefs. In this view he was partially followed by Mr. Brough Smyth, who, however, though stating that they were "essentially granitic," described them somewhat ambiguously as "micacised reefs"[1].

C.—AURIFEROUS REEFS.

Strike.

The reefs of south-east Wainád form a series of more or less parallel bands running obliquely to the foliation of the country-rock. Observation of the outcrops led Dr. King and others to the conclusion that their strike was in most cases about north-north-west to south-south-east: in such broken country, however, it is exceedingly difficult to deduce any conclusions from a series of isolated outcrops, which may or may not be parts of the same reef: it is consequently impossible to be certain of the strike except in those reefs which have been exploited to some extent, such as those on the Alpha and Phœnix properties, in which mines the strike of the reef is north-north-east to south-south-west and north-east to south-west[2] or respectively at angles of about 45° and 23° to that of the foliation of the country-rock.

Dip.

The dip of the reefs is in almost all cases south-easterly, at angles varying between 30° and 40°, the commonest being 33°: in the Phœnix mine, however, the reef dips to the westward, at about 33°.

Extent.

In many cases the reefs seem to be of very considerable extent; this, however, is a factor which must vary for each individual reef, and no generalisations are possible, for each case can be decided only by practical experiment.

[1] *Op. cit.*, p. 6.
[2] See Plates 5 and 6.

The fact that similar reefs, apparently corresponding in strike and continuous with some of the outcrops in south-east Wainád, occur in Malabar at the foot of the plateau,—*i.e.*, over two thousand feet lower down,—was considered by Dr. King as a strong argument in favour of a great extension in depth, and although such a conclusion would seen at first sight quite justifiable, yet owing to the great difficulty of proving a connection to exist between any two isolated outcrops, too great weight cannot be attached to this argument. So far, however, as it has been possible to examine the more important reefs in south-east Wainád, there is no reason to suppose that in most cases they are not continuous to a considerable distance both vertically and horizontally. Thus the reef at the Alpha mine, near Devála, has been proved, by numerous drives, to a depth of about 400 feet below the surface outcrops and shows no signs of pinching out. The reef at the Phœnix mine, however, near Pandalur, which has also been opened up to a considerable extent, was eventually lost in most of the drives and Dr. Hatch[1] found it to consist of a series of lenticular masses. Again, in south Wainád, the reef on the "Cootacovil" property, which is said to have yielded very good results, consisted only of a small isolated body of ore, which was completely removed, and all attempts to find any continuation of it were futile : this is said to have occurred also in several other instances. Although, therefore, some of the reefs may with a fair degree of certainty be described as "true" or "fissure" veins,[2] yet many of the ore-bodies are merely small irregular patches, which even though rich, are not of sufficient extent to be of any material value.

Country-rock.

The country-rock is in most cases biotite gneiss, which is decomposed, to a considerable depth below the surface, into a soft arenaceous clay. As already stated

[1] See below, p. 29.

[2] The sense in which these terms are used is that defined by Phillips and Louis : "A treatise on Ore Deposits," 2nd Edn. (1896).

(p. 13) it would seem that, previous to the formation of the auriferous reefs, the gneiss was subjected to great pressure, which gave rise to a series of parallel fissures, running obliquely to the direction of foliation of the country-rock and probably more or less parallel to the direction of pressure. In these fissures the vein material was deposited.

"Casing."

The walls of the lodes are frequently formed of an indeterminate mass of fragments of talcose schist, brecciated, quartz and much limonite: this selvage or "casing," which, however, is not always present, varies in thickness from an inch or so to about one foot and frequently contains small quantities of free gold. Not infrequently this casing is absent, and the lode abuts directly on the country-rock: this is especially the case where the latter is fairly hard, as in the hornblendic rocks of Hadiabetta.

Character and contents of the reefs.

The reefs, which are massive, are composed of hard, translucent and crystalline quartz, usually white and barren-looking on the outcrop (Pl. 1), but at times stained with films of ferruginous material; they contain also subordinate quantities of other minerals including pyrite, marcasite, arsenical pyrites, limonite, hæmatite, gold, silver, chlorite, talc, calcite, and in places pyrolusite. The pyrites, which is the chief source of the gold, occurs sometimes in bands in the quartz, sometimes in small patches or even as small isolated crystals: the total amount of pyrites as compared with that of the quartz is exceedingly small, and its distribution appears to be quite irregular. Limonite is very common as a product of decomposition of the pyrites. The gold occurs chiefly in the pyrites, but small specks of free gold are occasionally found in the quartz, where it is stained by thin ferruginous films, and in the nondescript talcose material forming the selvage or casing this latter material indeed was apparently also the chief source from which the native miners, who worked before and during the last century, obtained their gold, and many of the tunnels still remaining show that they burrowed along the walls of the reef, removing only so much of the quartz as was necessary to enable them to take out the selvage, which lent itself more readily to their rude methods of crushing and was usually richer and always more remunerative than the hard, white quartz.

Of the other minerals enumerated above, chlorite and calcite occur chiefly in the Phœnix mine near Pandalur, where they are both very common: the presence of much basic igneous rock (epidiorite) with lime-bearing felspars, in the neighbourhood of the reefs, indicates the source from which the latter mineral was probably derived.

Preliminary investigation, 1899-1900.

As already stated, the majority of the more important reefs in south and south-east Wainád were examined and, so far as possible, sampled during the preliminary examination (December 1899 to March 1900): the reefs examined included the reefs known as the Skull, Cavern, Kuruman (Coorumber), Bear, Hamlin's and the Monarch reefs; the reefs on the Perseverance Company's property (Sulimalai), on Hamsluck Hamslade, Adelphi and Harewood estates, all the above near Devála; reefs on the Dunbar, Balcarres, Richmond, Phœnix and Glenrock estates near Pandalur; a reef on Grange estate at Cherambádi, and several reefs in the neighbourhood of Meppadi and Vayitri in south Wainád.

Samples were taken, as a rule, from the whole thickness of the reef, but in places where the reef appeared to be unusually rich, separate samples of the rich patches were also taken. These rich patches consisted either of highly pyritous material, or else, as in "Wright's level" (Skull reef), were composed of the talcose and ferruginous "casing".

The results of the above sampling were decidedly discouraging, for although the richer patches frequently gave high results (over 1oz. of gold to the ton of ore), yet these patches were so small and of apparently such infrequent occurrence as to make no appreciable difference in the yield of gold for the whole reef, which latter usually gave results varying from *nil* to about 4 dwts. per ton, the general average being slightly over 2 dwts. per ton. It was, however, considered possible that exhaustive sampling might reveal the presence of either bands or chutes of the richer or more pyritous material, sufficiently large and continuous to allow of profitable mining, if the ore were carefully hand-picked before being sent to the mill. The results of the past season's investigations, however, give no grounds whatever for such hopes, for not only has the mode of occurrence of the pyritous patches been found to be discontinuous and irregular, but the quantity available is even smaller than was originally supposed.

Results of crushings made by the mining companies.

In this connection it may be interesting to quote the tabulated results of crushings made in Wainád up to and including the first quarter of the year 1883: these have been obtained from a pamphlet already quoted, *viz.*, "The Indian Gold-mining Industry," by D. E. W. Leighton,[1] who gives the returns of several Indian companies for the years 1880, 1881, 1882 and part of 1883; the following figures, relating to Wainád companies, have been taken from his list:—

	Quartz treated.	Yield.		
Prior to 1880.	Tons.	oz.	dwt.	grs.
Southern India Alpha Company .	779½	91	12	23
Prince of Wales' Tribute . .	323	160	18	12
1881				
Indian Gold Mines Company .	26½	7	15	0
1882.				
Indian Phœnix Company . .	768	136	10	0
Indian Glenrock	400	20	4	0
Rhodes Reef	1,200	45	0	0
1883 (1st quarter).				
Indian Phœnix Company . .	100	20	0	0
TOTAL .	3,597	482	0	11

[1] *Op. cit.*, p. 29.

Thus 3,597 tons of ore yielded 9,641 dwts. of gold, the yield per ton of ore being, therefore, just under 2·7 dwts., a figure which agrees admirably with the results obtained during the recent investigations and it is clear that with the methods at present available for the treatment of low grade ores there is no hope of gold-mining in Wainád becoming remunerative.

Part II.—F. H. HATCH: the Alpha and Phœnix Mines in the South-East Wainad.

As the result of a preliminary survey of the more important quartz veins of the south and south-east Wainád, made last year by Mr. H. H. Hayden,[1] Officiating Deputy Superintendent of the Geological Survey of India, it was decided to submit two of the mines that had been most opened up during the mining activity of the early eighties to a detailed examination with a view to determining once for all whether, with the improved appliances and perfected processes of modern gold-recovery, there might be any chance of profitable gold-mining being carried on in this district. Mr. Hayden's researches led him to the conclusion that the two properties most suitable for such an examination were those known as the "Alpha" and the "Phœnix" for the reasons: firstly, that extensive drives on the course of the vein were known to exist in both of these mines, so that it would be possible, if they were made accessible, to institute a thorough sampling of the ore-bodies and thus to arrive at a fair approximation of the average value and stoping width of the ore; secondly, that these mines were credited by rumour with being capable of better results than had been obtained when they were formerly worked, if more efficient methods and better machinery were to be used.

These two mines having been selected it remained to render them accessible for sampling, and in order to do this a considerable

[1] See General Report of the Geological Survey of India, 1899-1900, p. 53.

amount of preliminary work was necessary to clear away the débris that, falling from the soft decomposed walls of the vein, had been washed down the stopes, and had gradually silted up the tunnels, in some cases partially, in others completely. The back of the drives had also to be supported in many dangerous places by close timbering. This task, which exacted considerable care and constant supervision, in order to prevent the occurrence of accidents to the native workmen, was carried out under the direction of Messrs. Hayden and Stonier of this Department, to whom every credit is due for the success which crowned their efforts.

The method of examination which appeared to me most suited to the requirements of the case was as follows:—Along the whole length of vein exposed in the drives places were marked for sampling at equal intervals of ten feet, irrespective of the appearance of the quartz at such places. Samples were then taken, with the aid of the moil and hammer, across the whole width of the vein exposed at the marked points. The broken quartz, which averaged about $\frac{4}{5}$lb. for every one foot width of vein sampled, was put into numbered bags and sealed, the width of the vein sampled and the number of the bag being noted. The samples thus obtained were forwarded to the office of the Geological Survey in Calcutta, where they were pulverised, quartered down, and assayed under the supervision of Mr. T. H. Holland, Officiating Superintendent, to whom I am much indebted for the care he has taken in checking the results and thus securing for me results on which I could place complete reliance. The work was not inconsiderable, for the number of samples sent for assay was 277 and their total weight about 1,000lbs. The assay returns were made in pennyweights of fine gold per ton of 2,240lbs. In order to arrive at the average gold-contents per ton for any given portion of the vein represented by the length of drive sampled, the assay value of each sample was multiplied by the respective width of the vein at the point where it was taken, and the sum of the products divided by the sum of the widths. The quotient gave the average assay value per ton. The average width was obtained by dividing the sum of the widths by the number of samples. To illustrate clearly the distribution of the gold-contents of the veins under description, plans of the workings have been prepared (from compass surveys by Lalla Kishen Singh of this Department) on which the assay results of the samples are entered, each in the place where the sample was taken, together with the width of the vein sampled (see the assay plans which accompany this Report).

The *Alpha Mine*, formerly the property of the Indian Gold Mines Company, is situated on the edge of the ghát above the Carcoor valley, about 1½ miles south of the town of Devála. The vein opened by this mine can be traced at various points along the surface, being variously known as "Wright's lode," the "Skull Reef" and the "Prince of Wales' Reef". Its strike is approximately north-north-east and south-south-west and its dip to the east: while the strike of the country-rock is east-north-east and west-south-west. The vein consists of a hard, white quartz, only occasionally being stained by the decomposition of iron-pyrites. The immediate walls consist generally of a silvery, talcose material and the country-rock (biotite gneiss) is usually decomposed to a soft clayey mass, necessitating careful timbering in drives and stopes to prevent dangerous falls of rock.

The workings on the portion of the lode, comprising the Alpha Mine, consist of a number of cross-cut tunnels or "adits" driven into the face of the ghát and intersecting the lode at different levels. From the points of intersection, drives were extended along the course of the vein both north and south of the adit cross-cut. Of these tunnels, six were opened for my inspection, namely, Nos. 2, 3, 6, 7, 8, and 9. Another tunnel, No. 11, still lower down the ghát, was attempted, but the flow of water constantly bringing down fresh supplies of débris from the soft and treacherous roof caused difficulties which ultimately proved insurmountable, and after clearing 150 feet of the adit, the work had to be abandoned.

The following scheme gives the details of measurements of the above tunnels : —

No. of Tunnel.	Length of cross-cut.	Length of drive cleared for examination.	Length of vein exposed and accessible for sampling.
No. 2	100 ft.	150 ft.	0 ft.
„ 3	20 „	380 „	280 „
Intermediate Level . . .	...	80 „	60 „
No. 6	250 ft	460 „	340 „
„ 7	30 „	170 „	160 „
„ 8	120 „	170 „	170 „
„ 9	440 „	820 „	730 „
TOTAL .	960 „	2,230 „	1,740 „

A considerable amount of ore has been stoped above No. 3 level and between No. 3 and No. 7 levels; but below the latter no ore has been taken out. The ore stoped was milled by the old Alpha Company; but I have no reliable figures dealing with these crushings; judging, however, by the results of sampling, the mill returns must have been remarkably poor.

The number of samples taken was 174: the results of their assay are summarized in the following table, a complete return of the assays being given in the appendix to this report:—

No. of Tunnel.	No. of samples taken.	Average width of vein sampled, in feet.	Average assay value, in dwts. of fine gold to the ton.
No. 3	28	5·5	1·5
Intermediate level . . .	6	5·5	1·0
No. 6	34	5·3	1·0
„ 7	16	4·5	1·1
„ 8	17	3·0	2·0
„ 9	73	3·5	2·3

The average of the whole 174 samples works out at 1·6 dwts. of fine gold per ton for an average width of 4·3 feet. These results of course show the ore to be absolutely unpayable. An inspection of the list of assays or of the assay-plan discloses the fact that the bulk of the quartz contains very little gold. A few samples only indicate spots of ore of higher grade: thus in No. 3 level and in No. 6 level there are two or three places running 4 to 6 dwts. per ton, one in No. 8 level of 8 dwts., and in No. 9 level there are spots of ore assaying respectively 6, 7, 11, 12, 14, and 34 dwts. per ton; but these places are isolated, there being nothing in the distribution of the gold-contents to indicate anything approaching definite chutes of payable ore. The bulk of the vein consists of barren quartz, and the gold, where present, is probably associated with iron-pyrites which occurs in small patches, seams and strings of sparse occurrence. A sample of pure pyrites (D 51) taken from one of these small bunches, assayed 3 ounces 5·3 dwts. to the ton. Occasionally also there is a layer, 3 or 4 inches in thickness, of soft ferruginous material on one of the walls of the lode; but its occurrence is limited in extent and its gold-contents small. A sample of this "casing" was taken in No. 7 adit on the hanging wall of the vein. The seam was 6 inches in width, and assayed 8½ dwts. per ton (sample D 99); another sample of the same material from the same adit only assayed 2 dwts. per ton for a width of 6 inches (D 67); and in No. 6 adit 14 inches of casing assayed 1·3 dwts. per ton (D 72).

The *Phœnix Mine*, formerly the property of the Indian Consolidated Gold Company, is situated on the southern flank of Hadiabetta, about 2 miles south of Pandalur and 6 miles from Deväla. The ore-body worked in this mine strikes approximately north-east and south-west and dips at about 30 degrees to the north-west. The country-rock consists of hornblende and biotite gneiss and the strike of the foliation of this rock is east-north-east and west-south-west, making an angle of about 23 degrees with the strike of the vein.

Like the Alpha vein the Phœnix consists of a hard, white to semi-transparent quartz, but there is more of the pyritic constituent than in the Alpha; the vein walls are also less defined, the lode swelling and pinching in a most irregular manner. The portion of the lode disclosed by the Phœnix workings consists in reality of large lenticular masses occurring at intervals in a plane of disruption and movement with the usual characteristics of vein deposits, such as more or less well-marked walls with films of chlorite or talc, seams of clay, strings of quartz, etc., even when the larger bodies of quartz are absent. Besides quartz the vein contains a considerable amount of carbonate of lime in the form of calcite, also patches and streak of chlorite and mica which appear to be altered fragments of the country-rock. The gold-contents are almost entirely associated with iron-pyrites, which occurs in small patches or geodes or disseminated in specks throughout the foot-wall portions of the lode. The gold is very finely divided and rarely if ever visible to the naked eye.

The mine has been opened up by three adits driven into the hill-side. These are known respectively as No. 3, No. 4, and No. 6. The ore-body exposed by adits No. 3 and No. 4, which has a length along the course of the vein of 400 feet, was practically all stoped out, and although No. 4 adit was continued for a further distance of 560 feet along the thin clay parting, marking the position of the vein, only a few small bunches of quartz were met with, and the level was finally abandoned, without having reached a second ore-body. No. 6 adit opened up 870 feet of the quartz vein, only a very small portion of which has been stoped. No samples could be taken in No. 3 level, as the stopes above this level have fallen in to a great extent. In No. 4 level 15 samples were taken from the pillars and other places where the vein was accessible; and in No. 6 level 78 samples were taken.

The following table gives the results of averaging the assays of these samples (the complete returns will be found in the appendix) :—

No. of level.	No. of samples taken.	Average width, in feet.	Average assay value in dwts. of fine gold to the ton.
No. 4	15	4·7	3·2
„ 6	78	5·5	1·8

The average assay value of the whole number of samples (93) is 2 dwts. of gold per ton for an average width of 5·4 feet. Although the majority of the samples show that the ore is of low grade, there are of course occasional places of higher value. Thus in No. 4 level samples were obtained assaying 7, 8½ and 15 dwts. to the ton; while in No. 6 level 6 samples (out of 78) gave results above 4 dwts. to the ton, namely, 4·6, 6·4, 6·4, 7·8, 12·0 and 17 dwts. to the ton.

These exceptions to the general run of low grade results are due to the places of sampling happening to coincide with the presence of small bunches or spots of pyrites. In order to test the value of these pyritic patches, I took a large sample of the pyrites at several different places in the level, scooping it out from the geodes with as little quartz as possible. After mixing and quartering down this sample (C 10) it was sent to Calcutta and assayed, giving 3 ounces of gold to the ton. After concentration by panning, its value was increased to 6 ounces to the ton. This result is not encouraging, considering the small quantity of the material available and the difficulty of separating it from the barren quartz.

Conclusions.—There can be no doubt after the careful and systematic sampling of the two mines, as to the unpayability of the ore-bodies that have been opened up by the Alpha and Phœnix workings; and the present developments are in my opinion sufficient to justify a condemnation of the veins on which these mines have been opened. If the presence of chutes of pay-ore could have been established, even though of small extent, there might have been some encouragement for the undertaking of further prospecting operations; but with the results rehearsed on the preceding pages such a course cannot be recommended.

List of Samples (and Assays) taken by DR. F. H. HATCH *in the Alpha and Phœnix Mines, South-East Wainád.*

Number of sample.	Place where taken.	Width of lode sampled, in feet.	Assay value, in dwts.	REMARKS.
		ALPHA MINE: No. 3 LEVEL.		
B 94	14 feet from end .	6 feet	6·7	Whole width of vein.
B 93	24 ditto .	5·5 „	trace	Ditto.
B 0	34 ditto .	3·5 „	„	Middle portion of vein.
B 84	44 ditto .	6·5 „	„	Whole width.
B 91	44 ditto .	1·0 „	„	Foot wall portion.
B 85	54 ditto .	7·0 „	1·5	Whole width.
B 76	70 ditto .	6·5 „	5·5	Ditto.
B 90	70 ditto .	4 inches	trace	Foot wall portion.
B 78	77 ditto .	6·5 feet	1·4	To foot wall. Hanging wall not accessible.
B 75	90 ditto .	9·0 „	trace	Full width.
B 77	90 ditto .	12 inches	„	Foot wall portion.
B 86	105 ditto .	7 feet	5·2	Full width.
B 79	115 ditto .	7·5 „	trace	To foot wall; hanging wall not accessible.
B 95	133 ditto .	7·0 „	1·7	Ditto ditto.
B 83	142 ditto .	3·0 „	trace	Foot wall portion.
B 98	152 ditto .	5·0 „	„	Ditto.
B 99	162 ditto .	4·5 „	„	To foot wall; hanging wall not exposed.
B 97	172 ditto .	4·5 „	„	Ditto ditto.
B 81	182 ditto .	3·7 „	„	Ditto ditto.
B 82	192 ditto .	5·5 „	„	Ditto ditto.
B 96	202 ditto .	3·3 „	0·8	Ditto ditto.
B 92	212 ditto .	4·0 „	trace	Ditto ditto.
B 69	222 ditto .	5·0 „	„	Ditto ditto.
B 66	232 ditto .	6·5 „	2·2	Ditto ditto.
B 87	244 ditto .	6·0 „	trace	Ditto ditto.

Number of sample.	Place where taken.	Width of lode sampled, in feet.	Assay value, in dwts.	REMARKS.
	ALPHA MINE: No. 3 LEVEL—*concld.*			
B 74	255 feet from end .	6·0 feet	trace	To foot wall; hanging wall not exposed.
B 88	265 ditto .	5·0 "	"	Ditto ditto.
B 73	275 ditto .	6·5 "	4·4	Ditto ditto.
B 71	285 ditto .	5·0 "	1·4	Ditto ditto.
B 72	295 ditto .	6·0 "	2·0	Ditto ditto.
B 68	305 ditto .	7·0 "	3·5	To hanging wall; foot wall not exposed.
	ALPHA MINE: INTERMEDIATE LEVEL.			
D 82	30 feet from south end.	6·5	0·7	Middle portion.
D 85	43 ditto .	6·2	0·7	Full width.
D 86	53 ditto .	5·5	0·7	Hanging wall not exposed.
D 79	63 ditto .	4·5	2·0	Ditto.
D 39	73 ditto .	5·0	0·7	Ditto.
D 43	85 ditto .	6·0	1·3	Ditto.
	ALPHA MINE: No. 7. LEVEL.			
D 66	at south end .	3·5	*nil*	Full width.
D 95	10 feet from south end.	3·5	0·7	Ditto.
D 94	20 ditto .	4·0	trace	Ditto.
D 98	30 ditto .	3·0	2·9	Hanging wall not exposed.
D 96	40 ditto .	3·0	0·7	Ditto.
D 97	50 ditto .	7·0	1·3	Full width.
D 32	57 ditto .	1·0	0·9	Casing on hanging wall.
D 36	63 ditto .	7·5	2·5	Full width.
D 99	63 ditto .	0·5	8·5	Casing on hanging wall.
D 0	10 feet from cross-cut.	4·0	0·7	Foot wall not exposed.
D 37	20 ditto .	5·8	trace	Full width.

Number of sample.	Place where taken.	Width of lode sampled, in feet.	Assay value, in dwts.	REMARKS.
	ALPHA MINE: No. 7 LEVEL—*concld.*			
D 33	30 feet from cross-cut.	5·5	1·7	Hanging wall not exposed.
D 69	40 ditto	6·0	3·25	Full width.
D 68	50 ditto	7·5	1·3	Ditto.
D 67	50 ditto	0·5	2·0	Casing on hanging wall.
D 74	60 ditto	5·8	trace	Middle portion.
D 75	10 feet from junction with No. 6.	6·0	"	Full width.
D 78	24 ditto	3·8	3·3	Ditto.
	ALPHA MINE: No. 6 LEVEL.			
D 70	89 feet from junction with No. 6.	3·5	trace	Hanging wall not exposed.
D 77	99 ditto	7·0	0·7	Foot wall not exposed.
D 76	109 ditto	7·0	trace	Ditto.
D 72	109 ditto	1·2	1·3	Casing on hanging wall.
D 71	123 ditto	4·8	trace	Full width.
D 80	137 ditto	6·2	"	Ditto.
D 81	147 ditto	7·0	"	Ditto.
D 84	162 ditto	6·5	"	Ditto.
D 91	179 ditto	6·0	0·6	Ditto.
D 93	189 ditto	7·0	2·5	Hanging wall not exposed.
D 73	199 ditto	6·5	1·3	Ditto.
D 92	213 ditto	6·0	*nil*	Ditto.
D 83	225 ditto	7·5	trace	Ditto.
A 50	237 ditto	6·0	"	Ditto.
A 39	247 ditto	6·0	"	Ditto.
A 35	257 ditto	6·5	"	Ditto.
A 38	267 ditto	5·0	*nil*	Full width.
A 34	277 ditto	5·0	trace	Ditto.
A 41	287 ditto	6·5	1·8	Ditto.

Number of sample.	Place where taken.	Width of lode sampled, in feet.	Assay value, in dwts.	REMARKS.
	ALPHA MINE: No. 6 LEVEL—*concld.*			
A 31	299 feet from junction with No. 6.	5·5	2·6	Full width.
A 42	309 ditto .	6·0	2·0	Ditto.
A 46	319 ditto .	6·0	1·7	Ditto.
A 30	329 ditto .	5·0	2·6	Ditto.
A 48	339 ditto .	4·7	0·8	Ditto.
A 47	349 ditto .	2·5	trace	Ditto.
A 44	359 ditto .	6·0	1·2	Mixed with "country."
A 45	369 ditto .	6·0	0·9	Ditto.
A 32	379 ditto .	5·0	trace	Ditto.
A 33	389 ditto .	3·0	1·2	Full width.
D 29	399 ditto .	1·3	6·5	Ditto.
D 3	409 ditto .	4·5	1·3	Ditto.
D 1	419 ditto .	3·0	2·6	Ditto.
D 30	429 ditto .	3·0	5·2	Ditto.
D 28	439 ditto .	4·0	1·3	Ditto.
D 47	450 ditto .	4·5	2·0	Ditto.
	ALPHA MINE: No. 8 LEVEL.			
B 62	18 feet from end .	3·5	9·2	To hanging wall; foot wall not exposed.
B 51	27 ditto .	4·0	1·2	Ditto.
B 89	37 ditto .	5·5	trace	Full width.
B 52	47 ditto .	4·0	,,	To foot wall; hanging wall not exposed.
B 53	57 ditto .	2·5	2·2	Full width.
B 54	78 ditto .	1·0	1·3	Ditto.
B 55	87 ditto .	1·7	7·8	No quartz; schist with pyrites.
B 56	109 ditto .	1·7	1·8	Full width.
B 70	119 ditto .	2·5	trace	Ditto.

Number of samples.	Place where taken.	Width of lode sampled, in feet.	Assay value, in dwts.	Remarks.
	Alpha Mine: No. 8 Level—*concld.*			
B 67	129 feet from end .	4·5	trace	Full width.
B 58	140 ditto .	4·0	"	From hanging wall; foot wall not exposed.
B 36	158 ditto .	4·5	6·4	Full width.
B 35	172 ditto .	5·0	1·4	Ditto.
B 37	184 ditto .	2·0	2·7	Two seams, full width.
	Alpha Mine: No. 9 Level.			
B 39	35 feet from north end.	1·0	1·2	Full width.
B 41	54 ditto .	2·5	2·3	Ditto.
B 42	64 ditto .	1·3	5·8	Ditto.
B 57	90 ditto .	6·0	trace	Country with quartz strings.
B 44	104 ditto .	width not recorded.	0·75	Foot wall not exposed.
B 43	113 ditto .	4·5	trace	Ditto.
B 59	123 ditto .	3·0	"	Full width.
B 46	133 ditto .	4·0	1·2	Ditto.
B 31	144 ditto .	5·0	2·9	Ditto.
B 30	155 ditto .	4·5	1·2	Ditto.
B 19	165 ditto .	4·0	0·8	Ditto.
B 47	175 ditto .	4·0	1·2	Ditto.
B 27	185 ditto .	7·5	1·2	Ditto.
B 21	194 ditto .	5·0	2·5	Ditto.
B 26	204 ditto .	5·5	0·8	Ditto.
B 22	215 ditto .	6·0	10·9	Ditto. Patches of pyrites.
B 29	225 ditto .	7·0	0·8	Ditto.
B 45	235 feet from end .	3·5	trace	Foot wall not exposed.
B 65	245 ditto .	3·5	1·7	Full width.
B 48	255 ditto .	1·3	trace	Ditto.
B 38	265 ditto .	1·8	1·3	Ditto.

Number of samples.	Place where taken.	Width of lode sampled, in feet.	Assay value, in dwts.	REMARKS.
	ALPHA MINE: No. 9 LEVEL—*contd.*			
B 35	275 feet from end	3·0	trace	Full width.
B 18	285 ditto .	4·0	„	Ditto.
B 17	295 ditto .	1·0	„	Ditto.
B 13	304 ditto .	2·5	1·3	Ditto.
B 16	313 ditto .	3·0	*nil*	Ditto.
B 14	324 ditto .	3·5	3·3	Ditto.
B 40	334 ditto .	4·5	trace	Ditto.
B 15	343 ditto .	3·5	0·8	Ditto.
B 34	361 ditto .	4·0	1·2	Ditto.
B 33	374 ditto .	6·0	trace	Ditto; at cross-cut.
B 24	10 feet south of cross-cut.	6·0	„	Ditto.
B 49	67 ditto .	4·0	„	Ditto.
B 32	76 ditto .	6·0	„	Ditto.
B 60	83 ditto .	4·5	*nil*	Ditto.
B 20	92 ditto .	3·0	trace	Ditto.
B 63	102 ditto .	3·5	0·8	Ditto.
B 64	113 ditto .	4·5	14·3	Ditto.
B 7	123 ditto .	4·0	*nil*	Ditto.
B 1	134 ditto .	4·0	0·8	Ditto.
B 3	144 ditto .	4·0	trace	Ditto.
B 2	154 ditto .	3·7	„	Ditto.
B 4	164 ditto .	4·5	„	Ditto.
B 10	174 ditto .	4·5	„	Ditto.
B 28	184 ditto .	4·8	*nil*	Foot wall not exposed.
B 23	195 ditto .	5·8	trace	Full width.
B 9	206 ditto .	4·0	„	Ditto.
B 8	217 ditto .	4·5	3·3	Ditto.
B 61	228 ditto .	5·5	0·8	Ditto.

Number of sample.	Place where taken.	Width of lode sampled, in feet.	Assay value, in dwts.	REMARKS.
	ALPHA MINE: NO. 9 LEVEL—*concld.*			
B 12	238 feet south of cross-cut.	4·5	2·0	Full width.
B 5	25 feet from south end	2·5	*nil*	Ditto.
B 11	56 ditto .	1·5	1·7	Ditto.
B 6	66 ditto .	1·3	7·0	Ditto, pyritic.
B 80	76 ditto .	1·3	1·3	Full width.
D 44	86 ditto .	2·3	trace	Ditto.
D 88	96 ditto .	1·5	0·7	Ditto.
D 87	106 ditto .	2·0	0·5	Ditto.
D 41	116 ditto .	3·0	*nil*	Ditto.
D 40	126 ditto .	3·5	trace	Ditto.
D 38	136 ditto .	3·5	3·3	Ditto.
D 35	146 ditto .	3·0	5·2	Ditto.
D 46	156 ditto .	1·8	0·7	Ditto.
D 42	166 ditto .	4·5	34·0	Ditto, pyritic.
D 45	176 ditto .	2·5	12·4	Ditto, do.
D 51	176 ditto .	...	65·3	Pure pyrites.
D 90	186 ditto .	3·5	5·2	Full width.
D 34	196 ditto .	2·0	1·0	Ditto.
D 49	206 ditto .	3·0	3·9	Ditto.
D 50	216 ditto .	3·0	*nil*	Ditto.
D 48	226 ditto .	4·5	0·7	Ditto.
	SAMPLE FROM QUARRY.			
D 31		6	trace	
	PHŒNIX MINE: NO. 6 LEVEL.			
E 86	N. end of tunnel .	4·0	1·0	Mixed with "country."
E 97	52 feet from do. .	2·0	trace	Full width.
E 81	62 ditto .	3·0	1·3	Foot wall not exposed.

Number of samples.	Place where taken.	Width of lode sampled, in feet.	Assay value, in dwts.	REMARKS.
		PHŒNIX MINE: NO. 6 LEVEL—*contd.*		
E 53	72 feet from N. end of tunnel.	3·5	17·0	Hanging wall not exposed.
E 84	82 ditto .	5·5	1·2	Ditto.
E 83	92 ditto .	5·0	2·0	Ditto.
E 98	102 ditto .	3·8	0·7	Ditto.
E 40	112 ditto .	2·0	trace	Ditto.
E 50	122 ditto .	5·0	2·6	Full width.
E 95	132 ditto .	6·0	1·8	Hanging wall not exposed.
E 55	142 ditto .	4·5	trace	Ditto.
E 60	152 ditto .	3·5	„	Full width.
E 45	162 ditto .	4·0	1·2	Ditto.
E 47	172 ditto .	4·0	1·4	Ditto.
E 46	190 ditto .	5·5	1·0	Ditto.
E 74	200 ditto .	3·0	6·4	In stope.
E 51	215 ditto .	6·0	7·8	
E 43	225 ditto .	2·0	trace	Hanging wall portion.
E 57	225 ditto .	3·0	2·6	Foot wall portion.
E 56	235 ditto .	5·5	trace	Foot wall not exposed.
E 48	251 ditto .	6·0	„	Full width: pillar in stope.
E 71	261 ditto .	5·5	„	Ditto ditto.
E 7	272 ditto .	4·0	0·8	Hanging wall not exposed.
E 67	282 ditto .	8·5	1·3	Foot wall not exposed.
E 85	292 ditto .	4·5	trace	Middle portion.
E 0	302 ditto .	8·0	0·8	Foot wall not exposed.
E 88	312 ditto .	6·0	*nil*	Pillar in stope.
E 65	322 ditto .	4·5	trace	Hanging wall not exposed.
E 87	335 ditto	5·0	„	Ditto.
D 5	347 ditto .	3·0	12·0	Foot wall vein.
E 92	357 ditto .	4·7	trace	Full width.

Number of sample.	Place where taken.	Width of lode sampled, in feet.	Assay value, in dwts.	Remarks.
	Phœnix Mine: No. 6 Level.—*contd.*			
E 62	367 feet from N. end of tunnel.	7·0	3·9	Full width.
E 30	377 feet from end .	8	3·2	Ditto.
E 14	390 ditto .	7	1·2	Ditto.
E 22	400 ditto .	5·5	1·4	Hanging wall not exposed.
E 8	410 ditto .	4·5	7·8	Full width.
E 32	420 ditto .	4·5	trace	Ditto.
E 25	435 ditto .	4·0	1·3	Ditto.
E 28	445 ditto .	2·5	4·0	Ditto.
E 24	455 ditto .	1·8	2·8	Ditto.
E 26	468 ditto .	4·0	*nil*	Ditto.
E 52	478 ditto .	2·5	3·9	Ditto.
E 20	488 ditto .	5·0	trace	Ditto.
E 44	498 ditto .	4·7	1·6	Hanging wall not exposed.
E 39	500 ditto .	7·5	1·8	Foot wall not exposed.
E 42	518 ditto .	6·5	2·6	Full width.
E 21	528 ditto .	5·8	*nil*	Ditto.
E 31	538 ditto .	6·5	2·6	Ditto.
E 19	548 ditto .	6·0	trace	Ditto.
E 70	558 ditto .	8·0	"	Ditto.
E 38	568 ditto .	5·0	2·6	Ditto.
E 17	578 ditto .	8·0	trace	Ditto.
E 18	588 ditto .	7·0	*nil*	Foot wall not exposed.
E 36	598 ditto .	5·5	3·2	Full width.
E 1	608 ditto .	7·0	0·8	Ditto.
E 33	618 ditto .	6·5	1·8	Ditto.
E 3	628 ditto .	6·5	0·8	Ditto.
E 34	637 ditto .	4·0	2·6	Ditto.
E 29	648 ditto .	4·5	1·8	Ditto.

Number of sample.	Place where taken.	Width of lode sampled, in feet.	Assay value, in dwts.	REMARKS.
	PHŒNIX MINE: NO. 6 LEVEL.—*concld.*			
E 4	658 feet from end .	5·5	trace	Full width.
E 6	668 ditto .	5·5	1·7	Ditto.
E 35	678 ditto .	5·5	0·9	Hanging wall not exposed.
E 93	688 ditto .	6·0	trace	Ditto.
E 11	698 ditto .	9·0	1·8	Full width.
E 78	708 ditto .	8·0	3·2	Ditto.
E 41	718 ditto .	7·5	3·2	Hanging wall not exposed.
E 9	728 ditto .	6·5	2·6	Ditto.
E 2	738 ditto .	7·0	0·8	Ditto.
E 63	751 ditto .	7 5	3·9	Full width.
E 12	761 ditto .	4·0	trace	Hanging wall not exposed.
E 61	771 ditto .	5·5	6·4	Ditto.
E 80	786 ditto .	9·0	2·6	Middle portion in stope.
E 68	806 ditto .	6 5	trace	Foot wall not exposed.
E 15	818 ditto .	8·0	1·0	Full width.
E 49	828 ditto .	8·5	2·6	Foot wall not exposed.
E 91	838 ditto .	8·0	2·0	Full width at cross-cut adit.
E 37	848 ditto .	3·0	1·3	Foot wall not exposed.
E 13	858 ditto .	3·0	1·3	Hanging wall not exposed.
E 58	898 ditto .	2·5	0·7	Full width.
E 89	908 ditto .	4·0	2·1	Ditto.
E 82	918 ditto .	2·5	4·6	Ditto.
	PHŒNIX MINE: NO. 4 LEVEL.			
C 55	60 feet from north end	2	2·6	Full width.
C 53	100 ditto .	2·5	1·0	Ditto.
C 78	580 ditto .	1·5	8·5	Ditto.
C 52	590 ditto .	2·5	trace	Ditto.
C 61	620 ditto .	1·7	0·7	Foot wall seam.

Number of sample.	Place where taken.	Width of lode sampled, in feet.	Assay value, in dwts.	REMARKS.
	PHŒNIX MINE: NO. 4 LEVEL—*concld.*			
C 62	620 feet from north end.	1·7	7·2	Hanging wall seam.
C 63	630 ditto	2·0	1·3	Foot wall seam.
C 4	640 ditto	5·0	1·3	Full width.
C 98	713 ditto	8·0	1·3	Full width; pillar in stope.
C 2	790 ditto	4·5	1·6	Ditto.
C 94	810 ditto	4·7	1·0	Full width.
C 70	830 ditto	6·5	1·3	Ditto.
C 3	845 ditto	7·5	2·0	Ditto.
C 64	860 ditto	8·5	trace	Ditto.
C 59	876 ditto	8·0	15·0	Ditto.
C 1	926 ditto	4·5	3·9	Foot wall portion, pillar in stope.
C 95	1,011 ditto	3·7	1·3	Ditto.
C 10	Pyritic patches in No. 4 level.	...	3 oz. 1·4 dwt.	Pyrites alone.
C 30	Ditto	...	6 oz. 2·8 dwt.	Panned.
C 54	Between Nos. 3 and 4 levels.	1·0	1 oz. 2·9 dwt.	Rich place in stope pointed out by Kurumbars.

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GEOGRAPHICAL INDEX.

PLATE II.

Fig. 1. Garnetiferous biotite gneiss (typical): see p. 10.

„ 2. Garnet in process of alteration into chlorite: in biotite gneiss near its junction with the charnockite.

„ 3. Quartz-garnet-iron-ore schist (Dharwar): the garnets are largely altered to chlorite.

„ 4. Quartz-iron-ore schist (Dharwar): the rock originally contained a considerable amount of garnet, which has now been largely replaced by limonite, small irregular fragment of garnet only remaining.

PLATE III.

Fig. 1. Contact rock at junction of charnockite and biotite gneiss: see p. 11.

" 2. Altered felspar in similar contact rock: the felspars contain much epidote and sericite.

" 3. Charnockite: highly garnetiferous variety from Marpanmudi ridge.

" 4. Epidiorite: from Phœnix mine, Hadiabetta, near Pandalur.

2.—Some Auriferous localities in North Coimbatore, *by* H. H. Hayden, B.A., B.E., F.G.S., *Officiating Deputy Superintendent, Geological Survey of India.* (With Plates VIII and IX.)

The above localities lie in the Satyamangalam and Kollegál taluks of Coimbatore district, in the broken country lying to the east of the road from Haussanúr to Kollegál. Although quartz reefs were known to exist in certain parts of this area and were examined by Messrs. Middlemiss and Smith, of this department, in the course of their geological survey of the area, it is only within the last few years that detailed search has been made for old native workings. The discovery of the majority of these is due to the energy of Mr. Randolph Morris, of Attikán Estate, who has spent much time in searching for them, and to whom I am greatly indebted for the valuable assistance rendered me by him during my examination of the localities in question.

Little prospecting hitherto done.

Unfortunately little prospecting has been done in this area, the presence of the old workings being considered sufficient evidence of the auriferous character of the quartz reefs, and I found therefore that there was no possibility of thoroughly sampling the reefs, for the old native workings, instead of being of assistance, are in reality an impediment, in that the outcrops of the reefs have been almost completely broken away and the whole neighbourhood of the lodes covered over and obscured by débris. The workings themselves consist, as a rule, merely of depressions in the surface or of mounds of broken material, all old shafts which may have formerly existed being now completely filled in and obliterated, and only by finding such shafts and clearing them out, as has been done in a few cases, or else by sinking new prospecting shafts and making cross-cuts, would it be possible to obtain satisfactory samples. It is indeed not unusual to find that old workings are considered by many prospectors as a proof of the

Old workings do not necessarily imply rich reefs.

existence of rich ore, but this view is in the majority of cases undoubtedly fallacious, for there are few auriferous areas in India, poor as well as rich, that have not at some period been exploited by the natives. It is argued, however, that ore that could be made to pay by a native with his primitive methods must yield much richer returns if worked on modern principles: this no doubt is in a sense correct, but we do not yet know what grade of ore was considered by the native as the "irreducible minimum"; for it must be remembered that many of the reefs were probably mined by forced labour or by slaves, and, in the latter case, provided that more gold was obtained than was sufficient to cover the expense of feeding and clothing the workers, mining could then be carried on at a profit. The Wainád mines indeed furnish a case in point, for local tradition says that many of the old shafts were the work of gangs of slaves, and yet one of the reefs, which was perhaps worked more extensively than any other in Wainád, has given from nearly two hundred samples an average yield of about two pennyweights of gold to the ton of ore: other similar cases could be cited both from Wainád and elsewhere. It is therefore quite unjustifiable to infer, as is so frequently done, that extensive old native workings must of necessity imply rich reefs.

Country-rock.

The rocks of this area, which has already been surveyed geologically by Messrs. Middlemiss and Smith, consist chiefly of members of the charnockite series and bands supposed to be of Dharwar age, with some biotite gneiss and a great complex of basic intrusives, including diorite, felspar-hornblende-epidote rocks and gabbro. These rocks will be noticed in connection with the various localities in which they occur.

Localities examined.

Of the numerous old workings, four sets are situated in localities in which some further prospecting has recently been done, and these were examined by me. The localities are—

(*a*) Bensibetta, about 12 miles south-east of Bailúr.

(*b*) Porsedyke mine, near Porsegaundanpálayam.
(*c*) Hadabanatta, about 3 miles north-north-east of Porsegaundanpálayam.
(*d*) Kavudahalli, about 6 miles north east of Rámapúram.

I. Bensibetta.

Old workings.

Numerous and extensive old workings occur to the north, east and south-east of Bensibetta. The most southerly set is situated at some distance to the south-east of Bensibetta trigonometrical station, and about half way between the small villages of Marúr and Mádikada, where a small ridge is capped by great masses of reef quartz. This reef can be traced at intervals for about three miles in a north-north-east direction, across the eastern spur of Bensibetta and on to a small hill about one mile east-north-east of the village of Inbekombi.

The reef.

The reef is composed of white quartz, usually stained to some extent by ferruginous matter. At the outcrop, it is cavernous and full of hollows containing masses of limonite and very perfect quartz crystals. The chief minerals in the reef are *iron pyrites*, *limonite*, *hœmatite*, *chlorite*, and amorphous forms of silica (*jasper*, *chalcedony*). At the outcrop near Inbekombi, the quartz is full of hexagonal cavities several inches long by two or three inches across: I am indebted to Mr. Holland for the suggestion that these cavities originally contained crystals of *calcite*.

Free gold has not been observed in the quartz, but can be washed out from the soil at the outcrop.

The strike of the reef is approximately north-south, with a dip to the west, thus corresponding with that of the surrounding rocks and giving to it the appearance of what is technically termed a "bedded" reef. It has been much quarried and broken up by the natives, in times now locally forgotten. Eveywhere are old pits and dumps, and the broken material often completely covers and obliterates the reef.

A few hundred yards to the east of the main outcrop are a series of old shafts, sunk on small leaders, two of these shafts have been partially cleared out by Mr. Morris, and in each of these I took a series of samples.

The main reef.

Whatever deep workings may have formerly existed on the main reef are now completely filled up, and it was therefore impossible to obtain samples except from the surface outcrop. Two samples taken across the reef, where it had a thickness of 4 feet, gave traces of gold. In addition to these samples, a considerable amount of material was taken at various points from among the masses of débris covering the outcrop: these were panned and in all cases yielded a very good show of gold.

Shafts on the leaders No. 1.

Of the two shafts that have been cleared by Mr. Morris, the more northerly has been opened out to a depth of about 50 feet along a small lode.

A diagrammatic section of this shaft is shown in figure 1, which shows also the points at which samples were taken, the thickness of reef at each of these points, and the result of assay in pennyweights of gold to the ton of ore.

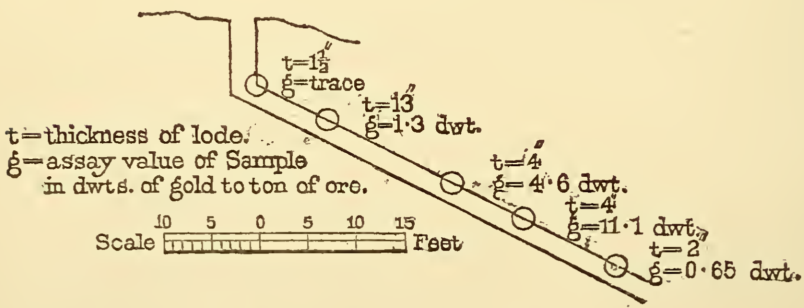

Fig. 1. Section of shaft No. 1, showing position and value of samples.

Six samples, each weighing about 4 lbs., were taken from the whole reef, and gave the following results :—

Sample.	Distance from end of shaft.	Thickness of ore-body.	Result of assay in dwts. to ton.	REMARKS.
C_{12}	0	$1\frac{1}{2}$ to 2 in.	0·65	
C_{11}	11 ft.	4 in.	11· 1	
C_8	19 ft.	4 in.	4· 6	
C_9	33 ft. 9 in.	13 in.	1· 3	including rider 4 inches.
C_7	41 ft. 9 in.	$1\frac{1}{2}$ in.	trace.	
C_6	53 ft. 3 in.	7 in.	18· 3	$11\frac{1}{2}$ ft. south of C_7.

The above figures give an average yield of 7 dwts. of gold per ton of ore for an average width of 5 inches.

No. 2.

The second shaft (fig. 2), partially cleared by Mr. Morris contains a somewhat thicker, but still very small, ore-body; it has, as in the previous case, been worked to a considerable extent by the natives, who burrowed along the vein in various directions. Samples were taken at three points, but gave only traces of gold.

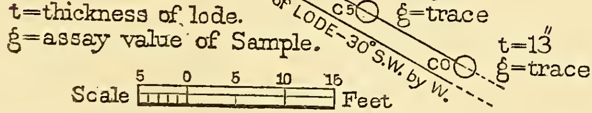

Fig. 2. Section of shaft No. 2, showing position and value of samples.

Sample.	Position.	Thickness of ore-body.	Result of assay.	REMARKS.
C_0	20 ft. 6 in. S. W. by S. from foot of vertical shaft.	13 in.	traces.	Shaft goes deeper but has not been cleared further.
C_5	9 ft. S. W. by S from foot of vertical shaft.	8 in.	"	
C_{14}	7 ft. E. from foot of shaft.	12 in.	"	

The results of the above assays are certainly not encouraging, for such small ore-bodies, unless very rich, would not be worth working.

Conclusions.

So far as the main reef is concerned it has already been stated that very extensive old workings occur in the neighbourhood of the two small shafts already cleared, and also at a point about two miles further to the north, almost due east of the summit of Bensibetta, as well as on a small hill about one mile east-north-east of Inbekombi village. Where outcrops of the reef are seen the stone is almost always white and barren-looking, all other minerals having been leached out of it, and consequently samples taken from these outcrops would not give reliable results. The most southerly workings, *viz.*, those between Marúr and Mádikada, are the most extensive, and among these are what may possibly be the remains of old shafts on the reef. The two samples taken from the outcrop yielded on assay only traces of gold, and although the invariable presence of gold in the débris in the neighbourhood of the outcrop would seem to point to the fact that the fresh rock may contain a workable amount of gold, yet this conclusion is by no means inevitable, for it must be remembered that during the process of weathering and disintegration of the reef, the gold, owing to its great specific gravity, would necessarily become concentrated in the surrounding soil. On the whole therefore there are no grounds to justify the recommendations of extensive prospecting operations on this reef, but it might be worth while to test it so far as this can be done at a small cost, *e.g.*, by clearing out any old shafts if such can be found on the main reef and by making a few cross-cuts through the reef: for in such an area as this, in which rainfall is small, weathering and decomposition are not likely to extend to any great depth, and it is reasonable to suppose that fresh material will be found at no great distance below the surface.

Country-rock.

Charnockite and Dharwars?

The rocks in which the reef occurs consist of crushed chloritic and garnetiferous quartz-sericite schists, passing outwards into highly brecciated and mylonitic ("trap-shotten") members of the charnockite series. The ridge of Bensibetta is composed of a great mass of green, somewhat schistose, quartzite, containing much kyanite and fibrolite, some rutile and green mica (fuchsite). This rock is very characteristic and can be traced northwards from Bensibetta to a prominent hill, Karáyanbetta, a few miles east of Bailúr: a short distance north of Karáyanbetta it occurs in a small hill named Pachikalwáre, where it has apparently been quarried.

Green quartzite.

It has been recorded from this last locality or from its neighbourhood by Mr. Middlemiss, who mentions it as occurring "3 miles east-south-east of Bailúr." He also found an exactly similar rock near Satyamangalam, and it is possible that this occurrence is merely the continuation of the same band. Other rocks, belonging probably to the same series as the schists and quartzite, are light and dark green amphibole schists containing very large quantities of epidote, which mineral is indeed one of the commonest in the rocks found in this area.

The age of these schistose beds has already been stated by Mr. Middlemiss to be in all probability lower transition or Dharwar, and the occasional occurrence of the quartz-iron-ore schists so typical of the Dharwars favours this assumption.

The other rocks of the neighbourhood consist, as already stated, of members of the charnockite series, much crushed and brecciated, and some biotite gneiss with chlorite.

Basic intrusives.

Basic rocks of an intrusive character are very numerous, great masses of a very fine-grained dolerite (s.g. 3·02) occurring to the east of Kádhati, between Bensibetta and Bailúr, while between Bailúr and Pachikalwáre gabbro is very common, and masses of steatite, more or less impure, are found everywhere. My visit to the neighbourhood was made purely to report on the auriferous localities, and I was unfortunately unable to devote any time to the many interesting rocks forming this igneous complex.

2. "Porsedyke."

The mine known as "Porsedyke," belonging to Mr. Hamilton Holmes, is situated at about 1½ miles north-east of the village of Porsegaundanpálayam. It consists of three vertical shafts sunk beside the outcrop of a large reef which runs nearly north to south along the flat top of a small ridge.

The reef.

The reef is composed of white and yellowish quartz stained with iron, and has been extensively worked by the natives. In 1896, Mr. F. H. Smith of this department visited the locality and reported on it, but at the time of his visit the only prospecting operations which had been carried out consisted of a small shaft some 30 ft. deep, in which, however, the reef was not exposed. He was therefore unable to offer any opinion as to its value.

Northern shaft.

Of the three shafts at present in existence, the most northerly is said to have been sunk to a depth of over 100 feet, but no reef is said to have been found in it: I was unable to examine this shaft as the winding gear was not in working order.

Central shaft.

The second shaft, which had reached a depth of 141 feet, is situated to the south of the first, along the strike of the reef and beside some old workings. In this shaft a drive runs to the east at a depth of 80 feet; reef quartz is said to have been found in this drive and to have been followed down for some distance; at the time of my visit, however, the drive was full of foul air and all attempts to enter it failed; it was therefore impossible to obtain samples from the lode. I was, however, shown some quartz at the surface which was said to have come from this level. This quartz is of a rich blue colour and contains *felspar*, *iron pyrites* and *hypersthene*; it is quite different from the reef seen at the surface and is, as a matter of fact, not reef quartz but one of the contemporaneous veins so common in the charnockite and pyroxenite, which is the country-rock at this portion of the shaft.

From the bottom of the shaft (141 feet) another drive has been run for a short distance to the east, but there is no trace of reef in this level, which is being driven through tough pyroxenite.

Southern shaft.

The third shaft, which is still further to the south, has been sunk just beside (west of) an outcrop of the reef. The old workings here were extensive and numerous, but no trace of reef has been found below ground. The shaft has a vertical depth of about 80 feet, and from the base a drive has been run to the east for a distance of 160 feet, entirely through pyroxenite, but no reef has been struck.

Country-rock. ? Dharwar.

Chiefly pyroxenite.

Probably intrusive.

The country-rock in which the reef occurs at the surface is quartz-chlorite schist, and like the rock of Bensibetta and other auriferous localities in this district is probably of Dharwar age. But almost the whole of the ridge in which the outcrop occurs is composed of a coarse pyroxenite, and it would seem that the small band of Dharwars with its accompanying reef has been caught up by the intruding basic rock and is therefore possibly merely a small isolated patch. The present levels which are being run in this mine are, as already stated, being driven through tough pyroxenite, and as this must involve much labour and expense with no certainty of eventually striking the reef, it would in my opinion be more advantageous to sink from the surface along the reef; it would then be possible to ascertain whether or no the reef is merely, as suggested, a small isolated patch caught up in an intrusive mass of pyroxenite.

3. Hadabanatta.

Old workings.

About two miles north of "Porsedyke" mine, and near the village of Hadabanatta (Adapullnutta) a lode is seen cropping out on the northerly slope of the end of the same ridge. On this lode are very extensive old workings (see plates 8 and 9) which were discovered by Mr. R. Morris. When first found, these workings were completely filled up by broken rock and débris, but have been cleared out by Mr. Morris. According to local tradition they were worked during the times of Tippu Sultán and Haidar Ali, but on the approach of the British, they are said to have been filled in.

The reef.

As will be seen from the plan and photograph, these old workings were fairly extensive, though their greatest depth is not more than about twenty feet below the surface. The reef, which varies in thickness from 1′9″ to about 8 feet, strikes nearly east-west and has a dip of about 33° to the south and south-south-east. A good deal of the reef has been exposed by clearing out the old workings and a certain amount of new ground has also been opened up by Mr. Morris.

The chief minerals found in the reef, in addition to quartz, are *copper pyrites*, *bornite*, *malachite*, *iron pyrites*, *hæmatite*, *limonite*, and various forms of *amorphous silica*. Near the outcrop one of the commonest of these minerals is malachite, which has been derived from the decomposition of the other ores of copper. This reef is in fact chiefly valuable as a copper lode and has already been examined by Messrs. John Taylor and Sons.

The lode was carefully sampled and the results obtained on assay will be found in the following table :—

Results of assay.

Sample.	Position.	Thickness of lode sampled.		Result of assay in dwts. of gold to ton of ore.	REMARKS.
		ft.	in.		
E 5	Old native workings	2	6	trace	Upper part only exposed : total thickness probably 6 ft.
E16	Shaft A	4	0	trace	Lower level, lower part of lode : total thickness probably 7 ft.
E23	do.	0	8	5·2 dwts.	Small band in centre of lode, said to have yielded visible gold.
E54	15 ft. west of E16	1	9	trace	Total thickness probably 4 ft.
E59	42 ft. west of E5	3	0	trace	Whole lode.
E66	11 ft. west of E59	1	8	trace	Lode not exposed between E66 and E75.
E75	42 ft. west of E66	1	4½	trace.	
E76	5 ft. further west	2	4	trace.	
E77	6 ft. " "	1	9	trace.	
E73	8 ft. " "	1	9	2 dwts.	
E79	7 ft. 6in. "	3	2	trace	Made up of lode 1′ 9″; country, 2′, lode, 6″.
E69	4 ft. 6in. "	2	3	trace.	

Of the above samples the first six—*viz.*, E 5, 16, 23, 54, 59, 66—were taken from the old native workings, and the last six—E75, 76, 77, 73, 79, 69—from a western continuation of the lode recently opened out by Mr. Morris.

Those from the old native workings were taken from as much of the reef as was accessible: this was in a few cases only part of the whole width: but those taken from the new trench along the reef were taken from the whole width of the ore-body, and represent as nearly as possible an accurate average of the lode at each point. So far as we can judge from the small amount of reef that has been made accessible, it will be seen that the gold-contents of the lode are small. It is, however, supposed that the natives worked originally for gold, as no signs can be found of furnaces or of slag, traces of which would probably be still visible had they smelted copper.

In addition to the above assays for gold, an estimation was made of the amount of copper in the samples from the newly opened portion of the reef. The results of this show that the ore near the surface contains about three per cent. of copper. As much of the copper, however, has been leached out of the lode near the surface by the action of percolating water, it is probable that richer ore will be found at some depth below ground. The lode would therefore in all probability be worth exploiting for copper, and I should recommend that more extensive prospecting be undertaken with this view.

Small workings near Dinhalli.

Between Hadabanatta and Rámapúram and about one mile east of the village of Dinhalli are some very small old workings. These are on a small outcrop of white, barren-looking quartz and are of no importance.

Blue quartz of charnockite series.

Numerous bands of blue quartz with felspar and iron pyrites are found in the charnockite series. Although these resemble quartz reefs, they are in reality acid segregation veins in the charnockite; samples taken from one of these veins near Dinhalli were assayed but yielded only traces of gold.

4. Kavudahalli.

Previously visited by Mr. Middlemiss.

The Kavudahalli workings were examined during the season of 1895-96 by Mr. Middlemiss, and the following observations made by me during the past season agree entirely with those recorded by him.

About three miles north of Rámapúram are the remains of fairly extensive old workings. The reef on which they are situated strikes nearly north-north-east—south-south-west and can be traced for about 3 miles. Throughout the whole of this distance old workings are found along the outcrop. The quartz is white and barren looking, with occasional patches of ferruginous material and iron pyrites. Mr. Middlemiss states that he found visible gold in the reef "near Alisupagadda hill." Still further to the north-north-east, in a direction corresponding with the strike of this reef, and about 1½ mile north-east of the village of Kavudahalli, some prospecting shafts were sunk by Mr. Holmes in the neighbourhood of old workings: these old workings were, however, apparently only in small stringers of quartz, and no reef was found during the prospecting operations, which were subsequently abandoned. About 6 miles further to the north, and about 1½ mile north-north-east of the village of Hosúr, are a few old workings, consisting chiefly of small quarries in the gneiss. Thin bands of white quartz only about two or three inches in thickness apparently constitute the only ore-body, and are of no practical importance.

The reef.

Prospecting shafts sunk by Mr. Holmes.

Old workings at Hosur.

Summary.

The general results of the above may be summarised as follows:

1. Numerous old native workings for gold occur in the Kollegál and Satyamangalam taluks of Coimbatore district: but they are as a rule small and unimportant, and the ore-bodies are either very thin or barren.

2. Three reefs have been exploited to some extent, and a few prospecting operations undertaken. These are—

(*a*) *Bensibetta reef:* a large reef on which are extensive old workings. The soil and débris at the outcrop contains a considerable quantity of gold. Samples from the outcrop of the main reef gave only a trace of gold, and of two small reefs sampled, one gave an average of about 7 dwts. per ton for an average thickness of 5 inches; the other only traces. It might be worth while to undertake some small prospecting operations, provided these could be carried out at no great cost; an attempt, for example, might be made to clear out any old shafts on the main reef and some cross-cuts might be made through the reef.

(*b*) *Porsedyke mine:* a large reef crops out at the surface and has been worked to some considerable extent. Three vertical shafts have been sunk by Mr. Holmes, and cross-cuts made in order to strike the reef: this, however, has not been found, having been probably cut off by a great mass of intrusive pyroxenite. It would seem advisable to sink on the reef itself in preference to continuing expensive work in the pyroxenite.

(*c*) *Hadabanatta:* this lode contains small quantities of gold but probably not in sufficient quantity to be worth working for that mineral alone. Samples taken from near the surface yield, however, 3 per cent. of copper, and more extensive prospecting operations should be undertaken with a view to proving the value of the lode.

3. Old native workings occur also at Kavudahalli, Hosúr and Dinhalli. Prospecting operations carried on a few years ago near Kavudahalli failed to prove the existence of any workable body of ore.

The old workings near Hosúr and also those near Dinhalli are small and unimportant.

Geographical Index.

	Latitude N.			Longitude E.		
Bailúr (Payalur) . . .	11°	49′	9″	77°	18′	20″
Bensibetta	11°	42′	30″	77°	21′	
Dinhalli (Dinne Alli) . .	11°	55′	20″	77°	24′	15″
Hadabanatta (Adapullnutta)	11°	56′	30″	77°	21′	30″
Haussanúr	11°	40′	40″	77°	18′	50″
Hosúr (Osaur) . . .	12°	5′	30″	77°	33′	
Inbekombi	11°	43′	40″	77°	21′	30″
Kádhati (Caudutty) . .	11°	44′	10″	77°	21′	
Karáyanbetta . . .	11°	47′	30″	77°	20′	30″
Kavudahalli . . .	12°	3′	40″	77°	30′	10″
Kollegál	12°	9′		77°	10′	
Marúr (Murroor) . . .	11°	41′	20″	77°	22′	40″
Mádikada	11°	41′		77°	21′	20″
Pachikalwáre . . .	11°	48′	30″	77°	20′	30″
Porsegaundanpálayam . .	11°	53′	30″	77°	21′	15″
Rámapúram . . .	12°			77°	27′	
Satyamangalam . . .	11°	30′	30″	77°	18′	30″

III.—Report on the auriferous quartzites of Parhardiah, Chota Nagpur, *by* Frederick H. Hatch, Ph.D., F.G.S., *Assoc. M. Inst. C.E., Mining Specialist, Geological Survey of India.* (With Plate X.)

Situation.

The property is situated at Parhardiah near the village of Somij, in the zemindary of Anandapur, Singhboom district, Chota Nagpur. It is reached by a country road from Manharpur Station on the Bengal-Nagpur Railway, from which it is distant some 14 miles.

Description of the "veins".—The so-called "veins" which have been prospected by the Company are in reality highly silicified beds of quartzite which are associated with a series of calc-chlorite schists, the whole constituting a part of the great group of Transition rocks. The beds strike approximately east and west and dip at an angle of 60 to 70 degrees to the north.

The quartzite is a bluish to whitish grey rock, consisting of an aggregate of closely interlocked granules of quartz. Examined under the microscope, the granules are seen to be small and of fairly uniform size but of irregular shape and with ragged edges. Calcite occurs in the sections in patches and streaks, and here and there is an occasional shred of talc. It is evident from the way in which these beds are veined with small seams of secondary quartz that they have formed a channel for the passage of mineralizing solutions, and to this fact must be ascribed the presence of the metalliferous constituents, namely, iron-pyrites and gold.

The calc-chlorite schist consists of calcite, chlorite and magnetite. The carbonate constitutes the biggest proportion of the rock and is evidently of secondary origin. The magnetite is present in well-defined octohedral crystals. A small quantity of talc is also present. In places this rock is also veined with secondary quartz. Apparently the calc-chlorite schist has been produced by dynamic metamorphism from a volcanic tuff or breccia, as an examination with the microscope discloses in some of the sections the presence of fragments of a rock of the nature of an andesite in which clearly discernible porphyritic crystals of plagioclase felspar are preserved.

Description of workings on the quartzite beds.—The largest of the quartzite beds—some 20 feet in width—the outcrop of which forms a prominent feature of the property, has apparently not been reached by the cross-cuts extended from the shafts put down on its hanging wall side by the modern workers, although there is distinct evidence of an ancient working upon it. To what depth, however, the ancients were able to penetrate on this bed, I was not able to ascertain as the old working is filled up.

As far as could be seen by the small amount of development work that has been done, the "veins" intersected by the cross-cuts driven from the prospecting shafts consist of one or more smaller beds of quartzite, lying to the north (*i.e.*, on the hanging wall side of the big bed). The correctness (or *vice versâ*) of this view could be easiiy determined by extending the cross-cuts some twenty or thirty feet to the south, and this should be done if further developments are undertaken.

Workings.

The amount of work done and the supposed position of the beds are shown on the sketch cross-sections which I have drawn to illustrate this report.

There are five shafts in all, but only three are of importance. These are known as No. 3, No. 4 and "Verner's."

No. 3 shaft is down 72 feet from the top set. At 70 feet the vein has been cut across. It is here about 12 feet thick. The total length of drivage on the vein (including the width of the shaft) is 70 feet.

No. 4 shaft is down 60 feet. From the bottom the "vein" has been cross-cut. Its hanging wall is 7 feet from the side of the shaft and its foot wall 22 feet. The drivage on the course of the vein amounts to 23 feet. From the end of the cross-cut a rise communicates with an old working coming from the surface.

Verner's shaft is down 83 feet. From the bottom a cross-cut has been put in 30 feet to the south. At 9 feet from the shaft a small quartzite bed, 3 feet thick, has been intersected, and at 19 feet there is a 4-inch vein. The main body has not been reached.

With regard to relative position, No. 3 shaft is about 160 feet to the west of No. 4, and Verner's shaft about 400 feet west of No. 3.

The following samples were taken:—

No. 3 Shaft—

C 34. From 70 foot level, full width of vein 12 feet. Assayed 4·5 dwts.

C 39. From supposed rich place on 70 foot level, pointed out by Mr. Mervyn Smith, 12 inches . . 3·25 dwts.

C 90. From supposed rich place 50 feet down shaft, 6 feet only of vein exposed . . . assayed 1·3 dwts.

No. 4 Shaft—

C 93. From bottom, full width of vein, 12 feet. Assayed 2·0 dwts.

Verner's Shaft—

C 76. 3-foot "vein" in cross-cut. Assayed 7·8 dwts.

C 71. 4-inch ,, ,, ,, ,, 5·2 dwts.

Summary.

The "veins" are mineralized quartzite beds carrying cubical pyrites and gold. There are apparently at least two such beds, of which only the smaller one has been tapped by the present workings; the other is a much bigger body and should be prospected as there is a reasonable chance of its also being auriferous, especially as there are signs of the ancients having done some work upon it.

The assay result obtained from the samples taken by me from the "veins" of 12 and 3 feet thickness, at different points in their course, are sufficiently encouraging to warrant some money being spent in their further development.

After a comparison of my specimens with those containing visible gold, reputed to come from No. 3 shaft, I have little doubt that these rich specimens did in reality come from the property, as the quartz is of closely similar nature and their sections, cut from both rocks, were found to have an identical microscopic structure; but personally I did not obtain specimens carrying visible gold.

Photographed by H. H. Hayden. *Bemrose, Collo., Derby.*

OUTCROP OF AURIFEROUS REEF, S.E. WAINÁD.

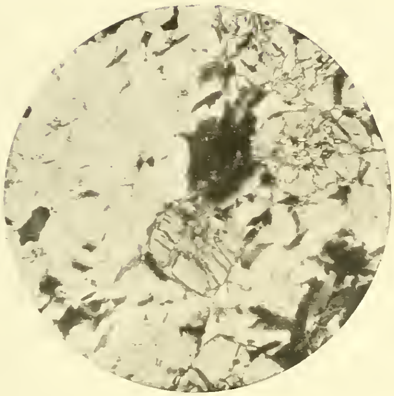

FIG. 1.

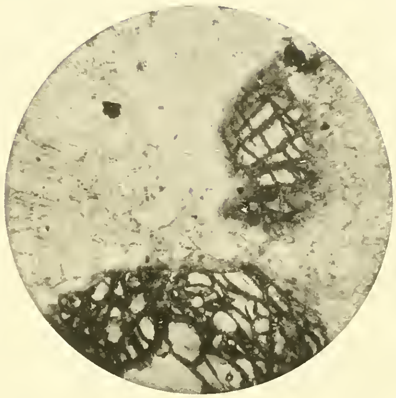

FIG. 2.

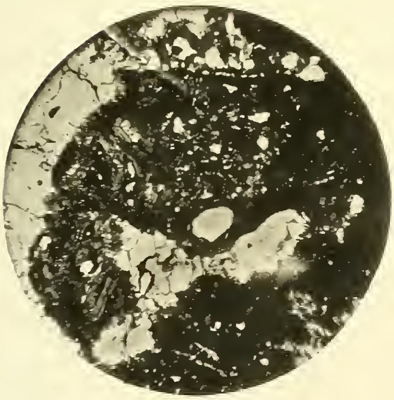

FIG. 3.

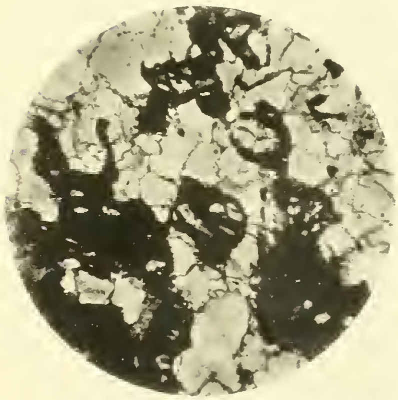

FIG. 4.

Photographed by H. H. Hayden. *Bemrose, Collo., Derby.*

WAINÁD ROCK STRUCTURES.

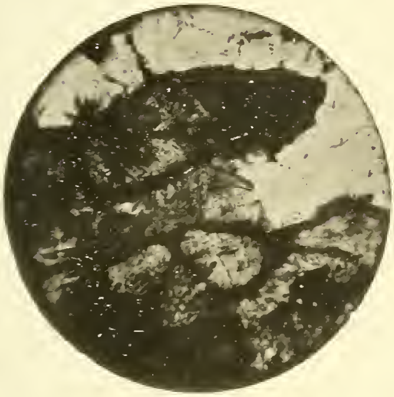

FIG. 1.

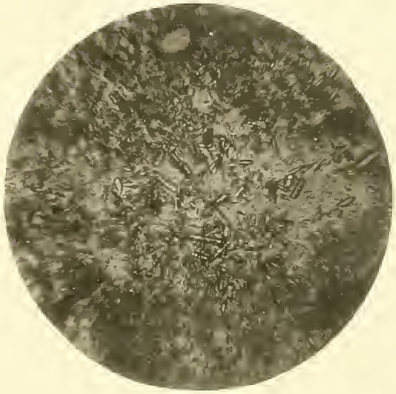

FIG. 2.

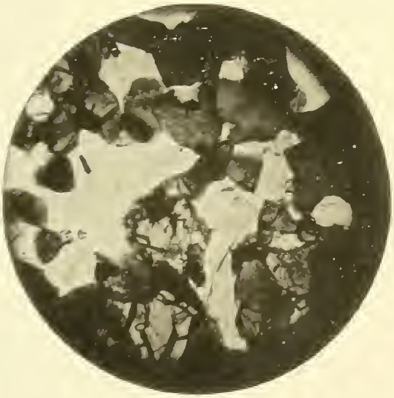

FIG. 3.

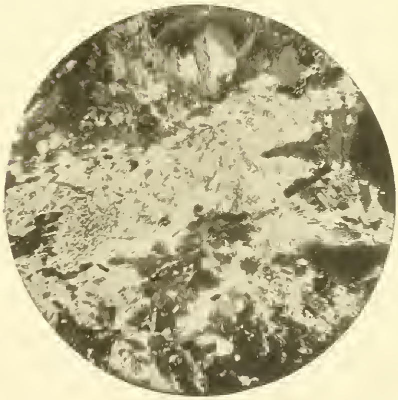

FIG. 4.

Photographed by H. H. Hayden. *Bemrose, Collo., Derby.*

WAINÁD ROCK STRUCTURES.


THE
AURIFEROUS QUARTZ REEFS
OF
SOUTH-EAST WAINAD.
Scale 4 Miles 1 Inch.
ACCORDING TO
Dr. W. KING,
Late Director, Geological Survey of India.
INDEX
Auriferous Quartz Reefs.
Dip & Strike of Strata.
Dip of Quartz Reefs.
Gunapuddyvuttum
Tirur
Pudyeddem
Kotar
Padree
Mootlylerrah
Irtyempeth
Coilaudy
Nemmainy
Vengalary
Yeddacul
Cheengaree
Yeddokulmullay
Moochellary
Chulicod
Chulaot
Wurrakaray
Molapilly
Paatviel
Nellacottah
Trikypetta
Munjaparah
Paladu
Padypurmbu
Munnymullay
Mottumullay
Kundamungalumcota
Coornjiloth
Mupucoon
Pungellary
Tullur
Polen
Poravauru
Nandenur
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Yalamar
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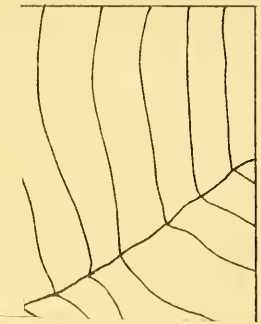
Devalocolah
Paundy R.
Palmulla in ruins
Wavootmullay or Camels Hump
Yeddum
Neelaghenry Peak
76 30
11 30



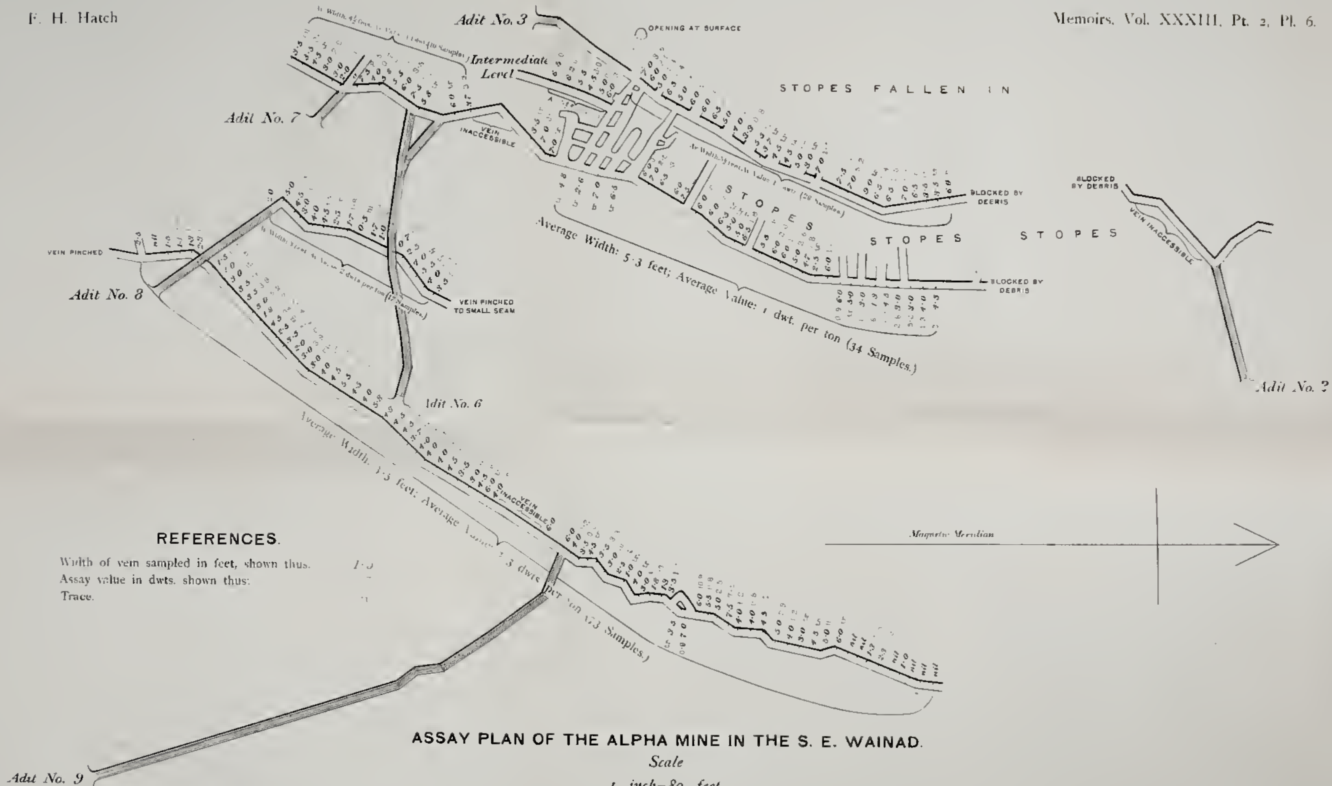
H. H. Hayden, del.

MAP OF THE ALPHA MINE, SHOWING OUTCROP OF THE SKULL REEF.

Surveyed by H. H. Hayden.

Scale.

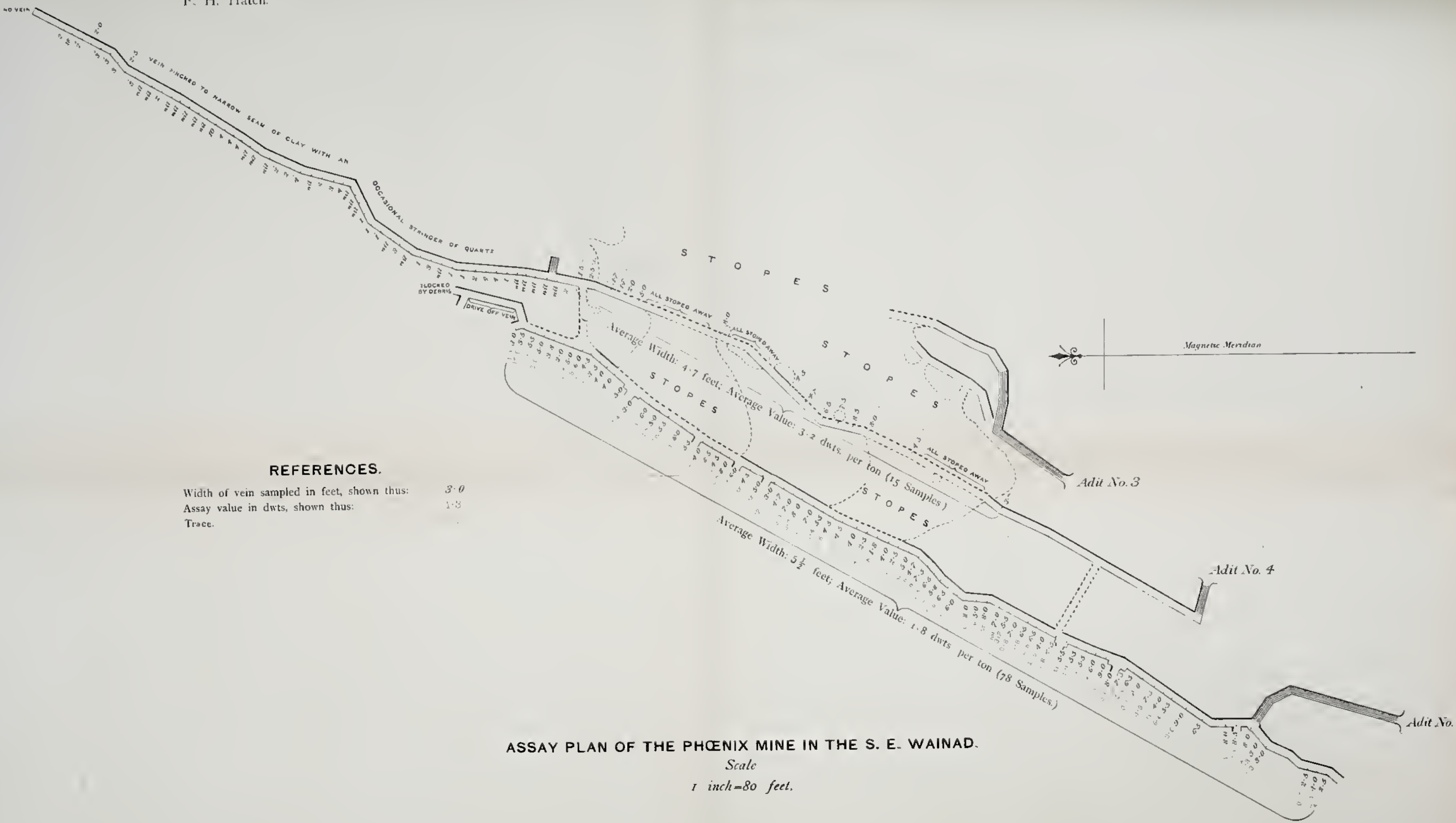
100 0 100 200 300 400 500 600 700



ASSAY PLAN OF THE ALPHA MINE IN THE S. E. WAINAD.

Scale

1 inch=80 feet.



REFERENCES.

Width of vein sampled in feet, shown thus: 3·0
Assay value in dwts, shown thus: 1·3
Trace.

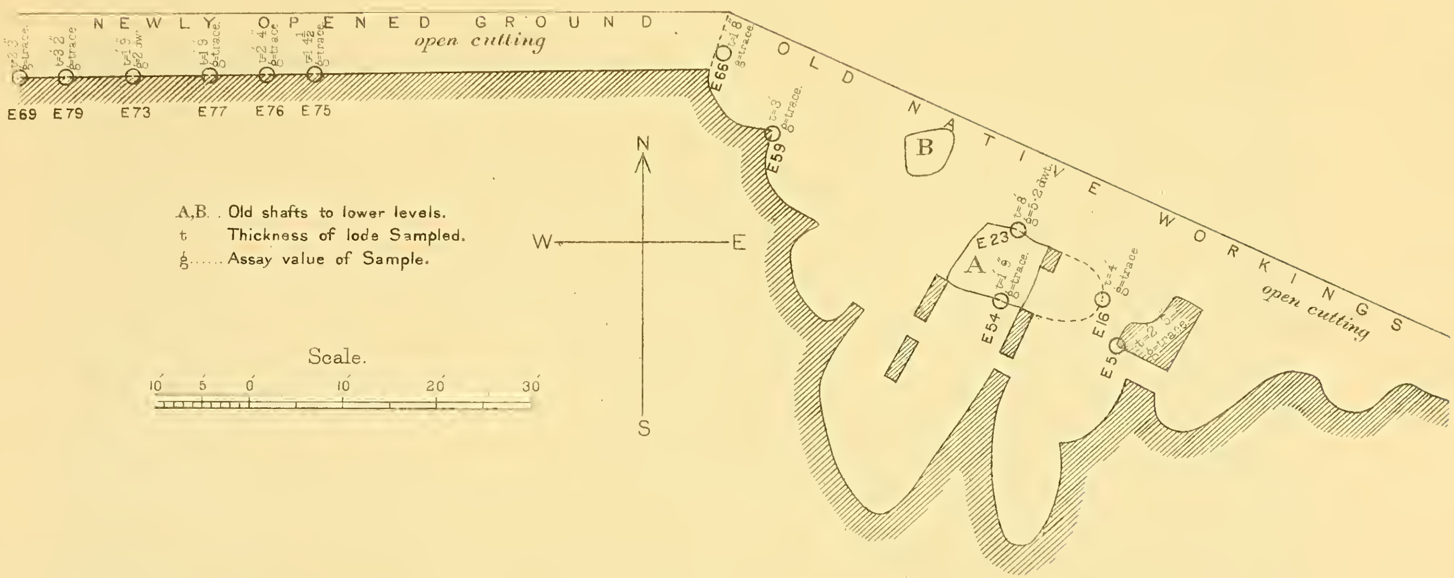
ASSAY PLAN OF THE PHŒNIX MINE IN THE S. E. WAINAD.

Scale

1 inch=80 feet.

H. H. Hayden.

Memoirs, Vol. XXXIII, Pt. 2, Pl. 8.



H. H. Hayden. del.

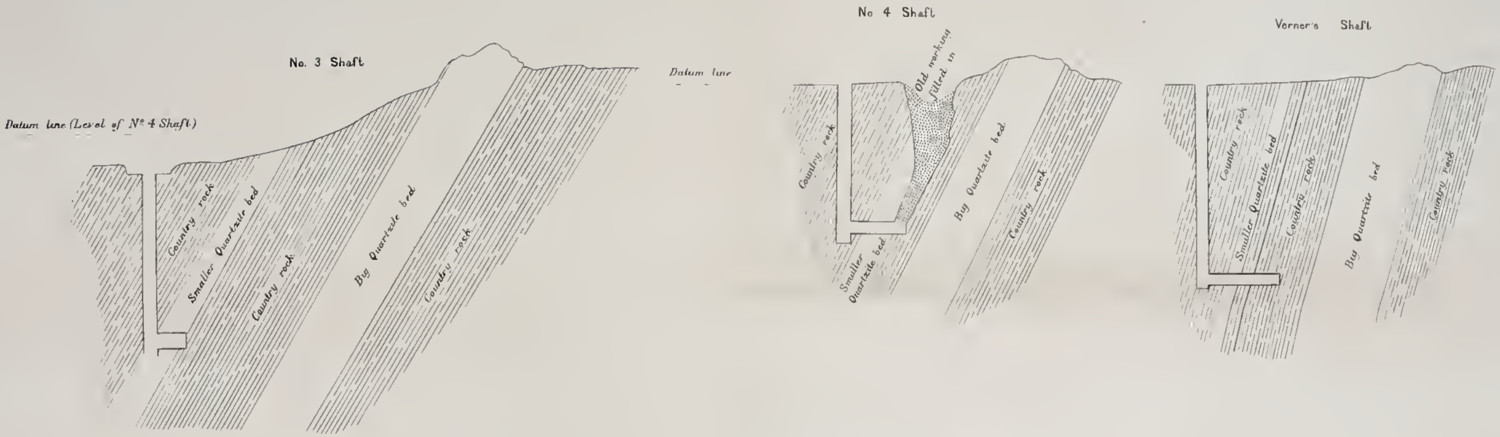
PLAN OF WORKINGS AT HADABANATTA.

Photographed by H. H. Hayden. *Bemrose, Collo., Derby.*

OLD NATIVE WORKINGS AT HADABANATTA.

F. H. Hatch.

Memoirs, Vol. XXXIII, Pt. 2, Pl. 10.



CROSS SECTIONS OF WORKINGS OF THE PAHARDIAH GOLDMINING Co.

Scale 1 inch equals 40 feet.

MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

VOL. XXXIII, PART 3.

THE GEOLOGY OF KALAHANDI STATE, CENTRAL PROVINCES, *by* T. L. WALKER, M.A., Ph.D., *Geological Survey of India.* (With map and one plate.)

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CONTENTS.

I.—INTRODUCTION.

The observations recorded in this paper were made during the first four months of the new century. The first part of the field season 1900-1901 was spent in the adjoining part of Jeypore zemindari, the geology of which is in many respects similar to that of the Kalahand state. About twenty years ago the north-western part of the state was traversed by the late Mr. Ball of this department, who published some notes [1] on the geology of the country explored.

The Kalahandi state is not easily reached, being nearly two hundred miles from Raipur, the only large centre connected with it by a good road. Comparatively bad roads lead to Sambalpur and to Vizianagram, but even then the distance is over a hundred and thirty miles. The state is not so backward as might be supposed from its isolated position.

[1] Rec. Geol. Surv. Ind., Vol. X, p. 167.

The north-western half of the state forms a plain from 600 to 800 feet above the sea-level, and can be traversed either by carts or by cooly transport. The south-eastern half, however, is part of the plateau of the eastern Ghauts which here rise to a little over 4,000 feet on an undulating plateau of about 3,000 feet. Here there are no cart roads, and as the plateau is only sparsely inhabited by Khonds who are very shy and difficult to collect in numbers sufficient for transport, I was assisted in carrying on my work by elephant transport kindly placed at my disposal by the state durbar and by the hill chiefs. The zeal shewn by the state officials in assisting me in my work was well seconded by the village people, who were friendly and always willing to supply my camp with such things as were produced locally. My best thanks are due to Mr. F. G. Sly, I.C.S., Political Agent, Raipur, and to the chiefs and officials of the state for the assistance given me in carrying out my investigations.

There are two fairly distinct peoples, the Hindoos of the plains who speak Uryia and make some claim to Aryan descent, and the Khond hill men of the 3,000-foot plateau who are aborigines only very slightly influenced by the doctrines of the Hindoos who inhabit the low country. Though the Khonds are still regarded as wild tribes, they devote themselves to agriculture and to the collection of forest products, and now that they have abandoned their old barbarous custom of sacrificing human lives to their gods, they seem to be little behind their Hindoo neighbours in civilisation, who are their inferiors from a physical point of view. The great moral virtue of the Khond is his truthfulness, as his vice is drunkenness. The progress of civilisation among the Khonds—*viz.*, the Hinduising and Uryiaising of these aborigines—does not seem to improve them. The light-heartedness of childhood is characteristic of Khonds of all ages.

Geologically the whole state is made up of non-fossiliferous rocks, chiefly crystalline schists and transitions with one small outcrop of Gondwanas on the extreme north eastern points of the state and occasional caps of laterite topping the broad hills which rise from the plateau forming the south-eastern half of the state.

On the geologically colored map which accompanies this report eight rock groups have been distinguished as follows:—

1. Crystalline Complex.
2. Granitoid Gneiss.
3. Charnockite Series.
4. Khondalite and associated rocks.
5. Cuddapahs or Vindhyans.
6. Gondwanas.
7. Laterite.
8. Dyke Rocks.

In the present state of our knowledge of the geological relations of the group of crystalline rocks which make up the northern part of the eastern Ghauts, it is impossible to speak definitely as to their genetic and chronological relations to one another. Detailed study has not been attempted as will become evident when it is stated that in a little over five months field work in Vizagapatam and Kalahandi nearly seven thousand square miles was mapped, most of the country being altogether new ground. In one outcrop, to be more fully described hereafter, I observed what appeared to be fairly well banded gneisses in contact with Cuddapah slates which shewed well-marked contact metamorphism; if we may rely on this interpretation of the phenomena, we will be forced to regard some of the "gneisses" placed in the Crystalline Complex as nearly well banded granites of post Cuddapah age, a conclusion little in accord with the accepted views as to the relative ages of these two rock groups.

II.—THE CRYSTALLINE COMPLEX.

I have attempted to divide the crystalline rocks of Kalahandi into four groups, three of which have fairly distinct relationships and are described separately in the three following chapters. The remaining crystallines are dealt with in the present chapter. It seems very probable that they do not represent a geological unit as they include both metamorphosed igneous rocks—ortho-schists—and metamorphosed sediments or para-schists. In mapping the crystalline schists in four groups, it must be understood that the boundaries indicated are only approximate. This is due to several reasons, the two chief being that the time spent on the work was too short for detailed mapping even if the forest growth and the alluvial covering permitted it, and to the well-known fact that members of a crystalline complex are often so closely related as to origin and subsequent history—genetically and metamorphically—that they pass gradually and imperceptibly into one another, and sharp and definite boundaries do not really exist. Examples of this will be cited in the geology of Kalahandi state in the following pages.

The rocks of the Schist Complex occupy the western part of the state. To the west they are almost identical with those described in Nawrangapur in the first part of the present report. They occupy the whole of the 800-foot plain east to the edge of the 3,000-foot plateau and as far north as Lat. 19° 47′ from which point they are bounded on the east by the Granitoid Gneiss.

The chief rock of this complex is a pink fairly felspathic biotite gneiss with hornblende and frequently monoclinic pyroxene (specimens 15·143, 15·144 and 15·148). Usually the rock is distinctly foliated or banded and strikes about north-north-west, but this is not always the case. Subordinate bands of mica schist, amphibolite and quartzite occur. The gneiss is very probably an intrusive granite banded by movement in the solidifying magma and subsequently foliated. It is much more felspathic than is usual in the case of para-schists.

Near Chachanbali I observed these gneisses in contact with slates of the Cuddapah system, which were flecked and knotted near the contact as if they had been acted upon by an igneous intrusion. Though typical contact minerals such as cordierite and andalusite were not observed, the general megascopic appearance of these peculiar slates is certainly such as to suggest contact metamorphism. This would mean that (1) some at least of these rocks which look like gneisses should really be regarded as foliated granite which on its intrusion metamorphosed the slates, and (2) that they are post Cuddapah in age. Whether this holds only for the gneisses in the immediate vicinity of Chachanbali or for the wide area here described, is at present impossible to decide. (Specimens 15·202 to 15·209.)

III.—THE GRANITOID GNEISS.

In the vicinity of Bondesor occurs a very coarse-grained granitoid gneiss in which large pink felspar crystals and broken red garnets are contained in a dark groundmass. Usually the felspar crystals, which are sometimes nearly a foot long, are approximately parallel, the direction being north-westerly. At times these giant phenocrysts are not bounded by polyhedral surfaces, but are more or less ovoid in form causing the rock to become an augen gneiss (specimen 15·162), resembling at first glance a coarse conglomerate with rounded pinkish pebbles in a dark fine-grained cement. In addition to the north-westerly parallelism of the phenocrysts, which is probably the direction of the flow prior to consolidation of the magma, a north-easterly system of joints and slickensides, caused by subsequent earth-movements, is often well developed.

On examination of thin sections of this rock with the microscope it is seen that in addition to large crystals of felspar and grains of garnets, which are easily distinguished macroscopically, the chief constituents of the dark groundmass are quartz, twinned and untwinned felspars, biotite and small grains and crystals of garnet and pyroxene. The pyroxene is usually pleochroic with the colors of hypersthene—rose and greenish blue—but it is sometimes seen to be distinctly monoclinic, shewing a maximum extinction of 15° when measured against the cleavage lines. In some varieties brown hornblende and a pale green monoclinic pyroxene are very frequent.

The history of this rock as revealed by the microscope agrees with that based on field and macroscopic observation. Large quartz grains shew wandering extinction and are frequently surrounded with a border of small grains of quartz (cataclastic structure). The larger felspar crystals of the groundmass are often bent or curved and secondary twinning has been induced by pressure, in some of the plagioclase crystals. All the larger garnet crystals are much shattered, though isotropic when examined in parallel polarised light. From the microscopic slides alone one would therefore be justified in maintaining that since consolidation these rocks have been subjected to great pressure which has induced such secondary characteristics as shattered or bent crystals, granulation, stress phenomena as indicated by wandering extinction in quartz grains and secondary twinning in felspars, a conclusion quite in accord with that reached from field and macroscopic observations.

In some places where pressure was most intense the whole rock was crushed and granulated resulting in a mylonite which can only be referred to the coarse form by its geographical position. In some cases bands of this mylonite cut the coarse rock almost like dykes (specimens 15·167 and 15·168). This intense crushing is most frequent on the north-eastern borders of the granitoid gneiss.

Geographically the granitoid gneiss occupies the north-eastern part of the Kalahandi 800-foot plain, and extends south-east into the hills of the 3,000-foot plateau, in a band ten or fifteen miles wide, to Lonjigar and beyond at least as far as Singapore in Vizagapatam district.

Most of the hills on the plains made up by these rocks are composed of garnet sillimanite schist described in a later chapter. In the south-eastern extension of the granitoid gneiss into the 3,000-foot plateau, the higher points are usually composed of sillimanite garnet schist, while the bases of the hills and the valleys shew outcrops of granitoid gneiss. As to the relationship between these rocks and the charnockites, there is very little positive information, but two main facts, (1) both being undoubtedly of igneous origin, and (2) the presence in both of a pyroxene with the pleochroism of hypersthene, should be borne in mind. It may be that they are derived from a common magma which differentiated into more basic—charnockite—

and more acid—granitoid gneiss—sections, both being marked by the peculiar pyroxene which they have in common. About a hundred miles south, in Vizagapatam district, I have seen rocks almost exactly like the granitoid gneiss occurring as coarse acid patches in the great charnockite massif. It seems very probable that these two rock masses in Kalahandi may have a common origin, such as is all but certain in the case of similar rocks a little farther south.

Basic borders have been found in several places around the margin of the granitoid gneiss mass. On the north-eastern border near Madhanpur more basic forms, near the intermediate charnockites, have been collected, while on the west near Turkel, rocks related to the Canadian anorthosites occur. (Specimens 15·171, 15·172, 15·175 and 15·176.)

IV.—CHARNOCKITE SERIES.

These rocks are very prominent in the south-eastern part of Kalahandi. In the plateau they are very well exposed from Moulpatna to Rampur and for some distance to the east; farther east the higher hills are made up of garnet sillimanite schist, charnockite only being seen in the valleys and at the bases of the hills.

In exploring the Jeypore zemindari[1] it was found that the 3,000-foot plateau is almost entirely made up of charnockite, which apparently forms a great elliptical massif extending almost from the Godavari to the Mahanadi. The charnockite occurrences in Kalahandi form part of the north-western section of this massif.

Macroscopically the rocks are usually fairly coarsely crystalline, brownish black in color, and frequently exhibit porphyritic felspars and garnets. In the field a north-north-easterly parallelism or strike can often be observed, conditioned by a regular orientation of the felspar crystals. An examination of thin sections under the microscope shows that the commonest form is a rock made up of plagioclase, orthoclase and a mineral more or less resembling the rhombic pyroxenes in regard to inclusions, pleochroism and color, but seldom extinguishing straight along the chief lines of cleavage. Garnet, a little brown

[1] General Report, Geol. Surv. Ind., 1899-1900, p. 168.

hornblende, biotite and quartz are usually present in varying amounts.

It will thus be seen that the rocks in question differ somewhat from the typical charnockites described by Mr. Holland,[1] though I incline to the opinion that they all belong to the same petrological province. The granitoid gneiss described in the last chapter is also characterised by the presence of small quantities of the pyroxene seen in the Kalahandi charnockites. (Specimens 15·178 and 15·179.)

V.—THE GARNET SILLIMANITE SCHISTS—KHONDALITE.

Most of the hills rising from the 800-foot and 3,000-foot plateaux as well as those along the Ganjam-Kalahandi frontier are composed of rocks, usually foliated, consisting of quartz, garnet, sillimanite and graphite. In hand specimens they are greyish to reddish in color and frequently shew numerous small shattered red garnets in a very much crushed groundmass. The microscope shews that the groundmass is made up of quartz grains penetrated by innumerable disjointed sillimanite needles usually more or less parallel, and occasional ragged flakes of graphite, see Pl. 2. The sillimanite is sometimes made up of almost hair-like needles, so that the quartz sillimanite intergrowth approaches typical fibrolite, at other times, it forms independent disjointed crystals of considerable dimensions. The specific gravity varies from 2·85 in the more quartzose varieties to about 3·05 in the more garnetiferous. (Specimens 151·80, 15·181, 15·187.)

These rocks are well defined schists, apparently altered sediments overlying the granitoid gneiss, charnockites, and in some instances the more massive gneisses of the crystalline complex. Along the Ganjam frontier the hills are almost entirely made up of sillimanite garnet schists. Farther south in the 3,000-foot plateau it is usual to find charnockite or granitoid gneiss exposed in the valleys and on the lower slopes of the hills, the main mass of which is composed of sillima-

[1] Mem. Geol. Surv. Ind., Vol. XXVIII, p. 119.

nite schist. Frequently the hills are flat topped and crowned with a sheet of laterite from 80 to 200 feet in thickness.

The usual strike is north-north-easterly. Where the Khonds have not cut down the forest in clearing land for cultivation, hills composed of sillimanite schist are usually well wooded, the gently sloping hill-sides being covered with loose blocks of various sizes rendering it difficult to obtain large outcrops of these rocks for geological study.

Along with the sillimanite rocks, probably interbanded with them, occur occasional masses of garnetiferous quartzite and of a white rock resembling crystalline limestone but which the microscope shews to be made up of a colourless pyroxene (wollastonite ?), a greenish pyroxene, probably diopside, green spinels, brown garnet scapolite and sometimes calcite and sphene, all minerals which are frequent and characteristic of crystalline limestone formed by the metamorphism of slightly impure limestone either by regional or contact action. The essential difference between the rock in question and the ordinary marble consists in the large rôle played by calcite in the latter and its very subordinate proportion in the former. The more impure the original limestone, the greater the rôle played by the accessory minerals. Judged from this point of view we may conclude that the rocks under discussion were probably produced by the metamorphism of extremely impure calcareous sediments. (Specimens 15·216, 15·217, 15·218 and 15·219.)

Unfortunately none of these impure marbles have been chemically analysed.

Specimen 15·181, which I regard as a typical garnet sillimanite schist, yielded on analysis—

SiO_2	74·17%
Al_2O_3	17·16%
Fe_2O_3	7·82%
MgO	·83%
CaO	·61%
K_2O	trace.
Na_2O	·49%
Loss on Ignition	·11%
TOTAL	101·19%

S. G. . . 2·91

The remarkable thing about this analysis is the very high proportion of silica and alumina as compared with the insignificant proportion of alkalies. Chemically it does not resemble any known igneous rock, though rocks of this chemical composition could be obtained by the metamorphism of well leached clay mixed with a little quartz.

The composition of the sillimanite schist taken along with the nature of the rocks with which it is associated compels one to regard this group as para-schists, while their occurring above the charnockites, granitoid gneiss and other coarse gneisses, all of which appear to be igneous in origin, suggests that we are dealing with rocks formed by the metamorphism of ancient sediments, very probably by the intrusion of the great igneous masses referred to, and by the action of a mountain building force acting in a line at right angles to the north-north-eastern foliation frequently observed in the rocks of Kalahandi state. In this case we must regard the sillimanite schists as older than either the charnockite or the granitoid gneiss and even older than many of the gneisses of the crystalline complex.

Mr. Smith found these schists over a great part of the Ganjam Malias,[1] and I have observed them farther south along the eastern border of the eastern Ghauts in Vizagapatam district. Apparently these isolated outcrops are remnants of a once continuous arch of altered sediments covering the great igneous massif of charnockite and related igneous rocks which extends almost from the Godavari to the Mahanadi. At present these rocks are known to occur as hills on the 3,000-foot plateau, which is composed essentially of charnockite, and as a fairly broad border along the northern and eastern margins of the massif. For some reason, as yet unexplained, sillimanite schists do not occur along the western margin in the vicinity of Jeypore. There are, however, evidences indicating a faulted western boundary for the charnockite ellipse, in which case the upthrow of the schists would expose them to denudation, which may account for their absence along the western side of the massif.

[1] General Report, Geol. Surv. Ind., 1899-1900, p. 153.

Professor Lacroix has described[1] sillimanite schists from Ceylon where they apparently occur along with the charnockites of that colony. In India sillimanite schists and charnockite accompany one another quite as their relatives, pyroxene-granulite and granulite, frequently do in Europe.

Their distribution in Peninsular India so far as at present known is almost subject to the same boundaries as Khondistan or the country of the Khonds. Instead of the awkward descriptive name, garnet-sillimanite-graphite schist, I propose to call these rocks Khondalite, in honour of those fine hill men the Khonds in whose mountain jungles Khondalite is better developed than in any region hitherto described. These rocks are not new to petrology, neither is the selection of a special name imperative, but for the sake of brevity of nomenclature and as a local convenience I trust the new designation will be of service.

More garnetiferous somewhat massive rock, closely related to the Khondalites, occur frequently on the plain east of the eastern Ghauts from the Godavari to the Mahanadi, and provides most of the blocks used for bridge work and other construction along the East Coast Railway in this region.

VI.—THE CUDDAPAH SYSTEM.

The rocks referred to this system resemble in most respects those described under this heading in the preceding report on the Geology of Nawrangapur taluq in Vizagapatam district. Petrologically they resemble the typical Cuddapahs of the south and the Vindhyans to the north. Being non-fossiliferous it is necessary in correlating these rocks, to rely upon petrological characteristics, a not altogether satisfactory method when applied to rocks separated from one another by several hundred miles.

In the Kalahandi State these rocks occupy a narrow strip along

[1] A. Lacroix : Bulletin de la Société de Minéralogie, Vol. XII, pp. 59 and 83.

the Jeypore frontier near Ampani, and one or two small outliers in the adjacent gneiss region.

The Cuddapahs are here represented by slates, grey chocolate and drab, and by white and buff quartzites. In the small outlier made up of the two narrow hills just west of Chochanbali, the rocks along the line of junction of the gneiss and Cuddapahs resemble, in many respects, the contact products which are usual where granite is intruded into slates. Breccias, flecked slates and dark blue fairly massive varieties were observed, but under the microscope these last did not shew either cordierite or andalusite, though these minerals are frequent in rocks which resemble these rocks macroscopically. This interesting outcrop has been referred to in a previous chapter while discussing the age and origin of certain of the members of the schist complex. The schists around the hills in question are fairly well foliated gneiss (or granite ?), which judging from these contact results must have been formed by the foliation of an intrusive granite of post Cuddapah age. (Specimens of contact products 15·202 to 15·209.)

VII.—GONDWANAS.

Near the Kalahandi-Patna boundary on the south bank of the Tel river there is a small exposure, of gritty sandstone, not exceeding a few acres in extent. Very indistinct traces of original stratification can be observed in the rocks of the outcrop in question. The sandstone is usually coarse enough to be called a grit and frequently contains well rounded boulders of gneiss sometimes several pounds in weight.

Mr. Ball in his traverse of the country to the north discovered several small outcrops which he regarded as Talchir sandstone. It is probable that they are isolated patches forming outliers in the crystalline rocks, but geologically related to the Gondwanas of the Talchir coal field which is some seventy-five miles to the north-east. No fossils were discovered. (Specimens 15·212 and 15·213.)

VIII.—LATERITE.

Laterite is frequently observed in small outcrops on the 800-foot plain in Kalahandi state and in Nawrangapur taluq to the west, but it attains its highest development as a capping for the highest of the hills which rise from the 3,000-foot plateau. These hills usually rise from a base of charnockite or granitoid gneiss, the main mass being made up of Khondalite or sillimanite schist, while they are usually flat-topped and capped with a shell of laterite from 80 to 200 feet in thickness. The maximum altitude of these laterite capped hills is a little over 4,000 feet or 1,000 feet as viewed from the 3,000-foot plateau.

One of the hills of this class was visited by Mr. Ball,[1] who without examining the others farther east, recognised them as of the same geological structure as Baplaimali which he examined. In Ganjam district, to the east of Kalahandi, similar laterite capped hills were observed by Mr. Smith.

Viewed from the top of one of these hills the others of similar origin are easily recognised by their flat tops which all appear to rise to about the same altitude as if remnants preserved from the denudation of a once continuous laterite sheet. The small plateaux are almost devoid of forest growth or even of grass, as there does not appear to be sufficient soil to support vigorous vegetation.

The frequent occurrence of perennial springs of clear cool water from beneath these laterite caps has been mentioned by both Ball and Smith. A very good example occurs a short distance south of Korlapat, where in March, in the dry season, I noticed a tiny rill which dashed down the precipitous face of one of these hills, to be utilised to irrigate a second rice crop in the fields of the valley below.

Such occurrences of laterite at altitudes of 3,000 to 4,000 feet have been frequently studied under the name of high level laterite, though up to the present no very satisfactory account of their origin has been arrived at.

[1] *Loc. cit.*

IX.—DYKE ROCKS.

I have seen very few rocks of this class in Kalahandi state. West of Kutragas near Tuamal-Rampur I observed a garnetiferous epidiorite, apparently a dyke rock, and in a stream bed near Kuropodar a black heavy rock consisting of plagioclase, colorless monoclinic pyroxene and very pleocloric brown biotite, forms a well-defined dyke. The former rock is very probably derived from the alteration of a gabbro of some kind.

It may be well to note the unusual poverty of dyke rocks in the whole of the northern end of the eastern Ghauts. In the adjoining district of Gangam and Vizagapatam this property has been previously observed. Freedom from violent earth movements over this region for a long period may be suggested as the explanation.

X.—ECONOMIC GEOLOGY.

(*i*).—Graphite.

In studying the geology of the Ganjam Malias Mr. Smith of this department observed that one of the chief schists—the Khondalite of this report—almost always contains graphite in the form of flakes and scales. The principal minerals of this schist were found to be quartz garnet and sillimanite. Rocks of this type have also been observed along the eastern border of the eastern Ghauts near Sunki and Chotua in Vizagapatam and also as already indicated in many parts of the Kalahandi state. Graphite, though generally disseminated through these schists, has never been found in them in economic quantities either in Kalahandi or in the adjoining districts in the Madras Presidency.

In the Kalahandi state graphite is known to occur as veins or nests in several parts, not in the Khondalites but never very far off from outcrops of these schists. Some of these graphite deposits appears to be worth exploiting for industrial purposes, though before any large expenditure is incurred it would be well to have fair samples sent to Europe or America for valuation as the value depends upon freedom from certain harmful impurities, and on the physical properties of the mineral.

It is interesting to note that graphite deposits occur both in the hills composed of para-schists and in rocks that appear to have an igneous origin—the granitoid gneiss.

Specimens from the two chief occurrences, near Densurgi and near Lonjigarh, were sent in 1882 to the Geological Museum[1] by the Commissioner of the Chhattisgarh division, Central Provinces, but so far as I am aware the deposits have not been previously visited by an officer of this department.

The Koladi-Ghaut Graphite Outcrop.

This outcrop occurs about two hundred yards west of the 168th mile post from Raipur on the Raipur-Parvatipur road, three miles east of Santpur where the road winds upward around the north shoulder of Koladi hill.[2] So far as can be learned locally this outcrop was discovered in 1900 by Surju Singh, a road contractor, while excavating on the south side of the road for clay for top dressing. When I visited the place in January 1901, the pit was about five yards square and nearly the same in depth. The so-called clay had been formed by the decomposition of the rock *in situ* as the rock structure could be plainly seen in the clay. So far as I could determine from the rock fragments buried in the clay and from the clay itself the original rock was a complex of quartz-garnet-sillimanite schist—Khondalite—the most of the undecomposed fragments being garnetiferous quartzite. In the vicinity there is a very impure banded crystalline limestone containing

[1] Mallet: Geology of India, Part IV, p. 9

[2] This is probably the Lonjigarh outcrop mentioned by Mallet—in a straight line, however, the places are thirteen miles apart.

large quantities of diopside, scapolite sphene and a colorless pyroxene with a very small angle of extinction. These rocks may be regarded as para-schists formed by the metamorphism of sediments.

The graphite (specimen 15·229) which forms specks, spots and blotches on all four walls of the pit, appears to follow in a general way the banding or foliation of the country rock as shewn by the clay. The most promising exposure of graphite in this pit is in the north-western corner where it forms a band from 12 to 20 inches wide, follows the dip of the country rock and increases in width with depth. In this corner I had a pit sunk three feet and at the expense of the hire of three coolies for one day recovered four maunds of graphite of fair quality.

The graphite is crypto-crystalline and fairly free from gritty grains of other minerals. It is easily distinguished from the Densurgi graphite to be described later by the presence of pale sky-blue blades, resembling kyanite in color, but differing from it in being quite soft as if derived from some mineral by decomposition.

At the bottom of the pit the band was composed of graphite of fair quality, of thicker dimensions and more sharply defined than a few feet above. Though it would not pay to mine this band alone, it is not improbable that by driving a tunnel at right angles to the strike of the rock other bands may be found.

The Densurgi Graphite Deposit.

The second outcrop of graphite visited is a natural outcrop about half a mile north of Densurgi village (E. Long. 83° 31′; N. Lat. 20° 11′). The country rock is a medium-grained biotite gneiss with some accessory garnet. At the place in question the country is much cut up by nalas, and in two of these the graphite has become exposed by the removal of the easily denuded decomposed biotite gneiss. The general strike of the gneiss as distinguished by the phenocrysts of the gneiss is north-west, but a north-easterly foliation is very well developed. The graphite appears to follow the primary strike of the country rock as indicated by the phenocrysts. The eastern part of the deposit is best exposed. Here a mass, three or four feet high, eight yards wide, and twice as long, stands out in rugged gnarled slopes resembling on a large scale the forms assumed by kankar concretions. It is composed of graphite and calcium carbonate, the latter in all probability having been introduced and deposited by calcareous waters *pari passu* with the removal of the gneiss substance. I am not inclined to regard the graphite-limestone rock as a primary one. Though it is not possible at present to point with certainty to the original composition, a graphite gneiss seems to be the most probable source of the graphite. (Specimen 15·104.)

A partial chemical analysis of the rock showed 23·69°/₀ of carbon dioxide, corresponding to 53·85°/₀ of carbonate of lime. Allowing for a small quantity of earthy impurity, the calcareous graphite probably contains about 40°/₀ of pure graphite.

This mass is of no commercial value, but there seems to be reason to suppose that this calcareous form may be only superficial, the graphite a short distance below the surface being free from lime may be commercially valuable.

West and south-west of this mass of calcareous graphite, several bands of graphite of fair quality were found.

To the west of the large mass of calcareous graphite there is an open space several yards wide in which no important graphite outcrop occurs, but in the clay banks of a ravine several exposures of graphite occur. This second ravine cuts across the strike of the rocks and it is probable that the graphite exposures seen in its bed represent parallel graphite bands or veins following the strike of the country rock. The most northerly of these bands is about a foot and a half across and the largest band has a width of a yard on the eastern bank widening to two yards on the western bank. The third band is thirteen yards farther south. Loose blocks of calcareous graphite were observed several rods farther east than the most eastern extremity of the calcareous graphite, and as this is up-stream it seems probable that there is graphite farther east than I have mapped it. The total width from north to south over which graphite is observed is about twenty yards.

The sands and gravels which cut these graphite bands contain a large proportion of graphite in the form of boulders, pebbles, blocks, but chiefly as grains and flakes.

The graphite found in the outcrops along the western ravine (specimen 15·230) is of good quality being fairly free from gritty particles of other minerals. An analysis of an average sample obtained by grinding down several pounds of this graphite yielded on an assay—

Volatile matter	6·33%
Carbon	65·22%
Ash after ignition	31·21%
	102·76%

or, omitting the volatile matter and calculating to a hundred, 69·61% of pure carbon.

A sample was submitted to a firm of brokers in Colombo for valuation, but they replied that it had no commercial value. More favourable reports were obtained from a London firm which uses large quantities of graphite. In this case it was valued at £5 per ton and at that rate the firm in question was willing to purchase a trial lot of ten tons. The samples submitted were from the surface and may be surpassed by the graphite at a greater depth.

As to the quantity of graphite, it is very dangerous to even hazard a figure, for in dealing with mineral deposits in crystalline rocks it is impossible to predict the approximate amounts to be obtained by mining as is usual in dealing with deposits such as coal or iron which occur in younger sediments.

The rocks in which the graphite occurs at Densurgi would ordinarily be regarded as a fine grained variety of the granitoid gneiss. Graphite, however, is more frequent in para-schists. It does not seem possible to determine whether these rocks are really of igneous origin or metamorphosed arkoses in which the graphite occurs as metamorphosed carbonaceous deposits. In the former case the graphite might be of purely inorganic origin, formed by sublimation of hydrocarbons along old lines of fracture in the igneous rocks—as Weinschenk [1] and Walther [2] maintain that some of the Ceylon graphite deposits are,—or possibly from carbon derived from the absorption of carbonaceous sediments by the igneous magma before consolidation.

In the immediate vicinity the gneiss is traversed by several pegmatite veins from three inches to a couple of feet across. These dykes follow the strike of the country rocks—north-westerly—and are fairly felspathic with frequent occurrences of biotite and black tourmaline.

The Densurgi graphite deposit was discovered by the late Gopi Guru who was then tahsildar and afterwards superintendent of the state. As near as I can make out, about fifteen years ago he discovered it and called the attention of the villagers to the color of the streak of the mineral which at his suggestion was used as surma in place of antimony for darkening their eyes. In this way under the name of *surma patar* the graphite has become well known in central Kalahandi. My attention was called to this outcrop by the Naib Tahsildar of the state. It is remarkable that the commercial and scientific importance of this promising deposit has remained hidden up to the present, for neither the villagers nor the state officials had any idea of its possible utilization for industrial purposes.

(*ii*).—Iron.

I have not met with any large masses of iron ore in Kalahandi state though village smiths among the Hindoos of the 800-foot plain usually smelt their own iron. The ore used is as a rule nodular concretionary limonite which they dig up from the alluvial deposits. In one village, Olatura near Madanpur, I found one of the local iron smelters using a hematite which he obtained *in situ* in a hill near by. The rocks of this hill resemble in many respects those classified by

[1] Zeitschr d. deutsch Geol. Ges. 1889, 359.

[2] Abh. d. k. bayer. Akademie der Wiss. II cl, XXI Bd, II Abth.

Mr. Foote as Dharwars, but as the hill was very small and I was not sure of its geological relationships I have not colored it separately in the geological map which accompanies this report. Bands of good ore alternate with bands of garnetiferous quartzite. I do not think that any large quantity of high grade ore could be obtained there.

(*iii*).—Manganese and Cobalt.

Along with the iron ore at Olatura there occur some very manganiferous varieties containing as high as 41·03% of metallic manganese (specimen 15·227). Mammilary concretions probably best designated wad were found containing cobalt. A partial analysis of specimen 15·226 gave the following result:—

Insoluble in HCl	29·41%
Mn calculated to MnO_2	43·30%
BaO	4·51%
Fe_2O_3	7·84%
CoO	·82%
Loss on ignition	10·46%
Constituents of the soluble portion not determined	3·66%
TOTAL	100·00

This cobaltiferous wad approaches the New Caledonian and Australian asbolites in composition. The sample assayed is not rich enough in cobalt oxide to be of any commercial value, but it would not be surprising if an ore of such variable composition were locally richer than these samples, and in that case be rich enough to be worth exploiting

(*iv*).—Mica.

Occasional outcrops of mica bearing pegmatites were observed in Tundla and surrounding villages, but I have not seen any muscovite in sheets large enough to cut into merchantable sizes.

(*v*).—Ornamental stone.

A short distance east of Kasipur the sillimanite schist is traversed by narrow veins of a very fine grained cryptocrystalline aluminous rock, reddish or brownish in color and soft enough to be cut and carved into small ornaments. It is locally much prized under the name of *Lal patther*. (Specimen 13·183.) I think it is a fault rock formed from Khondalite.

(*vi*).—Diamonds.

In examining some sands obtained from the streams near Bondesor I observed several minute crystals of a highly refracting colorless mineral. These grains were examined under the microscope both by Mr. Hayden and myself and we came independently to the same conclusion, that they were diamonds. Though they were too small to be of value they very probably indicate that others of larger size may be found if carefully searched for. The sands in question must have been derived from the Khondalites which as previously stated usually contain graphite. A few years ago Professor Becke of Prague pointed out that when two or more minerals crystallising differently have the same chemical composition, the denser, the one with the higher specific gravity, is usually found in rocks that have been subjected to very great pressure. From this point of view it should be expected that rocks containing carbon in the form of graphite might contain diamonds, if the graphite-bearing rocks were subjected to sufficient pressure. These conditions are probably present in the Khondalites which may become diamondiferous instead of graphitic where the pressure has been intense.

Appendix.

Report on a sample of Graphite, obtained from the Kalahandi state, Central Provinces, by Dr. T. L. Walker of the Geological Survey of India, submitted by Mr. F. R. Mallet, F.R.S., formerly Superintendent of the Geological Survey of India, by Professor Wyndham R. Dunstan, M.A., F.R.S., Sec. C.S., Director of the Scientific and Technical Department of the Imperial Institute.

The material consisted of several large rounded pieces readily crumbling to powder. Its colour was greyish black, showing a slight metallic lustre but deficient in the laminated appearance characteristic of the best Ceylon graphite. The powder was distinctly greasy to the touch and readily marked paper. Its specific gravity was 2·05.

The following are the results of its chemical analysis :—

Moisture (at 120°C)	1·12 per cent.
Volatile matter (at red heat)	3·89 " "
Ash	31·87 " "

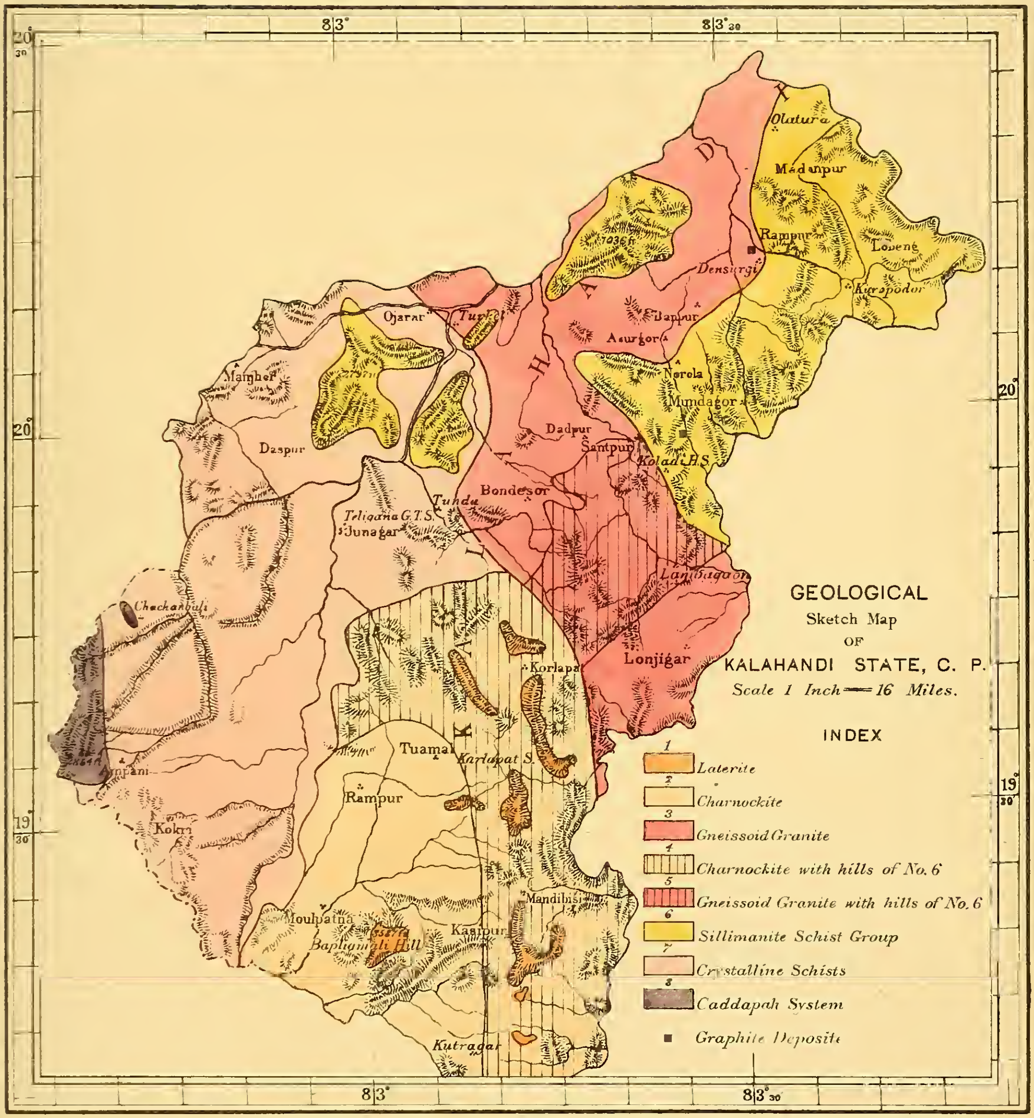
The ash was chiefly composed of silicate of aluminium and calcium, with some ferric oxide.

It is obvious from these results that the graphite is of poor quality and could not compete with the graphite now so largely exported from Ceylon. As, however, it seemed possible that it might be employed in the manufacture of crucibles, the Morgan Crucible Company were good enough, at my request, to give it a technical trial. They report that it is of very poor quality, being almost entirely deficient in flake and producing a very dead powder. They state that it might be used to a limited extent for the purpose for which the commonest Ceylon dust plumbago is used, but its value would certainly not be more than from £3 to £4 per ton delivered in barrels, c. i. f. London.

I may add as a point of some interest that this graphite appears to be associated with a small quantity of hydrocarbons of the nature of petroleum. This is a point which may deserve further investigation.

WYNDHAM R. DUNSTAN,
Director, Scientific and Technical Department.

21st November, 1901.


GEOLOGICAL
Sketch Map
OF
KALAHANDI STATE, C. P.
Scale 1 Inch = 16 Miles.
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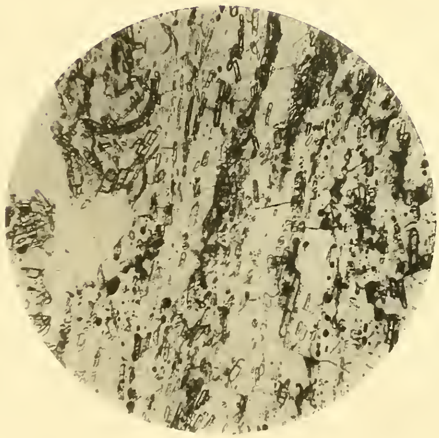

Microslide of Khondalite,
magnified 15 diameters.