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MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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VOL. XXXIV, PART 2.

THE MICA DEPOSITS OF INDIA, *by* THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Officiating Superintendent, Geological Survey of India.*

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I.—INTRODUCTION.

The primary object of this paper is to describe the Indian occurrences of mica commercially valuable. As this last expression implies mica-crystals of a certain size and without the flaws usually and easily produced by earth-movements, the geologist will readily see that the ground to be considered must of necessity be very limited in extent. Such an area must be one from which the sedimentary mantle has been completely removed and on which denudation has been sufficiently thorough to bring the deep-seated plutonic rocks to the surface, an area, too, which has escaped all tectonic movements since the formation of its pegmatites; for mica, being the most delicate, is amongst the first of rock-constituents to suffer deformation from crust disturbances. Occurrences combining these characters are necessarily few and comparatively restricted in extent, and for such reasons the available mica supplies of the world are strictly limited—a fact of the highest concern to the country which happens to possess an area so large and geologically so suitable that it is likely to have the means of controlling, if not of actually monopolising, the mica supplies of the world. The importance of this circumstance is further accentuated by the fact that the remarkable physical properties, which have secured for mica its extensive use in the Arts, are not possessed by any other mineral, and are not, and not likely to be, imitated by any artificial substance. The mica-miner should not be surprised, therefore, if the Government show an inclination to temper the encouragement given to his industry with restrictions intended to discourage his wasteful methods of mining and the tendency which he has shown, not unnaturally, to secure immediate returns by wantonly excavating shallow workings over large areas. It is hoped, nevertheless, that the criticisms which accompany the advice given in a subsequent chapter will be found to benefit the mica-miner as much as the holder of mineral rights, the interests of both being necessarily interdependent.

As a further object, this paper is intended to convey to the mica-miner a brief resumé of the nature and history of the mineral in which he is so largely interested; and, finally, it is made the means of recording, for the information of mineralogists interested only in scientific questions, the new facts of value concerning the natural history of mica which the detailed study of its Indian occurrences has revealed to the writer and his colleagues.

The use of simple names expressing the very prominent lustrous character of minerals like the micas, talc and selenite has made it difficult to determine the exact species referred to in any but the most recent scientific literature.[1] The highly perfect basal cleavage, which permits both mica and talc to be split into thin laminæ, has helped to maintain the confusion which exists in the popular mind between these two species, but which is now becoming removed gradually by the more extended use of the mineral mica in the Arts and its commoner appearance as an article of ordinary trade.

[1] Selenite, σεληνιτης (Dioscorides, *Cir. A.D.* 50), now used for the crystallized hydrous sulphate of lime or gypsum, was the equivalent of Pliny's *lapis specularis*, which, however, from its use (to produce a whiteness on the "Circus Maximus") was probably mica.

The word *mica* is referred to the Latin *mico*, I shine, and in some form or other its perfect reflective and sparkling properties are expressed by its names in most languages.

Mineralogists are accustomed to correct—not without a touch of self-conscious superiority—the common use of the word *talc* for the minerals now grouped under the generic term *mica*. But as a matter of priority the common usage has probably superior claims, as the word talc appears to be much older and was applied to the large sheets of mica used for window-panes. According to Lane the word طَلْق (*ṭalq*) is an Arabicized form of تَلْك (*talák*); but the original meaning of the word does not appear to be known. The prominent sparkling character of the mineral is expressed in Arabic by the name كوكب ال أرض (*kaukabu-l-az*), "the star of the earth," and references to its use as window-panes show the true nature of the mineral.[1] The use of the term mica for the minerals described in this note is now, however, so well established that it would be futile to attempt the reinstatement of the name talc, even if there was any advantage in the reform. The word talc is reserved by the mineralogist for the hydrous silicate of magnesia which is well known in one of its forms as steatite and French chalk.

The romance languages follow the Latin; but in German we have *Glimmer*, whilst the common name in Hindustani *abrak* (ابرق) from *abr*, a cloud, or *abru*, heavens, goes a step further, and connects its lustrous character with its supposed celestial origin. The Hindu classical writers imagined mica to be a sort of petrified lightning-flash, hence the use of *vajra* (*bazar*), thunderbolt, as one of its names. In ancient times, or *Sat Yoga*, it is supposed that in order to kill the enemy of the gods, *Baratur* (*Vitra*), Indra lifted his thunderbolt *vajra*, and a flash of lightning spread throughout the length and breadth of the sky, whilst the sparks which fell on the mountains were preserved in the form of mica.[2] Other names, like *gagana* (sky) and

[1] The writer is indebted to Col. G. S. A. Ranking, I.M.S., for this information.

[2] "Kabi-kal Padrama," a Sanskrit work quoted by Raja Sir Radha Kanto Deo in his Sanskrit Dictionary.

meghalála [from *megha* cloud, and *lála*, red (sparks)], are derived from a similar idea.[1]

In Tibetan a similar name for mica is used—*nam-do*, sky-stone.[2]

As in the case of gems,[3] ancient Hindu writers distinguished four qualities of mica under the names of their four great divisions of caste :—The *Brahman* was white and colourless ; the *Kshatriya*, red-tinted ; the *Vaisya*, yellow, and the *Súdra*, black. Four varieties were also distinguished by special names and were supposed to be possessed of wonderful medicinal properties—the *Pináka* variety when thrown into fire splits into laminæ, and if swallowed accidentally produces leprosy ; the *Dadura* when thrown into fire emits a noise like a croaking frog, and its internal use produces death ; the *Nága* variety hisses like a snake when heated, and would give rise to fistula if swallowed ; whilst the *Vajra* is not affected by fire, and is the best of all, removing the infirmities of age and preventing untimely death. Apparently the main use of mica in ancient times in India was for medicinal purposes, and the legend of its origin served as a good base on which to build accounts of its magical properties—properties which produced the most calamitous results when the mineral was used unrefined, and healing properties for the most deadly diseases when prepared by the long and tedious processes detailed by the physician, whose chief idea seems to have been to mystify the uninitiated by processes too complicated and long for imitation by the amateur, a relic of which we have in the language and characters of the modern prescription.[4]

[1] The writer is indebted to Raja Sir Sourindro Mohan Tagore, Kt., C.I.E., Lala Kishen Singh of the Geological Survey and Babu Brajendra Lal Mitra, M.A., a former pupil in the Presidency College, Calcutta, for numerous extracts from the Sanskrit classics with reference to mica. Here and in the pages which follow many of these references are made use of without special acknowledgment, as most of them have been obtained by all three friends, showing a fairly complete research, for which the writer is much indebted.

[2] Waddell, " Among the Himalayas," 1899, 408.

[3] See Geol. Surv. Ind. Manual on Corundum (1898), p. 58.

[4] A detailed account of the laborious methods said to be necessary in preparing mica for medicinal purposes is given in Sir Sourindro Mohan Tagore's "Abhra" (Calcutta, 1899) and in Dr. U. C. Dutt's "Materia Medica." The former work contains a list of 224 medicines in which mica is used, with the diseases in which the medicines are employed.

The establishment all over India of Government dispensaries in charge of qualified apothecaries has almost put an end to the absurd use of mica as a drug; and the consumption of the mineral within the country is practically confined to purposes of ornament which are referred to on a later page.

II.—MINERALOGICAL AND CHEMICAL CHARACTERS.

The minerals of the mica group, though differing considerably in chemical composition and though exhibiting variations in certain physical properties, possess one common striking characteristic—a highly perfect, basal cleavage, by which the crystals can be split into the thinnest films.

The acute bisectrix of the optic axes being very nearly at right angles to the basal plane of the mica-crystal, these lamellæ, so easily obtained, form a convenient means for classifying the different varieties of mica according to their optical properties.[1] Two groups are distinguished according to whether the optic axial plane is approximately parallel, or approximately at right angles, to the equivalent of the plane of symmetry. These are as follows:—

GROUP I.	GROUP II.
(*Optic axial plane perpendicular to the plane of symmetry.*)[3]	(*Optic axial plane parallel to the plane of symmetry.*)[3]
Muscovite.	Phlogopite.
Lepidolite.	Lepidomelane.
Paragonite.	Zinnwaldite.
Margarite.	Biotite (Meroxene variety.)[3]
Anomite (a variety of Biotite.)[3]	

[1] As stated in the introduction, this paper is primarily intended for the use of those in India interested in the mica industry. The writer's acquaintance with most of these leads him to suppose that an account of the properties of the minerals, as worked out by mineralogists, will not be unappreciated, and although many unfamiliar terms are, for the sake of precision, necessarily employed without explanation, they represent properties concerning the nature of which an empirical knowledge at least is easily acquired. For the satisfaction of the trained mineralogist it is necessary to state that, whilst many of the facts recorded in this chapter

The crystal-outlines are not always visible in mica, more generally they are not exhibited in ordinary specimens. In such cases the direction of the so-called plane of symmetry can be determined by producing a *percussion-figure.* For this purpose a thin mica plate is placed on a sheet of cardboard, or similar firm plane surface, and is then struck a sharp blow with a blunt needle point. A six-rayed star is produced in this way, the cracks intersecting at the centre of percussion at angles of 60° *approximately.*[1]

The ray which lies nearly parallel to the clinopinacoidal plane (that is, to the plane of symmetry)[2] is spoken of as the characteristic, or leading, ray, and this, in the first group of micas (muscovite and its fellows), lies at right angles to plane of the optic axes, whilst in the second group of micas (biotite, phlogopite, etc.) it lies nearly parallel

are mere restatements of facts known concerning the mica group, the statements are not made without special verification on micas of Indian origin, and some of them represent facts hitherto unrecorded.

[2] The plane of symmetry is referred to as if the micas were all monoclinic in their system of crystallization. Reasons are given below for considering muscovite to be truly monoclinic; but in some other micas the asymmetry of the etch-figures and the slight divergence of the optic-axial plane from what appears to be the symmetral plane of the geometrical crystal indicate triclinic forms. It is possible that the apparently higher type of symmetry is produced by a twinning of a triclinic form on a scale too minute for recognition by tests less precise than that afforded by etch-figures. This introduces theoretical questions beyond the scope of this paper; it is sufficient to recognise the fact that, as in the case of the felspars, there is a sufficient homology of crystal-habit recognisable throughout both monoclinic and triclinic types to permit identification of corresponding forms. The expression "plane of symmetry" may thus be not quite correct in the case of some micas, whilst "parallel to" and "perpendicular to" this plane mean *approximately* parallel, or perpendicular, to the plane which occupies the position of the symmetral plane in a monoclinic mineral.

[3] Tschermak divides biotite into two varieties, *meroxene,* which includes all ordinary forms met with in crystalline rocks, and *anomite* (from ἄνομος, contrary to law) a rarer variety having its optic axial plane at right angles to the usual direction.

[1] It will be seen below that the common assumption of the mineralogical text-book is not quite correct in referring the angles of the percussion-figure to 60°.

[2] See foot-note 2, p. 16.

to that plane. These two statements are represented diagrammatically by figs. 1 and 2.

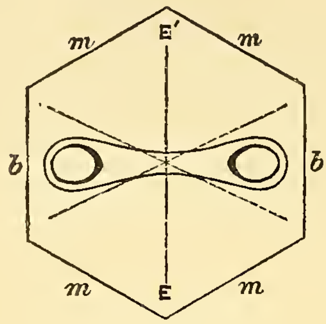

FIG. 1.

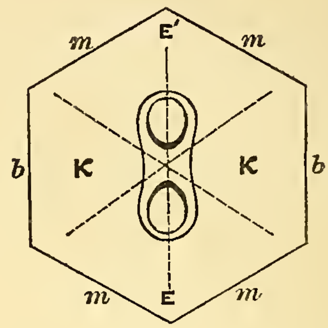

FIG. 2.

m, Traces of the prism faces.
b, Traces of the clinopinacoid or its equivalent.
EE′, Leading line of the percussion-figure.

By subjecting a sheet of mica to a gradually increasing pressure with a blunt punch, another six-rayed figure, the so-called *pressure-figure*, is produced with rays approximately bisecting the angles of the percussion-figure (see plates VI and VII). Mica-crystals are often found in which these pressure-figures have been produced by natural earth pressures when embedded in the rocks (see plate VI), and the crystals often split along these lines, forming pseudo-crystal faces, which are inclined at about 67° to the basal cleavage-planes. The occurrence of numerous fissures parallel to the pressure-figure lines is the cause of the fibrous mica so frequently found in these so-called gliding planes. These fibres are often found in muscovite aligned most perfectly at right angles to the leading ray of the percussion-figure.

Allusion has already been made in a foot-note to the fact that the rays of the percussion-figure do not (as was generally supposed on account of the statements of Max Bauer) intersect one another at angles of 60°. Dr. T. L. Walker, who first called attention to this fact, has measured the angles of the percussion-figures in a large number of micas from various parts of the world, and has found that the angle indicated by the letter κ in figure 2, varies from about 51° in some muscovites to 64° in some phlogopites, whilst the lithia-micas and biotite approximate more nearly to 60°.[1]

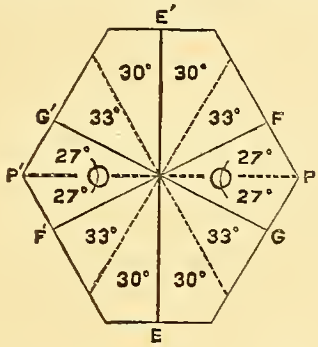

FIG. 3. *Diagram showing the average relations of the pressure-figure, percussion-figure and optic-axial plane in Indian muscovites.*

The writer has examined the percussion and pressure figures in some 30 Indian muscovites and has found the relations graphically expressed in figure 3 and on plates VI and VII to represent to the nearest degree the average of some 200 determinations. The principal results may be summarised as follows :—

(1) The principal ray of the percussion-figure EE′ lies in the plane of symmetry and at right angles to the optic-axial plane.

(2) The principal ray is cut perpendicularly by the ray PP′ of the pressure-figure, which lies in the optic-axial plane.

(3) The angle κ between the rays FF′ and GG′ averages $53^\circ\ 55'$ (nearly 54°).

(4) The remaining angles of the percussion-figure are, to the nearest degree, each 63°.

(5) The rays of the pressure-figure intersect one another as nearly as can be measured at angles of 60°.

[1] T. L. Walker, "The crystal symmetry of the minerals of the mica group." *Amer. Journ. Sci.*, Vol. VII, 1899, p. 199; "Percussion-figures on micas." *Rec. Geol. Surv. Ind.*, Vol. XXX (1897), p. 250.

(6) The subordinate rays of the percussion-figure meet the subordinate rays of the pressure-figure at angles of 93° and 33°.

(7) The etch-figures produced by the action of hydrofluoric acid or by fused potash are bisected symmetrically by the principal ray EE′ of the percussion-figure.

The physical properties of a plate of muscovite are thus ranged symmetrically with regard to a single line, namely, the leading ray of the percussion-figure; and, as the optic-axial plane is, according to Tschermak, slightly inclined to the basal cleavage-plane, the mineral muscovite must be regarded as monoclinic in its crystallization. In many points muscovite is imitated by its chemically near relative, lepidolite; but the asymmetric character of the etch-figures in phlogopite and biotite, and the oblique disposition of their optic-axial planes with reference to the leading percussion rays, suggest that their crystal symmetry belongs to a lower grade.[1] But the micas frequently show twin-lamellæ parallel to the basal plane, and, as the general effect of twinning is an apparent increase of symmetry, it is just possible that the higher grade of symmetry exhibited by muscovite may be due to twinning on a scale too minute to be detected by our ordinary physical tests.

A very interesting occurrence of *natural pressure* and *percussion figures* was found by Dr. T. L. Walker at Gudladona in the Nellore district. The rays of both figures appeared to radiate from an inclusion in the mica, apparently an altered allanite; on examination it was found that the rays of the compound figure intersected one another as nearly as possible at angles of 30°, and that one of the rays occupied the correct position of the principal ray of the artificially produced percussion-figure. Regarding this compound twelve-rayed figure as the result of the symmetrical intersection of the percussion and pressure figures we have to meet the difficulty that the natural percussion-figure, unlike that produced by artificial means, is formed

[1] *Cf.* Walker, *loc. cit.*

by the intersection of rays at 60°. It occurred to the writer that possibly at a higher temperature, muscovite, like some other minerals, might present a higher grade of crystalline symmetry ; in other words its percussion-figure might possibly be hexagonal instead of monoclinic in its symmetry at the temperature at which these natural figures were produced. To test this idea the writer produced percussion-figures on several muscovites heated to the temperature of melted lead (about 300°C.), and found that the angle κ was invariably larger when produced at a high temperature than the corresponding angle obtained on the same mica at ordinary temperatures. The following are the figures actually obtained as averages of several determinations on each sample of mica :—

Locality.	Angle κ of percussion-figure produced at	
	ordinary temperatures.	about 300° C.
Saidápuram, Nellore	55°	57° 30′
Inikúrti, Nellore	54°	57°
Útukúr, Nellore	53° 30′	56°
Koderma, Hazáribágh	53°	56°

In the commonest form of *twinning* the individuals are joined along their basal planes, and the vertical faces then show re-entrant angles as in fig. 4. Twinning of this type repeated on a very minute scale is probably the cause of some micas behaving as monoclinic crystals to

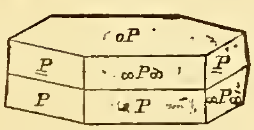

Fig. 4. *Muscovite crystal twinned parallel to the basal plane.*

optical tests, whilst their etch-figures indicate triclinic crystallization.

In other cases a well formed, six-sided crystal, apparently simple, may be found on examination in polarised light to be composed of two or more individuals, having an irregular junction-line, but with their lateral axes (determined by the position of the optic-axial plane) disposed at angles of about 60° to one another. Some fine examples of this form of twinning have been obtained near Kangayam in the Coimbatore district, Madras. One such is represented by fig. 5, which recalls the intergrowths sometimes found in apparently simple hexagonal crystals of quartz.

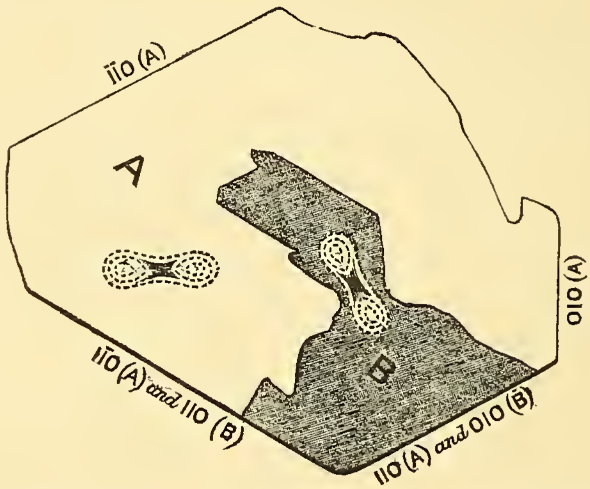

Fig. 5. *Six-sided crystal of muscovite formed by the intergrowth of two individuals, from near Kangayam, Coimbatore district, Madras.*

All micas are negative in the kind of *double refraction* which they exhibit, but the angle between the optic axes varies from 70° in muscovite to about 10° in phlogopite and still less in biotite; so that the character of the figure obtained by examining cleavage plates in convergent polarised light forms a ready means of distinguishing between the common members of groups I and II (p. 16).

Muscovite is practically devoid of *pleochroism*, whilst in biotite there is always a great contrast between the colour of rays vibrating parallel to, and that of the rays vibrating across, the basal cleavage lines. The absorption of the rays vibrating parallel to the cleavage in biotite is always very great and is sometimes sufficient in the deeply coloured varieties to make the thin section of the mineral appear almost black.

The *colours* in ordinary light vary very greatly, but the ferro-magnesian micas are most deeply coloured and are often deep-brown, even in thin films. The characteristic colour of lepidolite is a delicate lilac, pink or grey (Pihra, Hazáribágh district). Some of the muscovite raised in the Hazáribágh district is noted for its red tint which in thick sheets may be a deep ruby-colour. Amber-coloured, smoky brown and, in one locality, deep grass-green muscovite is obtained in the Nellore district of Madras. The colours and the character of the lustre are changed on hydrous alteration of the mica, or are modified by the presence of inclusions of other mineral matter. A peculiar pearly or silvery lustre, displayed by muscovite obtained near Bendi in the Hazáribágh district and a few other localities, is due to the removal of exceedingly thin films of decomposed mica from the cleavage surfaces. Numerous minute inclusions in phlogopite, like that from near Waltair, Madras Presidency, give the mineral a bronzy colour and semi-metallic lustre. The same mineral often exhibits the remarkable phenomenon of *asterism* from the same cause. The phlogopite from Waltair when interposed between the eye and a candle-flame or other small point of light, shows a six-rayed star, in which one pair of rays is specially pronounced and appears as a bright band of light always disposed at right angles to a prominent striation noticeable in the mineral, and at right angles also to the leading line of the percussion-figure (figs. 6 and 7). The less prominent rays of the ligh star cross the bright band at angles as nearly as can be measured of 60°. The pleochroism of this phlogopite is also quite distinct, showing a pink tinge for rays vibrating (nearly) at right angles to the striation, and a greenish tinge for rays vibrating (nearly) parallel to the striation. The optic-axial angle in this specimen is too narrow to permit a safe determination of the direction of the plane of the optic axes. The cause of asterism has been attributed to

Striated phlogopite from Waltair, Madras Presidency.

FIG. 6. *Percussion-figure with leading line parallel to the striation.*

FIG. 7. *Asterism with prominent ray traversing the striation perpendicularly.*

numerous lath-shaped or acicular inclusions in the mica crossing one another at angles of about 60°. These inclusions have been variously attributed to kyanite (G. Rose), rutile (Sandberger, Lacroix), and tourmaline (Rosenbusch). It is almost certain, however, that the striation producing this form of diffraction is much more minute than that caused by rods of recognisable inclusions.

The larger *inclusions* in mica are generally in the form of very thin plates lying between the cleavage sheets, though sometimes they cut through the bundles obliquely. The commonest of these inclusions are black, brown or red plates of iron-oxide, possibly magnetite, forming long strips or dendritic growths, having a regular crystallographic disposition with regard to their host the mica. Thin films of quartz, needles of black tourmaline, feathery, radiating plumes of red tourmaline, stout plates of garnet and stumpy crystals of green apatite have been observed in Indian muscovites.

Intergrowths of two varieties are quite common, especially intergrowths of biotite and muscovite. The junction line between the two varieties may be quite irregular, but the muscovite appears to be generally, if not always, outside and surrounding the biotite.

The *hardness* of mica varies between degrees 2 and 3 of Mohs' scale, being distinctly harder than talc, from which it can thus be readily distinguished. Mica itself varies considerably in hardness;

the smooth even sheets appear to be slightly softer than those which have been damaged by earth pressure, and a high degree of hardness is generally looked upon with disfavour in the trade ; it should be just possible to scratch the mica with the finger nail. The loss of hardness following hydrous decomposition is accompanied by reduction in strength, elasticity and consequent commercial value.

Although their remarkable physical characters mark the micas as a distinct and natural family amongst minerals, they vary so greatly in *chemical composition* that considerable difficulty has been experienced in discriminating the essential features in chemical constitution which are peculiar to the family and common to all its members. The subject has been elaborately studied by Tschermak (1878), Rammelsberg (1878-1889) and F.W. Clarke (1886-1889), who have expressed different views of the chemical constitution of the family.

Tschermak [1] regarded the micas as isomorphous mixtures of the following fundamental molecules—

$$K = Si_6\ Al_6K_2H_4O_{24}$$
$$M = Si_6\ Mg_{12}O_{24}$$
$$S = Si_{10}\ H_8O_{24}$$

Rammelsberg [2] considered them to be mixtures in different molecular ratios of the three silicates $R_2\ SiO_3$, $R_4\ SiO_4$ and $R_6\ SiO_5$, and divided them into an alkaline group and a ferromagnesian group.

Clarke [3] regards the micas, and in fact all such aluminous orthosilicates, as substitution products of the compound $Al_4\ (SiO_4)_3$ in which the Al-atom is successively replaced by an univalent (R) atom and Mg or other divalent metal. If we take magnesium as a generic representative of the bivalent metals, and give univalent elements or

[1] Tschermak, "Die Glimmergruppe: II Theil, Chemische Zusammensetzung", *Sitzber. Akad. Wien*, 1878, LXXVIII, 5–60.

[2] Rammelsberg, "Ueber die chemische Natur der Glimmer," *Sitzber. Akad. Berlin*, 14th February 1899, 99—109.

[3] F. W. Clarke, "A theory of the mica group". *Amer. Journ. Sci.*, (3) XXXVIII (1889), 384—393. See also same *Journ.*, XL (1890), 410 and XLI (1891), 242.

groups the general symbol R, we can imagine the following derivatives of $Al_4\ (SiO_4)_3$ as easily possible :—

I	II	III
$Al\begin{cases} SiO_4\equiv R_3 \\ SiO_4\equiv Al \\ SiO_4\equiv Al \end{cases}$	$Al\begin{cases} SiO_4\equiv R_3 \\ SiO_4\equiv R_3 \\ SiO_4\equiv Al \end{cases}$	$Al\begin{cases} SiO_4\equiv R_3 \\ SiO_4\equiv R_3 \\ SiO_4\equiv R_3 \end{cases}$
IV	**V**	**VI**
$Al\begin{cases} SiO_4\equiv MgR \\ SiO_4\equiv Al \\ SiO_4\equiv Al \end{cases}$	$Al\begin{cases} SiO_4\equiv MgR \\ SiO_4\equiv MgR \\ SiO_4\equiv Al \end{cases}$	$Al\begin{cases} SiO_4\equiv MgR \\ SiO_4\equiv MgR \\ SiO_4\equiv MgR \end{cases}$

To these we may add as the bivalent analogue of III, the compound $Al_2\ (SiO_4)_6\ Mg_9$ (VII). In the case of the fluorine-bearing forms R^1 is represented by the univalent groups MgF and AlF_2. Most of the micas, Clarke considers, can be regarded as intermediate mixtures of the above presumably isomorphous types. Thus No. I represents muscovite and paragonite ; No. VI some phlogopites ; Nos. II, V and VI are really unnecessary as types, being mixtures of pairs of Nos. I, III, IV and VII, whilst even No. IV may be regarded from the same point of view as superfluous. These formulæ are satisfactorily applicable to the micas which on analysis appear to be normal orthosilicates, but there are some in which the oxygen is in excess of SiO_4, and in these Clarke assumes the existence of AlO taking the part of R^1 and being the equivalent of $Al\ F_2$; in others the proportion of oxygen to silicon is lower than in SiO_4, and in these the polysilicic acid $H_4Si_3O_8$ is supposed to replace the (also tetrabasic) orthosilicate H_4SiO_4, giving rise to a set of circumstances paralelled amongst the plagioclase felspars in which albite ($NaAlSi_3O_8$) and anorthite ($CaAl_2\ (SiO_4)_2$) are apparently isomorphously replaceable.

In these three attempts to trace a chemical isomorphism corresponding to the evident physical similarities of the different members of the mica family, the existence of hypothetical compounds not yet found separate in Nature has been postulated; but Clarke's theory most nearly escapes the dangers of this method, and is supported by partial analogy with the felspar group. Clarke also asserts a similar form of chemical constitution for the "micaceous" minerals like the vermiculites, chlorites, margarite and the clintonite group.

The four chief mica species—muscovite, lepidolite, phlogopite and biotite—fall into two groups chemically as they do when classified by their physical properties. The first two may be conveniently known as alumino-alkaline micas, already placed together on p. 16 according to their physical properties (Group I), whilst the last two may be distinguished as ferromagnesian micas, referred to before as Group II.

Of the alumino-alkaline group, muscovite is characterised by its high content of alumina and potash, whilst lepidolite contains lithia accompanied by a decided quantity of fluorine. In the ferromagnesian group, phlogopite is more essentially magnesian, whilst biotite is distinctly ferriferous. The variations are too great to permit the representation of a species by definite types; but the following formulæ and corresponding percentage compositions represent the most frequent type of each species:—

MUSCOVITE.	SiO_2	45·2
$2\,H_2O.\ K_2O.\ 3\,Al_2O_3.\ 6\,SiO_2$	Al_2O_3	38·5
	K_2O	11·8
	H_2O	4·5
		100·0

LEPIDOLITE.	SiO_2	51·3
$H_2O.\ K_2O.\ Li_2O.\ 3\,Al_2O_3.\ 6\,SiO_2$	Al_2O_3	18·4
$3\,K_2O.\ 3\,Li_2O.\ 4\,Al\,F_3.$	$Al\,F_3$	12·0
$2\,Al_2\,O_3.\ 18\,SiO_2.$	K_2O	13·4
	Li_2O	4·2
	H_2O	0·7
		100·0

BIOTITE.	SiO_2	39·9
$(H, K)_2O.\ 2\,(Mg, Fe)O.$	$Al_2\,O_3+F_2O_3$	22·9
$(Al, Fe)_2\,O_3.\ 3\,SiO_2.$	$Fe\,O$	16·0
	MgO	8·8
	K_2O	10·4
	H_2O	2·0
		100·0

PHLOGOPITE. $3H_2O.K_2O.7MgO.Al_2O_3.7SiO_2$.	SiO_2	44·2
	Al_2O_3	10·8
	MgO	29·4
	K_2O	9·9
	H_2O	5·7
		100·0

The micas may thus be looked upon as silicates in different proportions of alumina, the alkalies (mainly potash), iron and magnesia. Arranging the bases according to their quantity and importance their order is seen to be reversed in the two groups:—

I. ALUMINO-ALKALINE.	II. FERROMAGNESIAN.
Silicates of { Alumina. Alkalies. Iron. Magnesia.	Silicates of { Magnesia. Iron. Alkalies. Alumina.

Muscovite is by far the most important of the Indian micas and the only one which has been worked to any serious extent, though the other three chief varieties also occur in quantity. The following two analyses of Indian mica, most probably from Bengal, shows the composition of the muscovite so largely mined and exported:—

	I.	II.
SiO_2	45·57	45·71
Al_2O_3	36.72	36.57
Fe_2O_3	0·95	1·19
FeO	1·28	1·07
MgO	0·38	0·71
CaO	0·21	0·46
K_2O	8·81	9·22
Li_2O	0·19	...
Na_2O	0·62	0·79
H_2O	5·05	4·83
F	0·15	0·12
	99·93	100·67
	Sp. Gr. = 2·831	Sp. Gr. = 2·830

I. Analysis by L. Sipöcz. 1873, *Tschermak's min. und petr. Mittheil.* p. 31.

II. Analysis by S. Blau . . *Ibid.* 1873, p. 32.

By calculating the sesquioxides as alumina, the protoxides as magnesia, and the alkalies as potash, and calculating to 100, we obtain the following as an average analysis, which, omitting the small quantity of magnesium fluoride, agrees nearly with the formula already given for typical muscovite, namely, $K_2O.\ 2\ H_2O.\ 3\ Al_2O_3.\ 6\ SiO_2$:—

SiO_2	45·7
Al_2O_3	37·4
MgO	1·4
K_2O	10·4
H_2O	4·9
F	0·2
	100·0

Small crystals of various micas have been *artificially* prepared by various workers, notably by Hautefeuille and St. Gilles, von Chrustschoff and Doelter, whilst Vogt and others have recorded the formation of some varieties of this mineral in furnace slags. Artificial micas have never been, and are not likely to be, made in crystals sufficiently large to be of marketable value; but Doelter's experiments to test the action of sodic and magnesic fluorides on certain natural silicates are particularly instructive on account of the way in which they show the formation of mica at the expense of other silicate minerals. In this way Doelter has shown that the variety biotite can be made by the alteration of hornblende, glaucophane and garnet, a phlogopite from pargasite, whilst a muscovite-like mica was formed by the action of potassium fluo-silicate and aluminic fluoride on andalusite. The last-named result is of importance, as pointed out below (p. 39), on account of the way it partially imitates the conditions under which valuable muscovite appears to have formed in pegmatite veins.

III.—GEOLOGICAL OCCURRENCE.

The commonest occurrence of muscovite is as a constituent of granite, which may be so fine in grain that the individual minerals can be recognised only with a microscope, or so excessively coarse that the crystals may measure several feet across. The latter form, on account of the size of the crystals, is known as giant-granite or granite-pegmatite, and it more usually occurs in dyke-like masses, lenses or veins, not generally in the form of large irregular bosses like the commoner, massive, fine-grained granite.

The term *pegmatite* was originally proposed in 1822 by the French Abbé Haüy[1] for the peculiar intergrowth of quartz and felspar now known as graphic granite; but in 1849 the term was extended in meaning by Delesse[2] to cover coarse-grained veins containing silvery mica and often tourmaline, as well as quartz and felspar. The name thus became used to indicate the large size of the crystals irrespective of any peculiarity of structure, and lately its meaning has been used in a still more general sense to cover the coarsely crystallized varieties of other forms of plutonic igneous rocks like coarse-grained syenite, diorite, gabbro, etc., the variations in composition being indicated by the use of compound names, as granite-pegmatite, syenite-pegmatite, diorite-pegmatite, etc.[3]

The pegmatites which contain muscovite in large crystals are exclusively acid (siliceous) in composition, having in general the mineral composition of granite. The only pegmatites we are concerned with in connection with mica belong, therefore, to the class of granite-

[1] Traité de Mineralogie, 2nd Ed., Vol. IV, p. 436.

[2] Delesse, " Sur la pegmatite avec tourmaline de Saint Étienne (Vosges)." *Ann. des Mines*, 4th ser., XVI, 97.

[3] *Cf.* W. C. Brögger, " Die Syenitpegmatitgänge der sudnorwegischen Augit und Nephelinsyenite", *Zeitsch für Kryst.*, XVI, 1890. G. H. Williams, " General relations of the granitic rocks in the Middle Atlantic Piedmont Plateau," 15th Ann. Rep. U. S. Geol. Surv., 675 (1894). H. Rosenbusch, " Mikroskopische Phys. der mass. Gest., 1896, 492-497 and Gesteinslehre, 1898, 220.

pegmatites and will be referred to in the succeeding pages shortly as pegmatites.[1]

By far the majority of pegmatites are composed, like ordinary granite, of quartz, felspar and mica; but on account of the gigantic scale on which the crystals have developed, many comparatively rare minerals have been detected in pegmatites which have not been noticed in ordinary granites, possibly because of the small size of their crystals in the latter rock; others are possibly peculiar to pegmatites, and are due to the special conditions (referred to below) under which pegmatites have been formed. The following minerals have been noticed in Indian granite-pegmatites :—

Albite.	Lepidolite.
Allanite.	Leucopyrite.
Amazon-stone.	Magnetite.
Apatite.	Moonstone.
Automolite.	Muscovite.
Beryl.	Orthoclase.
Biotite.	Pitchblende.[2]

[1] Coarse-grained felspar-rocks (syenite-pegmatite) occurring near the village of Karutapalaiyam in the Coimbatore district, Madras Presidency, contain crystals of muscovite 3 to 4 inches across, associated with corundum, automolite and chrysoberyl, but the veins are not now worked for mica. These rocks and the associated elæolite-syenites are described in a separate memoir. (*Mem. Geol. Surv. Ind.*, XXX, pt. 3 (1901).

[2] The following analysis of pitchblende from the Singar mica mines, Gáya district, has been made by Mr. W. R. Criper, A.R.S.M., F.C.S., of Messrs. D. Waldie & Co., Calcutta :—

Oxide of Uranium	79·55
Alumina and oxide of Iron (containing ·35% P_2O_5)	3·35
Sulphide of Lead	9·96
Sulphide of Tin	1·20
Lime	·30
Magnesia	trace
Siliceous matter	2·30
Combined water	2·90
Salts of alkalies (by difference)	·44
	100

Cassiterite.	Quartz, pink and white.
Columbite.	Staurolite.
Epidote.	Tourmaline, red, blue, green and black.
Fluor-spar.	Torbernite.
Garnet.	Triplite.
Ilmenite.	Uranium ochre.
Kyanite.	

The large size of the crystals, facilitating their extraction, makes some of these minerals, like the phosphates and felspar, worth attention from an economic point of view, whilst the most valuable constituent of all, mica, is of value purely because of the large size of the sheets it forms. Crystals or "books" of muscovite-mica have been obtained in Nellore district, measuring 10 feet across the basal planes, but usually, of course, they are much smaller, all gradations of size being obtained from those of marketable value down to scales of microscopic dimensions such as occur in the common massive granites.

Being the most delicate mineral in the rock the mica is the first to show the effects of crushing earth-movements, and large quantities of valuable mineral have by these means been destroyed; but it is on account of the remarkable stability of the Indian Peninsula, the geologically long and perfect quiescence it has enjoyed, that India is able to boast of the finest mica deposits of the world.

Whilst the Himalayan range is composed of rocks which have been crumpled and sheared even since late tertiary times, the Peninsula of India has remained as a firm solid mass since at least the lower palæozoic age, and as a result many very old rocks, like the pegmatites, have been preserved with remarkable freshness. The main mica-bearing area of the United States—the only area which has ever been a serious competitor with India for the first place in the mica market—owes its value to a similar cause: the crystalline mass with its included pegmatites, stretching from Georgia obliquely through the Carolinas to Virginia, presents to the contorted Appalachian range exactly the same relation as the Indian peninsula holds with regard to the

Himalayan chain—a firm, solid block of land against which the weaker part of the crust has been rolled up by tangential pressures.

Origin of pegmatites.

There is probably no other group of rocks whose origin has been the subject of more varied discussion than the pegmatites. De Saussure received the support of Credner, Klockmann, Dana, Huntington, Kerr and Sterry Hunt in likening them to metalliferous veins as the result of the successive deposition of mineral matter from solution in fissures, but recent researches support the earlier view of Charpentier (1823) who regarded the pegmatites as injections of granitic material which, originating in the still fluid granite, deep down, was pressed into the cracks of the already solidified granite and rocks above—"after-births," as it were, of the same granitic formation in the district in which they occur.[1]

Even before Charpentier's time, however, similar views were published by the old Cornish geologists, Carne, Davy and others, who distinguished between what they called "contemporaneous veins", which are related genetically to the granite which they accompany and often traverse, and the "true veins", filled with valuable ores and formed at a distinctly subsequent period by the chemical infilling of fissures.[2]

It is now generally conceded that pegmatites have resulted from the consolidation of injected fluid magmas, often directly traceable to some large granitic mass. This view, that they are merely contemporaneous injections of the residual granite magma, has been advocated by

[1] Charpentier, "Essai sur la const. géog. des Pyrenées", 1823, p. 158.

[2] Carne, "On the relative ages of the veins of Cornwall." *Trans. Roy. Geol. Soc. of Cornwall*, II (1822), 49. It is difficult to say who first used the term "contemporaneous veins". Dr. John Davy in 1818 (*Ibid.*, I, 20-26) referred to quartz veins traversing the granite of Porth Just as belonging "to that class of veins commonly considered contemporaneous". Those which were formerly called "contemporaneous veins" were in 1834 (Boase, "Primary Geology", p. 355) known as veins of segregation, a term introduced by Professor Sedgwick at the suggestion of Whewell "to express that they have been formed by a separation of parts during the gradual passage of the mineral masses into a solid state". This is the sense also in which the term "segregation" is used by Prof. H. Louis in the second edition of Phillips' "Ore deposits" (1896), p. 11, foot-note.

De la Beche, Bronn, Fournet, Durocher, Angelot, Naumann, Lehmann, Brögger, Reyer, Williams, Crosby and Fuller.

Recently evidence has accumulated to show that these residual portions of the granitic magmas, instead of being in a state of simple igneous fusion, contain much larger proportions of water than the average magma, and are consequently fluid at a very much lower temperature. Adopting the view expressed by Charpentier's expressive phrase, the hydrous condition of the magma injected to form these pegmatitic veins is capable of a simple explanation:—Most, perhaps all, igneous magmas contain water, and, as in the process of crystallization anhydrous minerals are separated, the water becomes concentrated in the residuary mother-liquor which can thus remain fluid at a much lower temperature. The injection of this aquo-igneous melt into the neighbouring rocks, or into fissures in the granite just solidified from the same magma, gives rise to the pegmatite veins.

With this view it is easy to explain also the coarse grain which is so characteristic of even the thinnest veins of pegmatite. The size of a crystal is directly dependent on the freedom of molecular translation within the molten magma (or solution) multiplied by the time during which molecular segregation is permitted. In a magma which becomes viscous on cooling, and in which the consolidation is rapidly accomplished, the crystals formed are necessarily small, as they always are for instance at the selvages of basic dykes, the converse being the case when the magma retains its fluidity for a long period. With what Reyer calls a *hydatopyrogenetic* (aquo-igneous) magma the latter condition is possible, for there is then a small difference between the temperature of the magma and of the rock into which it is injected, and consequently a very slow dissipation of heat. The reduction of temperature is still more retarded on account of the great specific heat of the water contained in an aquo-igneous melt; for to reduce water by one degree in temperature involves the equivalent rise of some three times the amount of average rock. The water, therefore, which becomes concentrated in the magmas that form our pegmatites, explains the high degree of fluidity and consequent injection to great distances of very thin films, as well as the remarkably well crystallized condition in which such thin veins of pegmatite are invariably found.

It is to be expected, naturally, that the proportion of water to solid matter in the material which forms pegmatite veins will not always be the same, and, as a consequence, we get all stages between veins which are practically formed from igneous magmas, and which show the usual phenomena of more essentially igneous injections, and those which contain an excess of water and consequently approach chemical precipitations from solutions in fissures. The latter circumstance accounts for the occasional "comby" structures found in pegmatitic veins, whilst the former has given rise to the idea that pegmatites are essentially igneous in origin.

After a long period of sharp, not to say bitter, controversy between two opposed schools, geologists are beginning to recognise the fact that pegmatites are not to be relegated to either extreme explanation; but that the phenomena they present are due to a combination of both igneous and aqueous agencies, a conclusion which involves no difficulty since Guthrie and others have taught us to observe that igneous fusion and aqueous solution are not separated by a sharp line of demarcation, but, like many other natural phenomena, pass into one another by insensible gradations.

Form of pegmatite masses.

In India, as in the mica-mining areas of America, the pegmatites are found associated with mica-schists, quartzites and other schistose

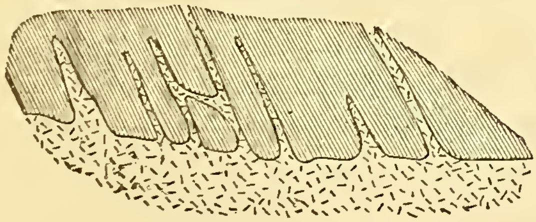

FIG. 8. *Pegmatite dyke cutting through the schists and sending out apophyses parallel to the folia (plan). E. of Gidhaur hill, Behar (after Mallet).*

(25)

rocks of the so-called upper division of the Archæan group. Into these schists the pegmatites have been intruded, generally along, but sometimes across, the folia, in the form of thin sheets, lenticular bodies, or large, thick, bosses (Plate VIII and figs. 8 and 9). The common disposition of the mica-bearing pegmatites in sheets seems to have been entirely overlooked by the miners in India, and ignorance

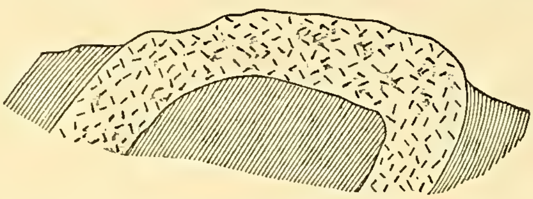

FIG. 9. *Section of pegmatite vein in mica schists, Sakri river, Hazáribágh district (after Mallet).*

of this fact is the principal cause of the exceedingly wasteful and primitive system of mining now being practised under European as well as Native management (see Chap. VI).

The general tendency of the pegmatite sheets[1] to follow the planes of foliation is probably due to the fact that this is the direction in which schistose rocks are more easily disrupted. Occasionally the pegmatite sheet changes its direction by following a fault plane before resuming its direction parallel to the schist folia. Where

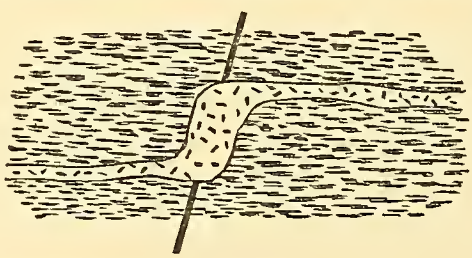

FIG. 10. *Thickening of pegmatite vein at a fault in the schists, Gáwan, Hazáribágh district.*

[1] The term "sheet" is more expressive than "vein," which gives one the idea of a more cylindrically shaped body. This appears to be the idea in the minds of the miners in the Behar area, who, by following the mica from "book" to "book," have made worm-like, tortuous excavations dignified in common talk by the name "mines". Reyer uses the term *Blatt* (pl. *Blätter*), leaf or sheet, instead of the commoner term *Gang* (pl. *Gänge*), vein (Theoretische Geol., 1888).

the sheet is so curved it is generally much thicker and carries larger sheets of mica than in the thin sheets (fig. 10). From sheets, uniform in thickness over large distances, we find various gradations down to small eye-like lenses, of which many may be found projecting from the schist surface over an area of only a few square yards, giving the impression that the pegmatite magma—the "granitic juice" as Zirkel would call it—has thoroughly impregnated the schists. Excellent examples of such occurrences are to be seen near Garanji (Ghorunjee) in the Hazáribágh district.

Many of the spaces occupied by the pegmatites are evidently of mechanical origin, the folia of the schists being forced asunder and left wrapping around the pegmatite-eye like the fibres of a piece of

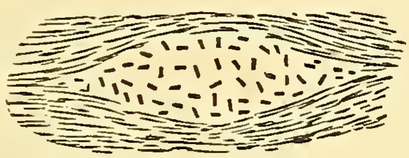

FIG. 11. *Lenticular body of pegmatite with schist folia following its outline. Koderma, Hazáribágh district.*

timber around a flat wedge (see fig. 11). At the same time this explanation is not universally applicable, for we find pegmatite masses occupying positions in schists which have suffered no disturbance in the direction of their folia, and the pegmatites appear to occupy spaces formed by the absorption or removal of the schist material. There appears to be no other explanation applicable to stout ellipsoids or blunted lenses of the kind illustrated in fig. 12. Such occurrences are more characteristic of the larger masses of pegmatite.

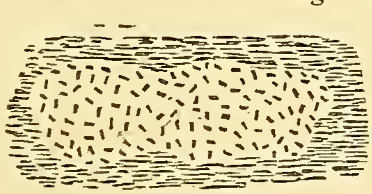

FIG. 12. *Pegmatite body in undistubed mica-schist, Gáwan, Hazáribágh district.*

The very frequent occurrence of valuable mica-bearing pegmatites in association with mica-schist is a circumstance worthy of note : the fact is important to the prospector and significant from the purely scientific point of view. More than once it has been asserted that in composition pegmatites vary with the rocks they traverse, and it has sometimes been rashly concluded in consequence that the minerals which compose the pegmatite have been derived by leaching out of the country rock and deposition of the materials in fissures.

The coarse-grained contemporaneous veins (pegmatites) which traverse diorites, syenites and granites are probably end-products of the differential consolidation of the magmas from which the associated massive diorites, syenites and granites are derived. In such cases, naturally, there is a mineralogical correspondence between the pegmatite vein and the rock it traverses, a correspondence not difficult to explain and one naturally to be expected. But as a matter of fact the best mica-bearing pegmatites, though having the mineral composition of granite, are not generally found traversing that rock. On the contrary, in the same area (take Gáwan in the Hazáribágh district, for instance), valuable mica-pegmatites will be found traversing the mica-schists, whilst worthless veins occur close at hand in the massive granite. That there is some essential connection between the mica-bearing characters of the schist and the pegmatite seems evident, and there are many facts to be observed in the mica-mining country which remind the observer of Doelter's artificial formation of muscovite by the action of potassium fluo-silicate and aluminic fluoride on andalusite.

We have found it necessary, in studying the physical conditions attending the injection of pegmatite magmas, to accept a compromise between the ultra-igneous theory and its antithesis. The writer considers it necessary also to accept a modification of the theory that mica-bearing pegmatites are the result of the simple consolidation of an injected magma, and to allow that, whilst the pegmatites have affected the surrounding schists, it seems likely that the schists in return have modified the composition of the pegmatites. The composition of the large masses of pegmatite cutting through the schists as clean dykes may be practically that of the magma which was injected; but in some places the schists are simply infested with numberless pegmatite-lenses and veins, as if the whole rock had been impregnated with the pegmatite juice, and, as far as mere composition is concerned, it is only necessary to introduce sufficient potash and possibly fluorine to account for the alteration of the aluminous and siliceous schists, to permit the formation of felspar, and to allow of its segregation with quartz and mica into the lens-shaped cavities produced by crumpling the schists. In our best mica-producing country we have large bodies of granite, with a few unimportant contemporaneous veins, protruding through mica-schists, which are full of pegmatite lenses, sheets and dykes. There is evidence that the granite is younger than the schist, intrusive into it and the cause apparently of a well-marked zone of metamorphism. It does not seem to be a wild supposition to expect that the vapours given off from such a granite-mass resembled in essential respects the reagents by which Doelter acted on andalusites. This mineral and its congeners, chiastolite, sillimanite and kyanite frequently occur in the schists, and various stages, from the commencement to the complete change of chiastolite into mica, are commonly observed.

There is an abundant evidence of fluorine in the district. Beside the muscovite, which contains this element, fluorine occurs more abundantly in lepidolite, fluor-spar, apatite and tourmaline. In some places, Ghorunjee for example, instead of mica-schist, the pegmatites are found cutting a granular quartz-rock with numerous large muscovite scales. Such a rock was presumably once a quartzite; but the granules of clear quartz are far larger than is usual in a quartzite, whilst the mica scales are certainly not of immediate detrital origin. The whole rock has evidently been recomposed, a process not improbably connected with the formation of the pegmatite. Experience teaches the prospector to look more hopefully at the pegmatites cutting mica-schists than those found in other " countries ", and the circumstance suggests a genetic connection. But it does not necessarily follow that the pegmatites were formed by the direct alteration of the schists; more probably the circumstances under which the pegmatite magma was injected permitted the permeation of the surrounding rocks with vapours which favoured their metamorphism with the formation of mica, and possibly also led to a modification locally in the composition of the pegmatite.

"Country" rock.

Pegmatites carrying valuable mica are not as a rule found traversing massive gneisses and granite. In India the only occurrences of value are found in the very composite group of schists, which are generally referred to as the upper division of the Archæan crystalline rocks, and are thought by some to be younger than the massive felspathic gneisses. The following types have been definitely determined in the "country" of Indian mica-bearing pegmatites:—

Compact quartzite.
Coarse granular quartz-rock with muscovite scales.
Quartz-biotite schists.
Quartz-schists with mica and kyanite.
  Ditto with fibrolite.
  Ditto with iron-ore.
Fibrolite-gneiss.
Chiastolite-mica schists.
Quartz-epidote gneiss.
Quartz-biotite-hornblende rock with large lumps of magnetite.
Epidiorite.
Hornblende-schist with garnets.
  Ditto with scapolite.
Pyroxene-granulite.
Granulite (leptynite).
Diopside-gneiss with sphene.
Anthophyllite-rock.
Garnetiferous biotite-gneiss (biotite-granulite).
  Ditto with octahedral magnetite.

Talc-schist and compact potstone.

Chlorite-schist.

Limestone and dolomite with chondrodite, wollastonite and tourmaline.

Ophicalcite and ophidolomite.

As an example of a section across a typical schist "country" containing pegmatites the accompanying section near the well-known mica centre, Koderma, may be given as one readily accessible for examination.

The two hills, Mowatand to the south-west and Banda to the north-east (fig. 13), are composed of a biotite-hornblende granite which is

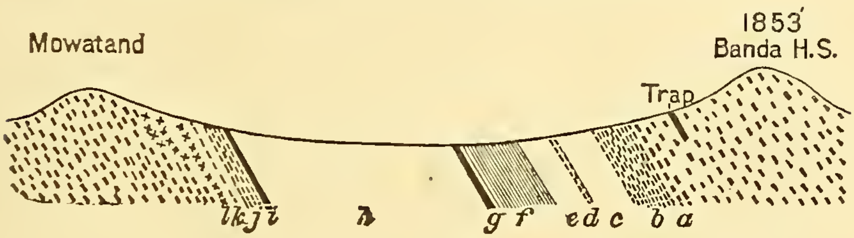

FIG. 13. *Section through the schists north-west of Koderma, Hazáribágh district. Scale 2 in. = 1 mile.*

foliated in conformity with the schists between. Near its junction with the schists there is generally a zone (*a*) of variable composition, apparently the result of contact action. Below this there is a zone of hornblende-gneiss (*b*) with garnetiferous felspathic bands; then comes mica-schist (*c*) including a band with large garnets, followed by hornblende-gneiss (*d*), and another band of mica-schist (*e*), in which pegmatite-lenses are common. Occasionally bands show biotite flakes an inch across and garnets as large as a fist. The next band (*f*) contains fibrolite, followed by a zone containing silvery mica and garnets, lying on mica-gneiss with fibrolitic bands and pegmatite sheets parallel to the folia. The schist bands are often only an inch or two thick and some contain lumps of magnetite; next occurs coarse biotite-gneiss with pegmatite. Then follows a thin bed of quartzite (*g*), lying on a thick zone of mica-schists (*h*), some with felspar and white silvery mica, others with diaspore and talc, and bands with andalusite knots, the lowest beds in this zone being coarse mica-schist with pegmatite sheets. Under this follow in order a thin band (about 20 feet) of quartzite (*h*), hornblende-gneiss with pegmatite (*j*), flaggy quartz-mica schist (*k*), and a very thick band of graphic granite (*l*) with large lumps of magnetite, separating the schists from the well-foliated margin of the granite mass forming Mowatand hill. Pegmatite veins are very abundantly developed in this transition zone, but become less prominent as the hill is approached and the granite is less distinctly foliated. The granite of the two hills, Mowatand and Banda, occurs quite commonly throughout this mica belt, forming characteristic dome-like masses, from which fact it was referred to formerly as the "dome gneiss". It is, however, a true granite, presenting, along its borders, a well marked contact zone, and its constant occurrence near the large network of pegmatite veins suggests that the latter are the final products of the consolidation of the magma which gave rise to the granite.

IV.—GEOGRAPHICAL DISTRIBUTION.

Pegmatites are known at a very large number of places where the old crystalline rocks have been exposed in India. Presumably, large quantities of the same rock are also concealed by the extensive mantles of younger sedimentary strata and the great sheet of Deccan Trap. Nevertheless, the pegmatites are not always mica-bearing, or only contain mica in small and consequently valueless crystals. In the following pages only those occurrences are described which have yielded mica approaching a marketable size. Some of these, indeed most of them, have not been worked hitherto with profit; but it is undesirable to omit them from the list, for they have of necessity been exploited but superficially, and it is well to keep in mind every known occurrence of possible value.

A glance at the list of districts will show that the known occurrences of marketable mica are practically, and the paying localities strictly, confined to the Peninsula. The Extra-Peninsular portions of India are either covered with younger sedimentary deposits, or the crystalline rocks have been so thoroughly deformed by profound earth-movements that all large crystals of mica have been too seriously mutilated to be of commercial value. It has already been pointed out that our experience in India, which is capable of such a simple explanation, is exactly paralleled by the distribution of mica-mines in other countries: only the few areas which have withstood the folding movements of the past, and which appear to be specially stable portions of the crust, are being worked for this valuable mineral. The belt of crystalline rocks forming a stable *Vorland* on the eastern flanks of the Appalachian mountain range in the United States, and presenting to that mountain range a relation corresponding to that existing between Peninsular India and the Himalayas, is also rich in valuable mica and the most formidable competitor of India in this respect. Exploration of the great stable mass of Central and Eastern Africa will most probably reveal good pegmatites; the essential conditions of geological stability exist there on a great crystalline mass very similar in many respects to Peninsular India, and it is hardly likely that such an area is devoid of mica-bearing pegmatites.[1]

The known mica-bearing areas are described in the following order:—

BENGAL PRESIDENCY.—
- Gáya, Hazáribágh and Monghyr districts.
- Sikkim-Tibet.

BOMBAY PRESIDENCY.—
- Chhota Udepur.
- Nárukot.

BURMA.

CENTRAL INDIA.—
- Rewah.

CENTRAL PROVINCES.—
- Bálaghát.
- Bastar.
- Biláspur.

COORG.

MADRAS PRESIDENCY.—
- Gánjám.
- Nellore.

MADRAS PRESIDENCY—contd.
- Nílgiris.
- Salem.
- Trichinopoli.
- Vizágapatám.
- Travancore.

MYSORE.

PUNJAB.—
- Bhábeh.
- Gurgáon.
- Kángra.

RAJPUTANA.—
- Ajmere-Merwára.
- Jaipur.
- Kishengarh.
- Sirohi.
- Tonk.

BENGAL.

Gáya, Hazáribágh and Monghyr.

It is to the material obtained from the very productive belt which stretches obliquely across the junctions of Gáya, Hazáribágh and Monghyr that India owes its earliest reputation for mica. Portions of the deposits of this area have been described by Dr. P. Breton (1826), Dr. J. McClelland (1849), Capt. W. S. Sherwill (1851), Mr. F. R. Mallet (1874) and Mr. A. Mervyn Smith (1898). The writer has recently, with the assistance of Mr. H. H. Hayden and Lala Kishen Singh, made a re-examination of the whole belt, and takes this

[1] Since the above was written the Acting Vice-Consul at Dar-es-Salem has reported the discovery of good mica on the Uluguru and Ungun hills in German East Africa. (Diplomatic and Consular Reports No. 2568, 1901, p. 23.)

opportunity of recording his indebtedness for the information and assistance readily given by all the mine owners and managers, amongst whom he is especially indebted to Messrs. Hannay and Macfadyen of Messrs. F. F. Chrestien & Co., Mr. Mervyn Smith of the Indian Mica Coy., and Mr. E. Lane of Messrs. Macdonald & Co.

The mica-producing area roughly coincides with a great belt of schists and associated gneissose granite, which is some 12 miles broad and stretches for about 60 miles from Bendi in Hazáribágh district, through the south-eastern corner of the Gáya district, east-north-eastwards to near Nawadih (Jha-Jha) on the East Indian Railway in Monghyr. Along this belt over 250 mines have been opened, turning out annually about 450 tons of mica fit for export valued at about 9 lakhs of rupees (for details see Chapter VI).

The principal mining centres are :—

Place.	District.	Latitude.	Longitude.
		° ′	° ′
Bendi (Bendee) . . .	Hazáribágh . . .	24 31	85 28
Charki (Churkee) . . .	Do. . . .	24 34	85 52
Dabúr (Doobour) . . .	Gáya	24 36	85 57
Dháb	Hazáribágh . . .	24 35	85 49
Domchánch	Do. . . .	24 28	85 44
Gáwan . . .	Do. . . .	24 37	85 57
Gharanji (Ghorunjee) . .	Do. . . .	24 34	86 11
Koderma	Do. . . .	24 28	86 38
Mahaisri (Muhaisree) . .	Monghyr . . .	24 43	86 19
Nawadih	Do. . . .	24 47	86 26
Rajauli (Rejowlee) . .	Gáya	24 39	85 33
Tisrí (Tesree) . . .	Hazáribágh . . .	26 10	75 56

The nearest convenient railway stations for most of the mines are Giridih on the East Indian Railway, 45 to 60 miles distant, Gáya about 20 miles from the north-west face of the belt, and Nawadih, now named Jha-Jha, 4 miles from the north-eastern end of the field. The largest quantity of material finds its way most conveniently through Giridih, to which the freight by road adds very seriously to the cost of the mineral, and is a serious tax on the industry. But the proposed line from Katrásgarh to Gáya will run through the mica-fields, and when constructed will be a great assistance towards the development of mining.

The schist belt forms an irregular scarp, with a series of gháts leading from the gneissic upland of North Hazáribágh to the Gangetic plain; the comparatively rapid action of the rivers has contributed to the irregularity of the surface-features, and has opened the country in a way which facilitates the detection of the pegmatite-veins as well as the processes of mining for mica. In this respect the Bengal mica-bearing belt possesses an advantage over the principal Madras field, which is situated on the flat, partly alluvial, plains of the Nellore district (see p. 59).

Prospects of the area.—Although the Bengal area has been worked for many years, and possibly the majority of available good veins have been attacked, the mining has been for the most part superficial, and there is no likelihood of early exhaustion. With a few exceptions the mines are very shallow, and most of them are mere worm-like excavations which have done practically nothing towards following the pegmatite sheets along the strike. Work has been carried only so far as the "books" of mica can be traced, and large quantities of pegmatite, containing doubtless mica as good as that removed, still remain untouched. The choice bits near the surface have been picked out, and the time has come for more systematic working with recognised modern mining methods. With the judicious outlay of sufficient capital, the industry is capable of indefinite development, and it appears to be altogether two early to consider the possible limitation of the resources of this field.

The dome-gneiss.—A striking landscape feature along this belt, and one which is of great geological importance, is the frequent occurrence of low, rounded hills of gneissose granitite, the "*dome-gneiss*" of earlier workers, so named on account of its peculiar habit of weathering into piles of dome-like hummocks and large, ellipsoidal masses of bare rock, in which the concentric surfaces, due to exfoliation by the action of sun and weather, form the most prominent divisional planes. The rock is sometimes porphyritic, and has generally a gneissose structure, due to parallel disposition of its inequiaxed constituents; but there is no definite banding due to alternating layers of dissimilar mineral composition, such as characterises the schist formation around. In mineral composition the "dome gneiss" shows the typical features of a granitite (Rosenbusch), being composed of quartz and microcline with smaller quantities of oligoclase, biotite, hornblende and accessory sphene, apatite and zircon. The prevailing colour of the felspathic constituents gives the rock a pink to purple tint. Besides its mineral composition, the rock resembles undoubtedly eruptive granites in the possession of autoliths formed by local concentration of its ferromagnesian constituents, contemporaneous coarse-grained veins, xenoliths of quartzite, and a well-marked zone due to contact-action near its junction with the schists. These features indicate an eruptive origin for the "dome-gneiss," and account for its appearance at different horizons in the schists, its occurrence in large roughly lenticular bosses, as well as in thin sheets intruded between the schist folia. As a consequence of this origin, its foliation planes sometimes underlie, and sometimes appear to rest on, those of the schists. Prominent and typical examples of the "dome-gneiss" are exhibited in the Nero hill, 1,737 feet, west of Domchánch (24°28′; 85°42′), Banda, 1,883 ft. near Koderma (24° 28′; 85° 38′), Maramoko, 2,052 ft., north-east of Koderma (24°34′; 85°43′), and Banresur, 1,739ft., north-east of Gáwan (24° 40′; 86°1′).

The fact that the pegmatites are most abundantly developed in the schists where the "dome-gneiss" is prevalent suggests a genetic relationship between the two, the most probable conclusion being that the pegmatites have been formed from the end-products of the magma whose earlier eruptions produced the "dome-gneiss". That the "dome-gneiss is foliated, whilst the pegmatites are practically unaffected by earth-movements, does not necessarily imply any great differences in their ages: the amount of deformation suffered by the "dome-gneiss" is no more than might have been brought about during consolidation, and was probably provoked by its own intrusion between the schists; indeed, it seems likely that the last disturbance of the area was connected with this great granitic eruption, the pegmatitic end-product having found its way as a more mobile, aquo-igneous liquid into the smaller fissures amongst the schists, forming the final phase in the disturbance.

The schists.—Earlier workers, conforming to the prevalent theory of the time, distinguished the "dome-gneiss" as "metamorphic" and grouped together the associated schists under the term "sub-metamorphic." The peculiar features of the former can all be explained most easily as due to the deformation of igneous intrusions, and the changes are not profound enough to merit the use of the term metamorphic. The *schists*, however, represent rocks of various origins, which have been made crystalline, and in other respects altered, by the commonly recognised processes of metamorphism. Many, like the hornblende-schists, epidiorites and granulites, differ very little in composition from known igneous types, and probably represent lava flows, intrusive sheets, or even laccolitic intrusions. Others, like the rock near Gáwan containing anthophyllite, retain in places structures which characterise volcanic ashes, whilst the crystalline limestones, quartzites and chiastolite-schists indicate, by their chemical compositions, their origins respectively as limestones, sandstones and shales. These leading types are found in alternating bands of various thickness, representing by their variety the common differences observable in a great sedimentary system, whilst before, during, and possibly since, their metamorphism they have been so profoundly crumpled and folded, that it would be ridiculous to regard the apparently inferior beds to be necessarily older than those resting upon them:

no stratigraphical sequence can be established amongst these schists, and their value is appraised simply by their interest as lithological types. A list of those so far recognised in the Indian mica-bearing tracts is given in Chapter II. Practically the whole of these occur in the Behar mica belt, and some of them have been recognised only in this area, which has had a more thorough examination, and is better dissected by atmospheric agents, than the other mica districts of India.

In his survey of this belt, Mr. Mallet distinguished three stages amongst the schists, an upper stage composed of quartzites as seen in the Mahábar hill, a thick middle stage in which mica-schists largely predominate, and a basal member in which quartzites again prevail, and, as in the Bhiaura ridge, are sometimes very strongly developed. Mr. Mallet was compelled by the general theory then prevailing to regard these rocks as younger than the associated "dome-gneiss," yet, with characteristic faithfulness, he recorded numbers of facts giving no support, and, in negative evidence at least, often conflicting with, his interpretation of the phenomena. His map, which is a remarkable piece of patient skill, shows a very intricate boundary between the schists and the dome-gneiss, whilst he states that the foliation planes in both rocks are found to follow the intricate twistings of the outline. The formation distinguished by him as the lowermost member of the schist-group is shown on the map as a narrow mantle wrapped around each protuberant mass of dome-gneiss. Microscopic examination of this mantle reveals far more than quartzitic rocks as they so often appear to be in hand-specimens: it displays many phenomena characteristic of igneous contact, and with the conclusion that the "dome-gneiss" is in reality an intrusive granite, younger than the schists, these phenomena at once become intelligible, and the difficult facts mentioned by Mr. Mallet are explained.

Accessory minerals.—In a few places minerals of economic value other than mica occur, and in some cases might be made accessory to the mica industry, though probably none of them is sufficiently abundant to found independent industries. The *oxides of iron* occur in quartzose schists similar to those better known in the South of India, and heaps of iron-slag in many places show that in the past a considerable industry existed; the *Kols* still in a casual way smelt a certain amount of iron in a bloomery, which is essentially similar to that employed for the direct process by other out-caste tribes of India. Much of the ore used is obtained by washing river-sand, and there are cases recorded of the accidental production of tin from the ore so obtained. In his geological notes on part of Northern Hazáribágh, Mr. Mallet mentions an instance of this, and the writer has lately had an opportunity of confirming the story by chemical examination of the furnace-products obtained through Mr. Mervyn Smith from the iron-smelters near Bendi. Although, on account of its greater specific gravity, cassiterite concentrates by washing even in the presence of iron-ore, the observations recorded above should warrant a careful watch for larger deposits of the mineral. According to Mr. Mallet's account of the ore discovered, and for a short while worked, near the Barákar river, eight miles west of Giridih, the tin-stone occurred in lenticular bands in the gneiss which, judging by the habits of cassiterite, were not improbably granitic veins. Isolated grains of cassiterite are often found in lepidolite near Pihra (24° 38′ 30″; 85° 51′), where its association also with indicolite and other forms of tourmaline and fluor-spar is in agreement with its occurrences in other parts of the world.

To a small extent it may be found possible to utilize as bye-products the *phosphatic minerals* occurring in the mica-bearing pegmatites. Pale-green *apatite* has been found in several localities, the most abundant being in the Lakamandwa mine near Koderma, where the schists surrounding the pegmatite-vein are also impregnated with phosphate of lime. Anexperiment was made by the writer to test the abundance of apatite obtainable from the waste material thrown out by the miners from the Lakamandwa mine. Three boys were shown specimens of the mineral, and for a pay of 4½ annas picked out, in 7 working hours, 100 lbs. of the mineral from the fresh waste. A much larger quantity might have been obtained if the boys had been practised previously in recognising the mineral, and still more if the mud and soft mica films which coated the apatite had been washed from the waste heaps. The experiment almost certainly, therefore, produced a result less favourable than would be obtained by proper organization in regular practice. As it was, the material so obtained was found to contain, on careful chemical analysis, 76 per cent. of phosphate of lime, or 82·5 per cent. of apatite, an amount which certainly more than repays the cost of labour, and would probably leave a decided margin after meeting the cost of royalty, packing and freight to Calcutta. The industry must always be a small one, and the mineral does not occur in sufficient abundance to warrant mining for it alone ; but at present it is thrown away with the waste, and might very well be turned to some account as an addition, however small, to the returns of a mine which is worked primarily for mica.

Another occurrence of phosphate, interesting because of its rarity elsewhere but probably of small value as a source of phosphoric acid, was noticed to occur as considerable masses of *triplite* near the remarkable mica mine, 2 miles south-east of the village of Singar (24° 35 ; 85° 35′) in the Gáya district. The mineral is a phosphate and fluoride of iron and manganese, containing about 32 per cent. of phosphoric acid. The locality from which the triplite was obtained also yielded small specimens of the more valuable mineral *uraninite* (pitchblende), associated with *uranium-ochre* and the beautiful *torbernite*, a phosphate of uranium and copper.

Amongst other minerals of casual value or interest might be mentioned the *leucopyrite*, an arsenide of iron, occasionally found in lumps several pounds in weight in the mica-bearing pegmatites, near Dábur, south of Gáwan on the Sakri river, and again one mile south-south-west of Dháb ; transparent, green *tourmaline*, sometimes suitable for optical uses, near Manimundar (24° 37′; 85° 52′) where it is associated with the blue variety, *indicolite*, and *lepidolite ;* and *columbite*, the tantalate and niobate of iron and manganese, found in large quantities in a mine 4 miles south of Nawadih (Jha-Jha) in the Monghyr district. If there was any market for a porcelain industry, an abundance of clean *felspar*, now rejected, would be available in any part of the mica belt; but kaolin does not occur in any abundance.

In some places, near Ghorunjee for instance, and also near Bagjunt, the felspar shows the peculiar opalescent appearance of the moonstone, and small fragments might be used for cheap jewellery. Pale-blue and pale-green *beryls* have been found in several localities, and in one mine, near Muhaisri in Monghyr district, a crystal 9 inches in diameter was found to include large, transparent and flawless fragments of a pale-green colour. The peculiar tint of the aquamarine was often observed, but not in transparent beryl. Crystalline, dolomitic *lime-stones* occur near Gáwan, and at Dhelwa, 5 miles further north; whilst small fragments of *noble serpentine* were found associated with the dolomite at the latter locality. *Garnets* are common throughout the district, and some of those in the coarse, flaky biotite-schist have the correct colour, though they are rarely clear enough, for the manufacture of cheap jewellery.

Details of the methods employed in mica-mining and the preparation of the mineral will be found in Chapter VI. Nearly every occurrence of valuable pegmatite has its peculiarities in the relations of the mica to the other constituents; but the variety is too great for detailed description, and the veins present no common character which would be of general use as a guide in exploitation. In some cases the hanging-wall, in others the foot-wall, contains the best mica, whilst in many instances the whole vein has to be worked out in order to secure the uniformly distributed "books": the special features of each vein must be settled in every particular case by intelligent prospecting; there is no rule to supersede common sense.

There is one feature in this area which is certain to inspire the curiosity of those interested in its geological features, although it has no necessary connection with the mica-mining industry. The well-marked ridge running for about three miles parallel to, and on the north-east side of, the railway line near Nawadih station, is composed of a peculiar breccia, which, at first sight, resembles a broken and recemented hornstone. Another row of small hillocks, made of the same material, rises above the cultivated soil further to the north-north-west, the whole series lying along what appears to be a fault plane. No satisfactory explanation for the peculiar structure of the material presented itself when these rocks were first examined; but near Nargujoo, 6 miles further to the south-east, gradations from ordinary "strain-slip cleavage" were traced into a structureless mylonite resembling the material of the breccia near Nawadih. The phenomena near Nargujoo strongly recalled the features of the so-called "trap-shotten" gneiss of South India, which has been shown to be due to mylonisation of the charnockite series along dislocation-planes.[1] Even with the teaching of the sections at Nargujoo, and the knowledge of similar phenomena elsewhere, the breccia near Nawadih is not easy to explain with confidence, for in some places it is quite 400 yards thick; no other explanation, however, at present offers itself.

Sikkim border of Tibet.

Lieutenant-Colonel L. A. Waddell, I.M.S., states that mica in considerable quantities is quarried near Tinki, three days' journey from Giagong at the head of the Lachen valley, about six or seven miles below the line of perpetual snow.[2]

BOMBAY PRESIDENCY.

Chhota Udepur.

The Political Agent of Rewa Kantha reports the occurrence of mica-deposits in the Gabadia hills, within three miles of Chhota Udepur town, which is 22 miles from Bodeli railway station on the Daboi-Bádharpur branch of H. H. The Gāikwar's State Railway. The locality has not, however, been submitted to expert examination.

Nárukot.

Major G. Fulljames directed attention in 1852 to the mica obtainable in the village of Dholasadra, south-west of Jambughoda and

[1] Holland, The Charnockite Series. *Mem. Geol. Surv. Ind.*, Vol. XXVIII, 1900, p. 198 *et seq.*
[2] "Among the Himalayas," 1899, p. 408.

six miles north-west of Bodeli railway station. The mica is said to be of small size, but the locality has not been critically examined.[1] The area within which both the above occurrences of mica are said to be exposed is occupied by a tract of the transition rocks distinguished as the Champaner beds, which pass by an apparent transition into gneissose rocks, possibly bearing the same relation to the Champaner beds as that found so often elsewhere to be the case when schistose rocks come into contact with granitoid gneisses.

BURMA.

Leases have been granted for mica mining near Ye-nya-u in the Thabeitkyin township, *Ruby Mines district*, and a small quantity of the mineral has been raised. Specimens have also been found on the road between Sakaw and Nanyetseik in the *Myitkyina district*; eight miles east of Manwe on the Indaw stream, near the corundum quarries, and on the Shwedaung Gyi hill at the exit of the stream from the Indawgi lake.

CENTRAL INDIA.

Rewah.

Muscovite, in sheets 4 to 5 inches square, has been found at Bardghatta on the Rehr river in the Singrauli iláqa, but the specimens sent by the Political Agent were damaged by pressure-figures, and were stained by dendritic inclusions. The latter, however, is not a serious fault, and the veins should be more thoroughly exploited for mica, as we know, from Mr. Mallet's description of the Singrauli crystalline rocks, that the geological conditions resemble in all essential respects the productive belt of Behar.[2] In Singrauli there is a development of the composite schists and gneisses, not unlike those of Behar, following the northern fringe of the massive gneisses. The foliation-planes have a general trend of west-south-west to east-north-east in the direction of the Behar mica-belt, which is but a continuation of the same series, the intermediate portions being covered by a

[1] *Selections, Rec. Bombay Govt.*, No. XXIII, p. 101.

[2] *Cf.* Manual Geol. of India, 2nd Ed., pp. 30 and 31.

southward trespass of Gangetic alluvium. In addition to the similarity in the schists there is a considerable development of schorlaceous pegmatites in the Singrauli area, but whether these are provided with mica crystals of sufficient size or not is a point to be determined by prospecting, which would, judging by the superficial geology, be a reasonable venture. The village of Bardghatta is within a mile to the south-east of Pipra, which is famous for its great corundum bed.

CENTRAL PROVINCES.

Bastar.

Mr. P. N. Bose, Deputy Superintendent, Geological Survey of India, found in 1899 muscovite plates measuring 4 to 5 inches across in a coarsely crystallized, granitoid rock, exposed in the Baordhig river, south of Jugani, four miles north of Lanjura Thana. The mica obtained was damaged by gliding-planes, but the specimens were from a weathered outcrop, and the vein would possibly yield better results on excavation.[1]

Biláspur.

A certain amount of prospecting has been undertaken at Komochoki, and although the pegmatite-veins are numerous in this area, the mica so far yielded has not exceeded 2 inches square, and is of second-rate quality.[2]

Bálaghát.

At Chitadongri and Bamni an experimental lease for mica-mining was granted in 1869, but the material raised does not appear to have given plates exceeding 2″ × 4″. There are still old workings to be seen in the Baihar subdivision of this district.[3]

COORG.

The central portion of Coorg is occupied by a complex group of schists, named provisionally by the writer the Mercara group, and

[1] Private communication with specimens.
[2] Private communication with specimens.
[3] C. Grant, Gazetteer of Central Provinces, 1870, p. 18.

similar in character and origin to the schists with which the mica is found in Nellore and in Bengal. Pegmatite-veins are occasionally found in the Mercara schists, and towards the south-eastern end of the belt, near Pollibetta, these have been found to carry muscovite, which, though excellent as regards freshness and elasticity, is often damaged by pressure-figures and is warped. The rocks are largely covered by cultivation of the thick soil-cap for coffee-growing; consequently the exposures are very few, and only traceable for short distances. Two definite occurrences of mica in sheets of marketable size have been opened up near Pollibetta. On the Beechlands Estate, Mr. H. G. Parsons obtained pieces 6 to 8 inches square, some of it, but a very small proportion, of excellent quality. On Elk Hill, Mr. J. Chisholm obtained much larger pieces from a pegmatite-vein in his estate. Six lots of these sent to London were valued by a firm of mica brokers, and were estimated to be worth from a few pence to 8 shillings and 6 pence a pound. The mica was cut to rectangles measuring 12″ × 14″, 9″ × 12″, 6″ × 9″, 5″ × 7″, and various sizes of narrow ribbons. The results obtained by this experiment are very encouraging, and, as long as the vein can be definitely traced, it might be advisable to sacrifice the coffee land for mica-mining; but it would be highly indiscreet to destroy good coffee land for mere prospecting operations, as pegmatites in schists so disturbed are likely to be very hysterical in their behaviour. Like the pegmatites of the Wainád, further to the south-east and probably in an exposure of the same formation, those of Coorg are remarkably free of accessory minerals. Garnets occur, but no trace of schorl, which is so common in Bengal and Nellore, has been found.

The London brokers, noticing a few plates amongst the samples striated and damaged, concluded that the defects were caused or aggravated by blasting; but unfortunately such is not the case: the striations that I have examined all conform to the pressure-figure (see p. 18) and must have been produced by the stresses suffered during earth-movements. Consequently, precaution and care in mining will not rid the mica of these defects, which must always contribute seriously to the proportion of waste. Notwithstanding the common opinion to the contrary, the mere shock of blasting does not generally injure mica.

There are some very interesting features in the Coorg pegmatites showing that earth-movement, occurring during the time when the pegmatites are consolidating, may give rise to phenomena often mistaken for subsequent crushing of the solid rocks. Fig. 14 represents a section through a specimen composed of muscovite and quartz. The former mineral is in a well-defined crystal which has been faulted out along its basal cleavage-surfaces like a pack of cards, but is otherwise undamaged. The quartz, when examined by the microscope in polarised light, is found to be in the form of very minute granules which are independent crystals, and the granular portions form tongue-

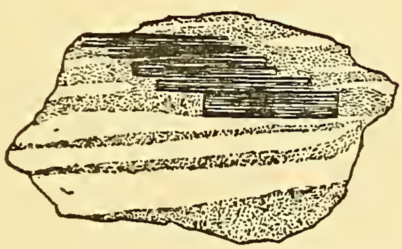

FIG. 14. *Faulted crystal of muscovite in quartz granulated by movement during crystallization.*

like, sugary-looking streaks between clearer layers which are crystallized on a larger scale. From a sample of the quartz alone one would naturally suppose that the mineral had at one time been all as clear and transparent as the glassy patches, and that the sugary structure of the white tongues had been produced by crushing. But the mica, which, compared with quartz, is a very delicate mineral, would never have been preserved so little damaged if the crushing had occurred when the quartz was solid. Now it is certain, from the fact that the mica crystals have their crystal outlines perfectly developed, that the mica crystallized before the quartz when the rock was formed, and was solid when the quartz was still in a liquid or viscous condition. As the magma from which the quartz finally crystallized probably passed through a long viscous stage, it is natural to infer that the mica-crystal was dislocated and faulted out by movement of the viscous material, and disturbance of this material during the crystallization of the quartz would result in the formation of crystals from numerous centres, whose growth would soon give rise to mutual interference, and produce a minutely granular mass in which the more prefectly crystallized portions would be embedded as clear bodies in a sugary matrix.

MADRAS PRESIDENCY.

Coimbatore.

An unsuccessful attempt was made to work the muscovite occurring associated with corundum, chrysoberyl and a zinc-alumina spinel in the peculiar, coarse felspar-veins (corundum-syenite pegmatite) exposed near the small hills of elæolite-syenite near Karutapalaiyam, 3 miles north-west of Kangayam in the Coimbatore district. The numerous pegmatite-veins in this area, and near the village of Padyur, a little further to the north, often contain good muscovite-crystals, but they are not sufficiently large and abundant to pay for mining mica alone.[1]

Ganjam.

The Collector of the district reports the occurrence of poor mica at the following places—4 miles north and 2 miles east of Rayagada and Guma hills of the Parlakimidi estate; Sisunda and Jillundi in the Gumsur taluk.

Nellore.

The mica-mining area in the Nellore district differs from that of Bengal in an important physical feature. In Bengal, as already ex-

[1] Described in a separate memoir. *Mem. Geol. Surv. Ind.*, Vol. XXX, part 3 (1901).

plained (p. 46), the schistose rocks form a scarp with its ghâts leading from a gneissic upland of from 1,000 to 1,500 feet down to the Gangetic alluvial plain, and the schist belt is consequently a region of erosion. In Nellore, on the other hand, the schists with their included pegmatites are found in the low-lying plain, forming the area on which the Penner and Swarnamukhi rivers, running eastwards from the Veligonda ridge, made by the Cuddapah quartzites, deposit their alluvium. Much of the mica deposits of Nellore are consequently concealed by sub-recent and recent formations and will never probably be detected although it seems likely, from the mica already raised, that the pegmatites are more valuable than those of Bengal. Mining too, on account of the flat surface, is generally more expensive than that permitted though little practised, in the hilly ground of the Bengal mica belt. An account of the methods pursued will be found in Chapter VI.

The mica mines of this district have been worked for very little more than a decade, and before the development of the industry the country had been only cursorily examined. The general geological features were mapped and described in outline by the late Dr. W. King in 1880.[1] Dr. H. Warth examined the mines being worked in 1891 and described the workings at Inikúrti (Podalakur, 14°22′; 79°48′) and Útkúr (14° 14′; 79°48′) in a special report to the Madras Government.[2] The industry has, however, considerably developed since that date, the mines now being worked numbering over 30. In 1898 the writer, accompanied by Dr. Walker, made a tour through the mining area, and the latter has since made a detailed examination of its geological features of which the following is a summary.

Geology.—The region specially examined by Dr. Walker extends from the fourteenth to the fifteenth parallel of north latitude, and from about the longitude of Nellore west to the Veligondas, a width of thirty

[1] *Mem. Geol. Surv. Ind.*, Vol. XVI, part 2.

[2] *Proceedings of the Board of Revenue* (*Madras*), No. 279, dated 10th June 1892.

to forty miles (fig. 15). Geologically this field is composed of a central

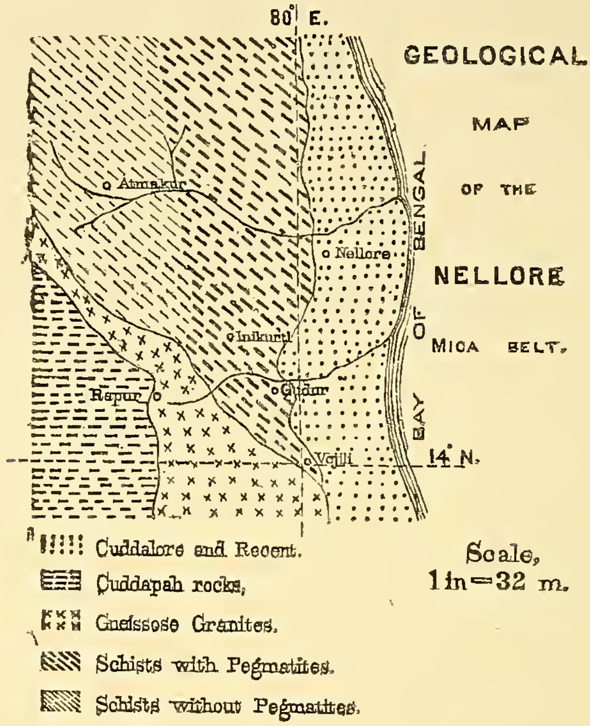

FIG. 15.

V-shaped fundament of well-foliated gneisses, the angle of the V being situated near Vojili (see fig. 15), one of the arms passing nearly due north past Nellore and Kavali, while the other arm goes in a north-west direction past Saidápuram and Udayagiri, and between this schist complex and the Bay of Bengal the surface rocks are of comparatively recent origin, none being older than the Rajmahal plant beds. On the west the gneisses are bounded by an area of igneous rocks, gneissoid granites and traps, or by the Cuddapah system of formations which make up the Veligondas. The eastern half of the schist complex is traversed by a large number of intrusive sheets and lenses of pegmatite often very rich in muscovite of great economic value. This constitutes the mica belt. The whole of the schists and the rocks to the west of them are in turn intersected by one, or possibly two, series of dykes, generally of olivine-free diabase, though some dykes are of beautifully fresh olivine-diabase with well developed ophitic structure. Recent formations, such as laterite, kankar and alluvium, conceal the older rocks in most places, so that opportunity for geological observation is very limited. The general strike of the rocks varies from west-north-west to north-north-west.

South of the Penner river the rocks of the *schist complex* are largely well-foliated biotite and hornblende-schists, at times containing nearly enough felspar to be called gneisses. Talcose and chloritic schists are chiefly confined to one band dipping at high angles, and extending past Saidápuram and Orupalle to the north-west for a considerable distance. These latter schists are generally garnetiferous and frequently kyanitiferous, whilst the talcose band near Saidápuram becomes massive in some places and is then of value as a potstone. Very prominent, but really of relatively small volume, is a series of narrow quartzite bands, which, having resisted the denuding forces better than the surrounding softer schists, stretch across the country in conspicuous narrow ridges, often lending variety to an otherwise ill-decked landscape. North of the Penner, biotite-schists and quartzites give way to the hornblende-rocks, which are on the whole more massive than to the south.

East of a line joining Cháganam (14°13′; 79°45′), and Yerraballe (15°; 79°40′) pegmatite masses in the schists are of frequent occurrence, though no petrological or structural feature has been observed sufficient to account for the abundance of the mica-bearing rocks in the eastern half of the schist complex and their complete absence in the western half.

The younger rocks between the schist complex and the coast are principally *alluvium* and blown sand, with a narrow band of *Cuddalore sandstone* and an occasional exposure of *Rajmahal plant beds*. The schist complex is mica-bearing practically up to the western boundary of this younger envelope, and it is unknown, of course, how much valuable material is so hidden by these deposits.

A grey *gneissoid granite,* at times hornblendic, at other times containing both micas so as to become a normal granite, and large, ill-defined masses of hornblende-plagioclase rock intervene between the schist complex and the Cuddapah rocks which form the Veligondas.

Near Gilakapad (14°15′; 79°40′) an interesting *quartz-porphyry* was found. Two narrow aphanitic dykes of diabase run east and west intersecting the quartz-porphyry.

The *diabase-dykes* which are seen in frequent outcrops throughout the district are most abundant towards the west in the vicinity of Rápúr. They are sometimes augite-plagioclase rocks and sometimes olivine-diabases.

Laterite very often forms the surface rock along the east of the schist complex, while to the north of the Penner river in the mica-belt, *kankar* is very abundant, being as a rule of the same distribution as the hornblendic rocks, from which it is very probably derived. A few miles east of Káligiri a long narrow ridge borders the Káligiri-Kávali road on the north side. This ridge is peculiar in that it is composed of well-rounded quartzite boulders, while elsewhere the loose rocks are almost always angular or sub-angular. As it is generally supposed that at no very distant geological time the sea extended inland to the Veligondas, it may be that this ridge owes its origin to the action of the sea on a former quartzite outcrop whose rocks were broken and rounded by the action of waves on the beach.

The *pegmatite masses* are generally in the form of intrusive sheets or dykes following the foliation of the schists, very rarely cutting across the folia. At times the dykes are of considerable thickness though some of the very thick masses are lenses, and still others are of indefinite form. They are most frequent in schists dipping at high angles. No well-defined contact action has been observed, though generally the central parts of the pegmatite masses are more acid and coarser than the borders. This is well illustrated by the way in which mica is found more abundantly in the outer zones of stock-like masses or lenses than towards the centres of them.

The pegmatites are often very coarse and not infrequently quartz and felspar are intergrown in the form of graphic granite, a form apparently not favourable for the formation of good mica. The felspar is, as a rule, microcline, cleavage fragments of half a cubic foot having been often observed on the waste heaps. The microscope shows that the glassy quartz is composed of large, interlocking individuals, usually free from pressure or strain. Tourmaline, garnets, apatite, beryl and columbite are prominent accessory minerals.

Mining prospects.—By far the largest mica-crystals obtained in India have been discovered in this young mining district, where the pegmatite so frequently occurs in large stock-like masses. In the Inikúrti mine, first successfully opened by Mr. E. H. Sargent, crystals of mica were found measuring 10 feet across the basal planes and up to 15 feet across the folia. Rectangular sheets, perfectly free of cracks and flaws, have frequently been obtained measuring 30″ × 24.″ It is difficult to predict the future of such an area: probably not a tithe of the available pegmatites have been detected, and much of the material may never be found under the thick coat of laterite, recent alluvium and sub-recent sandstones, for mica is a mineral which cannot be prospected for by borings. Nellore is a district in which, above many others, the regulations for prospecting might be advantageously relaxed without necessarily neglecting to claim the full tithe of rights when actual mining commences.

History.—Mining for mica in this district commenced in a small way in 1887 when the attention of the Madras Board of Revenue was called to the practice, and the Collector of the district was authorised to auction the rights in specified localities for periods of two years.

The sale of the mines was delayed till September 1888, pending receipt of the form of lease to be executed. Three mines, one in each of the villages of Útkúr, Podalakur and Chágaṇum, were put up to auction, of which only the one in Útkúr, about 5 acres in extent, was purchased in October 1888 for Rs. 75 per annum.

Subsequently, in April 1889, Mr. Lonsdale of Bangalore applied for and obtained the lease of 10 acres in Podalakur (which at the auction-sale of September 1888 did not find bidders) at an annual rental of Rs. 250. The lease was subsequently cancelled on the application of the party that he was satisfied of the non-existence of mica in the piece of land taken up by him.

In 1890 there were two applications, one from Mr. Sargent for the piece of land given up by Mr. Lonsdale in Podalakur, and the other from a native of the district for three blocks of land, one in each of the villages of Sydápuram, Chágaṇum and Útkúr, aggregating 10 acres. They were granted to the applicants at an average yearly rental of Rs. 50 per acre. The mine which was sold in 1888 for Rs. 75 per annum having yielded good mica, and the lessor being credited with having made large profits, there was undue competition for it when the term of lease expired in November 1890. It was put up to auction and fetched so much as Rs. 3,005 as yearly rental. This was followed by a very large number of applications by speculators for strips of land selected by them from surface indications, and it was thought best to auction them. They were sold in February 1891, and were purchased at high prices. Soon after purchasers found that they could get no mica of marketable value from the land, and all of them, with one exception, applied for cancelment of their leases, on which they had already paid considerable sums.

After such a number of failures applications for rights to mine mica became very rare, but Mr. Sargent continued work at Inikúrti with such marked success that interest in the industry revived again, and during the year 1898 the Government of Madras granted in this district as many as 71 leases for mining mica, amounting to 2,442 acres, whilst the sales from Government lands now bring in some Rs. 35,000 in royalty annually.

Nílgiris.

Mica-bearing pegmatites occur at numerous localities in south-east Wainád,[1] the chief localities hitherto recorded being—

Gudalur.	Pandalur.
Devála.	Cherambádi.
Nellakota.	

The best mica has been found in the neighbourhood of Cherambádi, where it is being mined by Mr. W. Morres on Naiken Shola and by Mr. W. MacKinlay on the Llewellyn Estate. Fairly large sheets of good quality have been found at the other localities, mostly, however, on the surface, and further prospecting will be necessary before their value can be determined.

At Cherambádi the mica is ruby-coloured of high quality, and occurs in considerable masses in the pegmatite-veins with quartz and felspar. Accessory minerals are very rare, only garnet and biotite having been identified. The trend of the veins corresponds with the strike of the foliation of the country rock, and is usually east-north-east to west-south-west, crossing the strike of the auriferous reefs at a high angle.

In all the pegmatite veins examined there is a peculiarly similar and persistent grouping of the constituent minerals. The quartz occurs in great wall or dyke-like masses, while beside it are masses of almost quartz-free felspar usually altered to a very pure, white kaolin. Between this kaolin and the quartz, the mica occurs in large "books," frequently found adhering to the quartz. The mica and felspar occur as a rule only on one side of the quartz (fig. 16).

The total thickness of the pegmatite bands seldom exceeds eight feet.

[1] This account of the mica-bearing localities in the Wainád is by my colleague Mr. H. H. Hayden (*see* also General Report, Geological Survey, India, 1899-1900, pp. 56 and 57).

So far, mining has been carried on only at Cherambádi by Messrs. Morres and MacKinlay, but the quality and size of the mica would justify fairly extensive operations.

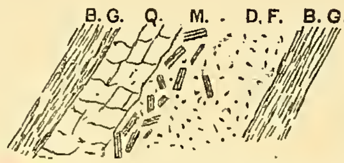

FIG. 16. *Section showing the common structure of the pegmatite veins in south-east Wainád.*

Sheets of mica have been obtained up to 3 feet in length, but as the workings have at present only reached depths of a few feet below the surface, much of the mica now obtained has suffered from weathering. In spite of this, considerable quantities of mica of high quality are being obtained, and when mining has been carried to greater depths and into fresher rock, the quality will no doubt improve.

Owing to the almost entire absence of accessory minerals, the larger plates are not spoilt, as is so frequently the case elsewhere, by inclusions of garnets, tourmaline, etc., and it is an interesting fact that no trace of this latter mineral has been found in the Wainád pegmatites (*cf. Coorg*). The country rock is usually a soft biotite-gneiss, in which mining should be easy and inexpensive.

References to some of these localities are incidentally made by R. Brough Smyth in his report on the gold mines of the Wainád (pp. 6 and 37).

Salem.

Mica occurs as a constituent of the contemporaneous pegmatite veins which traverse the great granite intrusions forming the conspicuous *drúgs* in the south-west of the district and in the Erode valley. Plates of brownish muscovite, measuring a foot across the cleavage planes, were obtained by Mr. C. S. Middlemiss near Iddapadi, and a small amount of work has been attempted in the villages of Chinnamalai and Arasiramani near Sankaridrúg.[1] The writer thinks, however, that it is not likely, judging by experience elsewhere, that the veins traversing granite will be found to contain mica in paying quantity: the proportion of large crystals is generally less and the veins more expensive to work.

Vizágapatám.

According to the District Manual (p. 155) mica occurs near Kodur in this district; but the kind and quantity are not given.

Specimens sent by M. M. Ry. M. V. Suryanarayana Rau, proprietor of the Waltair Estate, were examined by the writer and found to be phlogopite in even sheets, 4 to 5 inches in diameter. The peculiar properties of the mineral are referred to elsewhere (p. 23).

Permission to work mica has also been granted in the following districts of the Madras Presidency; but mining does not appear to have been so far profitable :—

Bellary district.—Rampuram in the Rayadrúg taluk.

Cuddapah district.—Polapolu in the Madanapalli taluk.

North Arcot district.—Gollapalli and neighbouring villages in the Chittoor taluk.

Trichinopoly district.—Shemmalai and Sigamkaradu in the Kulitalai taluk.

MYSORE.

The State of Mysore is composed entirely of crystalline and transition rocks, through which, at various places, pegmatites are intruded and occasionally carry mica of marketable quality. The most promising localities appear to be in the Mysore district, particularly in the neighbourhood of French Rocks, where clear muscovite sheets, 6 inches square, have been obtained; near Attikuppa and near Yelawal, where larger, but less valuable, mica-crystals have been found. The Hassan and Shimoga districts also contain deposits worth further prospecting, though they have so far yielded very little mica of value.

[1] Provisional Index, 1896, p. 16.

The State Geologist for Mysore has kindly furnished the following list of localities in which mica has been noticed, but apparently those already referred to above are the most promising:—

District.	Taluk.	Village.
Kolar	*Bagepalli*	Golapulli, Chokkampulli.
Mysore	*Mysore*	Yelawal, Banmanahalli, Manikapura.
	Seringapotam	Vadesamudra, Settihalli, Kalenahalli, and other places near French Rocks.
	Mandya	Pallavanhalli, Chikkanahalli, Yaliyur.
	Nanjangud	Tayur, Tagadur.
	Heggadavankote	Three miles west of the capital town.
	Cnamrajnagar	Begemalur.
	Malvalli	Ragimuddanahalli.
Hassan	*Hassan*	Upper Hosahalli, Barudala Bore.
	Manjarabad	Kage Nere jungle and near the Hemavati river.
	Hole-Narsipur	Margonhalli and Halli Maisur.
	Arakalgud	Hardur.
Shimoga	*Chamageri*	Chikka Bennur, Soolekere tank.
	Nagar	Balekoppa, Mavinhole, cart-track to Palaguppa and Pingalegudda.
	Tirtahalli	Kathimaseyavahalli, Balehalli and 56th mile, Agumbe-Hariharpur road.
Chitaldroog	*Holakere*	Visvanathanahalli.

PUNJAB.

Gurgaon.

According to Mr. Baden H. Powell, a fine specimen of mica in large plates from Mahanti and Bhunsi in the Gurgaon district, Delhi division, was exhibited at the Lahore Exhibition of 1864;[1] and Mr. F. C. Channing states that it is occasionally extracted near the latter locality.[2]

Bhábeh.

Plates of muscovite, 5 to 6 inches in diameter and 1 to 2 inches thick, of a brown colour, rarely silvery-white, were obtained by Mr. F. R. Mallet from granite veins near the Wangtu bridge on the Sutlej river.[3] Large plates of the mineral were sent to the Lahore Exhibition of 1864.[4]

Kúlú.

The contemporaneous veins in the gneissose granite and the pegmatitic veins traversing the associated schists in the Kúlú subdivision of the Kángra district are occasionally sufficiently coarse in grain to contain mica-crystals of marketable size; but the granitic formation, during or since its consolidation, has been deformed by earth-movements, and the mica-crystals have consequently been damaged. I have, however, seen plates from the Upper Chandra valley sufficiently free of flaws to give good plates five inches square. Quantities of small and damaged muscovite are raised in the granitised area around the Hamta pass; but the material is used only as a non-conducting material for roofs and snow-cellars. Small plates of excellent muscovite occur in the upper reaches of the Parbatti valley; but for the reason that this area has been, in common with the rest of the Himalayas, folded in late Tertiary times, these localities are not likely to become profitable sources of mica. In any vein coarse enough to give large crystals, the proportion of waste material will always be excessive, and the area is, moreover, far from any market, being some 150 miles from the nearest station on the North Western Railway. Tourmaline and garnets are common accessories in the pegmatitic veins of Kúlú

[1] Punjab Products, Vol. I, p. 42.
[2] Settlement Report, Gurgaon District, 1882, p. 14.
[3] *Mem. Geol. Surv. Ind.*, Vol. V, 1864, p. 169.
[4] Baden Powell, Punjab Products, Vol. I, 1868, p. 42.

and Lahaul, and whilst the conditions for the *formation* of mica have been typically developed, the conditions for the *preservation* of large sheets are wanting: no area could more perfectly impress the fact that marketable mica requires an exceptional combination of special circumstances which can only be obtained within limited areas (*cf.* Introduction, p. 11).

RAJPUTANA.

Ajmere-Merwára.

Dr. R. H. Irvine says the mineral is abundant in the Ajmere district, where large plates can be extracted.[1] The latter statement is confirmed by the specimens recently sent by the Extra Assistant Conservator of Forests, who states that prospecting licences have been granted, but no extensive work so far carried out. The mineral is said to occur near Ajmere, Tilana and Bhinai in the Ajmere district, and at Rawatmal, Kalinjar, Suliakhera and Salupura in Merwára.

Jaipur.

A plate of muscovite measuring $10\frac{1}{2} \times 5\frac{1}{2}$ inches was sent to the Colonial and Indian Exhibition of 1886. The quality was, however, inferior to Hazáribágh mica, and the mineral does not appear to be raised for export.

Kishengarh.

Specimens of mica obtained from this State in 1898, and sent to the Imperial Institute by the Reporter on Economic Products to the Government of India, were considered by experts in the London market to be quite worthless, the chief defect being the striated and cracked condition of the sheets.[2] The specimens were not, however, intended to represent the best or even the average material obtainable in the State, but were mere surface specimens sent for a preliminary

[1] Irvine, Topography of Ajmere, 1841, p. 165.

[2] W. R. Dunstan, Agricultural Ledger, No. 2 of 1900, p. 20, and No. 24 of 1900, p 229.

opinion, and an earlier answer without unnecessary publicity would have been obtained had the specimens been sent to the proper department in the first instance. An early opportunity was taken to depute an officer of the Geological Survey to examine the deposits, and Mr. E. Vredenburg has given a report of his inspection of the mica pegmatites and other minerals found in the Kishengarh State. He found numerous large veins of pegmatite traversing the gneissose formations, and many of them had been superficially broken in the search for mica; but the work was discontinued on account of misconceptions as to the mode of occurrence of the mineral. One of the most promising outcrops found was about a mile south-west of Dadia, and another, about a mile north of Neagaon, showed large mica-crystals in a pegmatite containing beryl. Mica of good size has also been obtained from pegmatites on the northern side of the road from Sarwar to Nasirabad, about two miles from Sarwar. So far, marketable material has not been obtained in quantity, but the veins have been only superficially examined, and the outcrops appear to warrant more thorough prospecting operations.

Tonk.

There are plates of muscovite in the Geological Museum, Calcutta, measuring 5 to 6 inches across and some of them are of fair quality. These have been obtained from several localities in the Chattarbhaj hills, north-east of Tonk.

Sirohi.

Major F. T. C. Hughes of the Errinpura Irregular Force reports the occurrence of mica near Rohera. Plates of good muscovite, 5 to 6 inches square, have been obtained. Major Hughes thinks there are indications of the same mineral in other parts of the Sirohi State.

V.—USES OF MICA.

A common question, and one which shows a justifiable curiosity, is occasioned by imperfect knowledge of the uses for which this peculiar mineral is purchased. As far as possible, I have gathered notes of the various ways in which mica is consumed in the Arts, but to an ingenious mind there must be numberless other ways in which some or all of its peculiar properties can be utilized. No other mineral, and no artificial substance, combines the natural properties of mica: its highly perfect cleavage, by which it can be split into the thinnest films; its transparency to light, combined with a comparative opacity to radiant heat rays; its imperfect powers of conducting electricity, giving it great value as an insulator; its chemical stability when exposed to the weather, or to corrosive oils and acids; the great flexibility of its folia, combined with a high elastic limit and consequent power to resist violent shocks or sudden changes of temperature, give mica a range of usefulness which is not likely to be imitated cheaply by any artificial substance.

The earliest use of the mineral was probably in the form of *window-panes*, as well as for *lanterns*, and mica was in consequence known as Muscovy glass (*Vitrium Muscoviticum*), which suggested the name *muscovite*, reserved in 1850 by the late Prof. J. D. Dana for the special variety which is by far the most abundant form so used. It was, however, subsequently replaced by the cheaper artificial substance, glass; but in the early stages of glass manufacture, when the processes for annealing plates had not been developed, mica was still retained for use in places where the window-pane would be subject to sudden shocks or violent vibrations, as, for example, on men-o'-war, where the shocks of heavy-gun firing shattered the badly annealed glass. Since, however, the processes for annealing glass have been developed to such perfection, and since it has been made possible to cast curved and variously shaped sheets of glass, it has entirely replaced mica for such purposes. In ordinary lanterns, too, mica has been replaced by glass and horn ; but as horn burns and glass cracks when exposed to a flame, mica is still retained to some extent for lantern uses.

As the transparency of mica is not affected by sudden exposure to heat, or by alternate heating and cooling, and as it is not readily attacked by vapours and gases, it is largely used in anthracite and gas *stoves*, from which a cheerful glow can be obtained if necessary, without exposure to direct heat. Its transparency for light, combined with opacity for radiant heat, creates for it a special usefulness as *fire-screens* in the peep-holes of furnaces, or as hand-screens in the laboratory and workshop for inspecting operations proceeding in highly-heated furnaces whose heat would otherwise be intolerable.

As *lamp-chimneys*, exposed to cold air draughts or rain-drop splashes, such as those outside drapers' show-windows in dangerous proximity to inflammable materials, or in the case of lamps giving out great heat, as in the case of the incandescent burners, mica is a convenient substitute for glass. Numbers of other uses for mica, depending on its non-inflammability and flexibility, have been devised ; thus the electric cables for street installations are sometimes rolled around with mica films kept in place by tarred twine, whilst the Indian Mica Company have lately proposed to make *envelopes* of the mineral to preserve valuable documents from fire and insects.

By far the largest quantity of sheet mica is used for *electrical purposes*, for which the principal consumption obtains in America. Its highly insulating properties, combined with flexibility, indifference to sudden exposure to high temperatures, and the ease with which sheets can be cut to any shape, render it of great value in covering various portions of dynamos and other electrical machines. For similar and related uses, thin films, down to one-thousandth of an inch in thickness, have lately been used for making the so-called *micanite* in which the films are made to adhere to one another by a fusible and highly insulating cement. The relamination of mica in this artificial preparation is said to increase its insulating property. Plates of micanite when heated can be bent to any form to make, for instance, cylinders for armature shafts and cores, commutator shells and field-magnet cores.

It can also be rolled in thinner form as micanite cloth or paper for repairing transformers, armatures, etc., and in this form it is sold in rolls many feet long or in separate sheets cut to various sizes. The invention of micanite has created a new opening for the use of the smaller grades of mica formerly rejected as waste, and in India, where simple skilled labour is so cheap, the riving of thin films from waste heaps has lately given new life to many mines.

Thin sheets are used also where it is desirable to combine lightness with a certain amount of rigidity, as in the vanes of an *anemometer*, such as in Dickinson's or Biram's anemometer, used for testing the ventilation currents in mines. Similar sheets can be silvered for *mirrors* and reflectors bent to any required shape. They are also used for *lantern-slides* painted with transparent pigments; for covering photographs and pictures, and as a substitute for glass-plates and celluloid films in preparing photographic plates, from which the negative with a thin carrying film may be subsequently split. For mounting soft and collapsible natural history specimens for exhibition in spirit, thin sheets of mica are admirably adapted, and no convenient substitute can be found to remain unaffected by the spirit and at the same time transparent and soft enough to permit the free use of needle and thread for purposes of attachment. For the preparation of microscopic sections of small fossils, and for various optical purposes, the peculiar properties of mica give the mineral uses which are interesting, though of small value to the industry.

Besides the large sheets and plates, the smaller *waste scrap* and artificially *pulverised mica* have been turned to account in various ways. As an *electric insulator* it has been used to replace porcelain cups on telegraph poles. The chief use of ground mica depends on its non-conductivity for heat, and it consequently forms *non-conducting packings* and jackets for boilers and steam-pipes. For these purposes mica appears to combine advantages which render it superior to all other forms of laggings. The parallel disposition of the flakes increase its resistance to the passage of heat by conduction or radiation to a degree not possible in materials with fibres disposed in all directions.

It will stand any usual high temperature which would calcine hair-felt or other organic fibre, and will not disintegrate by vibration in the proximity of machinery; it is free from moisture and acids which would attack iron structures, and in the presence of moisture resists decomposition. Being soft at the same time, its accidental inclusion in a bearing would have none of the abrasive properties of, for instance slag or glass-wool. For non-conducting jackets, mica waste is now used on most of the railways in the United States and Canada.

Scrap mica in a similar way can be used as a protection against heat, a layer in the roof of a house, carriage or article of clothing forming a most effectual guard against the sun's heat in tropical climates, an appreciable relief being obtained by the use of a very thin layer. Mr. Mervyn Smith informs the writer that a layer of mica-waste, ¼-inch thick, placed under an ordinary tiled roof exposed to the hot-weather sun in Bengal, made an average difference of 15° in the temperature of the air immediately under the roof. The same device is of course correspondingly effectual in keeping in the heat during a cold weather night, and for a similar reason it may be used as a packing for ice-boxes or freezing machines.

Various other uses, besides ornamental, have been suggested for pulverised mica. It has been used, mixed with graphite or grease, as a *lubricant* for bearings working under heavy pressures; as a base for *soap*, and as an inert, absorbent medium, instead of infusorial earth, for taking up nitro-glycerine in the manufacture of a form of *dynamite*.

As far as India is concerned, the most extensive use of mica is for *decorative* and *ornamental purposes*, either alone or coloured, and in the form of plates, as well as in the pulverulent condition. Pliny refers to the employment of it, under the name *lapis specularis*, to produce a brilliant glistening effect on the arena of the ancient Roman amphitheatre, whilst in America quantities of the mineral have been found in the ancient graves of Indian tribes, by whom it appears to have been used for ornamental purposes, and its occurrence in some localities indicate a certain amount of commercial intercourse among widely separated tribes during prehistoric times.

In India it is used largely at native festivals, like the Mahommedan maharam, and at weddings, for processional ornaments as lamps and tinsel decorations on banners, *taziahs* and umbrellas. The powder is sprinkled on clothes, fans, wall-paper, toys and pottery, to produce a pleasing sparkle. Considerable quantities are used in sheet form for painting on in various parts of India, and pictures so painted for screen-making are obtainable in most large bazárs. A surprisingly large quantity of mica is used in India for these purposes and the industry is by no means new, for some of the mines have been worked for hundreds of years.

Mica has been tried, it is said, with favourable results as a *fertilizer;* but any virtues it possesses in this respect are probably due merely to its mechanical action on the soil, for it undergoes decomposition too slowly to affect the supply of available plant-food. Another use for the waste material has been tried by Mr. J. L. Spoor, of Messrs. Arbuthnot & Co., Madras, who about three years ago made some very satisfactory *fire-bricks* out of compressed mica-waste.

Finally, the native physician makes considerable use of mica in India for the preparation, in accordance with absurdly elaborate and intricate processes, of *medicines* for most diseases. An account of the principal use of the mineral in medical preparations is given in U. C. Dutt's *Materia Medica of the Hindus*, whilst Raja Sir Sourindro Mohan Tagore has enumerated a list of 224 medicines in which prepared mica is an essential constituent, and the same distinguished pandit has given a corresponding list of the diseases for which the medicines are supposed to be efficacious. One example in practical Hindu Materia Medica will be sufficient to show that the process of preparation is considered to be important. After an elaborate process for the preparation of dhānyābhra, or mica flour, Sir Sourindro Mohan Tagore gives the details of one amongst the several methods for its preparation for use in Hindu pharmacy as follows:—

"Pound talc with the following:—milk of the cow, the she-buffalo, and the she-goat; gangāpatra; man's urine; the offshoots of the *vata* tree; and the blood of the goat. Sublime a hundred times, when the talc, on being calcined, will assume the red colour of the ruby. Talc thus calcined when taken internally, acts as a tonic, heightens the beauty of the complexion, strengthens the body, prevents untimely death, and removes the infirmities of age and all diseases."[1]

The Chinese also imagine that mica has certain virtues as a medicine. Although the effects obtained, or imagined to be obtained, in these cases, may be due to the substances administered with the mica, it certainly possesses one property which cannot be claimed for all medicines—it is perfectly inert and harmless.

Two sheets of transparent mica bent like a mediæval visor are used, suspended from the front of the head-dress, as a face guard whilst travelling on a fast motor car.

[1] *Abhra*, 1899, p. 5.

VI.—MINING PRACTICE.

(1) Underground and quarry work.

Two systems of mica-mining have been followed in India: in Nellore the mineral is raised in open quarries the slope of whose sides is determined by the angle of repose of the surrounding schists; in Bengal the mica is followed from crystal to crystal along tortuous, worm-like holes. The former practice is capable of improvement; the latter can best be improved by its abolition and the adoption of the rational methods employed elsewhere for mining ordinary lodes of known thickness, strike and hade. I am aware that the experience of the older workers in Bengal teaches them to favour the old native methods which have been followed for centuries. Till recent years, with an abundance of pegmatite-veins exposed, and with little competition, the old method may have been good enough. But it must be remembered that the practice of the past has been merely a process of "picking the eyes out" of the country, a practice satisfactory enough when the supplies of the mineral are more than sufficient to meet the demand, and when very little capital is available for more systematic operations. But now most of the promising pegmatites have been picked near the surface, and there is greater competition for the few mines available, it is by no means too early to regulate the extravagant and casual way in which the work is generally performed. However, these matters can best be discussed when the mining methods now practised are described, and we will commence first with Bengal, where mining has been carried on for so many years.

Bengal.—Capt. W. S. Sherwill gave the subjoined account of the method of mica mining followed by the natives in 1857:—

"A small and convenient hill having been chosen as the spot for commencing operations upon, a party of the wild hill tribes, named Bandathis, the members of which party have freely propitiated the local tutelary god or goddess, both by sacrifice and by getting very drunk, ascend to the top of the hill and commence sinking a series of pits, the whole way down the profile of the hill, about three feet in diameter each, and a few feet apart. These pits are not continued vertically downwards, but in a zig-zag shape, but nevertheless not so much out of the vertical proper, as that a basket containing the mineral cannot be hauled up from the bottom of the pit to the top; the zig-zag shape of the shaft being formed by sinking the shaft first inclining to the left a few feet and then to the right a few feet, the head of each cut or notch forming a landing-place or step, and thus the necessity of ladders is obviated; the projecting of salient angles of the notches forming a perfect flight of steps from the top to the bottom of the pits, which seldom reaches to a greater depth than forty feet when, darkness interfering with the workman's progress, the pit is forsaken and another commenced upon a few feet further down the hill. A slight framework of faggots, cut from the neighbouring trees, is placed over the mouth of each pit, upon which a man sits, waiting till the signal from below is given to haul up the basket containing the mica and rubbish, which has been dug from the sides of the pit by the aid of a rude pick. On arrival at the surface the good and bad materials are separated; the earth and rubbish are shot down the precipitous side of the hill."

Under European management the methods of mining have not greatly improved on this plan. The mica is followed from one "book" to another, and only as much material excavated as is necessary for working room, the mines are consequently developed into long meandering holes, sometimes down to a depth of 300 feet. The whole of the materials—mica, rubbish and water—are brought by a string of coolies up to the mouth of the hole, which is often near the summit of a hill, being the point where, by reason of better exposure, the pegmatite outcrop was originally discovered. On account of the accumulation of water, all mining operations are suspended during the monsoon season, and at the close of the rains the process of "forking" a mine occupies several days and sometimes weeks. In the same way, an hour every morning is spent in baling out the water accumulated over night. With the one exception now being inaugurated at Bendi, there is not a single vertical shaft in the whole mica-mining area of Bengal, not a single drive or cross-cut to show that the miners have appreciated the actual disposition of the pegmatite as normal intrusive sheets, and, notwithstanding the favourably-shaped natural contours of the ground, not a single adit for the removal of water. That mica-mining has yielded large profits under such remarkable circumstances affords strong presumptive evidence of the value of the deposits, and of the success which should be expected to follow a more scientific working of the many fine pegmatite sheets hitherto undeveloped.

The means adopted for ensuring the safety of the mines are, as a rule, most prefunctory, whilst no special effort whatever is made to ventilate the deep, narrow holes in which the miners are crowded, smoky oil-lamps used and explosives largely employed. Whilst present at a mine extended to just 300 feet below the surface, I witnessed the discharge of 25 holes charged with dynamite: the blasts went off in salvoes of twos and threes, and, after a slight discussion at the pit's mouth as to the number of successful fires, the miners streamed into the pit, whilst the fumes and dust from the explosions floated out at the mouth, and ventilation was allowed to proceed by simple diffusion. To a certain extent the ventilation difficulty cures itself by the cessation of work at nights; but the fact that I found it impossible, on account of the haze of smoke and dust, to obtain a photograph, even in strong magnesium light, at a depth of 110 feet in one of the mines, shows that the ventilation is not above reproach within two hours after the commencement of the day's work.

In order to reduce the fouling of the air in the mines to a minimum, blasting is generally performed as the last operation in the evening, and the mines are then left for the night. As a consequence of this practice, much of the mica thus freshly exposed is stolen in the night, and the owners have to pay in another way for the false economy of neglecting the recognised principles of mining.

Notwithstanding the definite regulations framed by the Local Government, there was not a single plan of any of the mines in existence when I visited the district in 1898, and the managers knew only in a general way of the positions of the works and miners under ground. The enforcement of this regulation is not only important to meet the questions which might arise in case of accident or trespass, but if plans were regularly made the managers would be able to direct the work in a much more economical and intelligent way than is done at present. A case in the Koderma area will illustrate this point:—A mine was opened near the summit (*C*, fig. 17) of a steep-sided, roughly

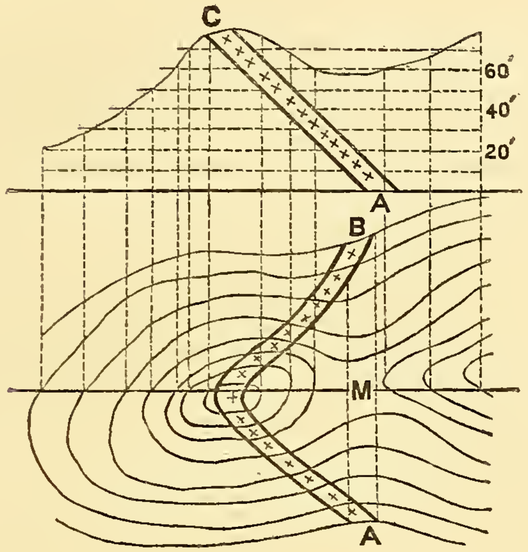

Fig. 17. *Plan of hill showing the outcrop of a pegmatite-sheet, and section of the same in the direction of dip. Scale, 1 inch=100 feet.*

conical hill, and followed as a slightly tortuous hole for 115 feet at an angle of 45°, almost exactly in the direction of true dip of the schists and that of the included pegmatite-sheet. The pegmatite was originally discovered at the summit of the hill because it had been laid bare by weathering, and it never occurred to the manager of the mine that the same sheet stretched obliquely through the hill with a continuous outcrop on either side, merely hidden by the thin layer of loose rubbish and vegetation (fig. 17). The whole of the materials—mica, rubbish and water—were handed up by a string of 80 cooly women to the mouth of the pit (*C*), whereas for a very small fraction of the working expense, the pegmatite vein might have been attacked on the flanks of the hill, the materials brought out by trams along gently sloping drives (A. M. and B.M., fig. 17) and the drainage problem allowed to settle itself by natural flow of the water along the same adit.

The saving effected would not be due merely to reduction of labour. The miners, working blindly at the bottom of a cœcal hole, damage large quantities of mica, more, very much more, than the manager appeared to suspect, whilst by tackling the pegmatite-sheet with systematic over-hand stoping from the adit described, such damage to the mica "books" would be reduced to a minimum. Fig. 17 is a plan of the hill showing how the position of the outcrop of the pegmatite might have been traced with merely the knowledge of its angle of dip and the position of the outcrop at the summit *C*. As at present worked the whole of the materials are brought out of the opening at *C*, whilst mining is going on at a point below ground corresponding to *M* in the plan. The instance referred to is a mine where by chance the contrast between the actual practice and the ideal method is unusually pronounced, and the surface features are not always so convenient for making a drive without the preliminary expense of a vertical shaft and cross-cut. In a level country such operations would of course necessitate the outlay of capital, with the attendant risk of the pegmatite proving less remunerative than indicated by the preliminary prospecting operations. Such a risk can, as a rule, be borne only by a company, whilst hitherto mica-mining in Bengal has been undertaken by individuals with, from a mining point of view, very limited resources. At present a mine is only continued as long as it pays from month to month, and this expensive system is preferred to the risks of a more complete organization. As already stated, such a system of work is satisfactory as long as there is an abundance of material near the surface, little competition for land, no capital available, and the miner ignorant of the structural characters of the pegmatite-sheets. But the time for the casual native method is past, and an economical system should be insisted on for the good of the mine-owners, as well as for the purpose of making the most of the natural resources of the country, which, as explained on an earlier page (p. 11), are necessarily limited.

Nellore.—The system of working mica in wide, open quarries, as practised in the Nellore district, suggested itself on account of the level nature of the surface, and the occurrence of the pegmatite in large lenses and stocks. The system was adopted by Mr. E. H. Sargent at Inikúrti, the first mine successfully worked, and the success attending Mr. Sargent's work has led to imitators in other plots where the conditions are less favourable. Inikúrti, however, is a most exceptional instance, the pegmatite stock being some 300 feet long and 150 feet wide, with the quartz forming a large boss in the centre and the mica and felspar disposed in a horse-shoe shaped zone around (fig. 18).

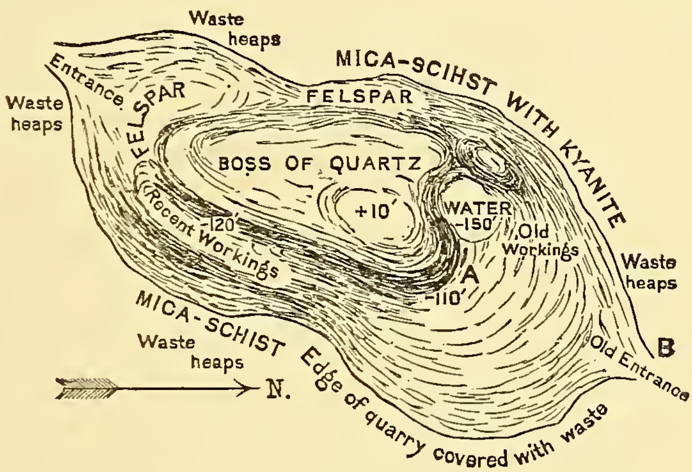

FIG. 18. *Plan of the Inikúrti quarry, December 1898.*
Scale, 1 inch = 100 feet.
Levels, + above, and — below, the surface of the plain.

Nevertheless, Inikúrti is now reaching a stage where the expense of working is gradually encroaching on the revenue obtained from the mica raised; for the sides of the open quarry, with the large masses of waste piled around, are slipping back into the quarry as fast as the bottom is being lowered, and the system which has allowed a sufficient margin of profit in the past will have to be substituted for a more rational organization in the future.

With a wide open quarry already made, the adoption of a system of shafts, cross-cuts and drives may be found inconvenient, and the sides of the quarry having extended back, in practically all such cases, by falling in during work, there will always be considerable trouble from falls of decomposed rock during the rainy season, a source of expense which will continue, and become an increasing charge, as long as simple open quarrying is continued and the sides allowed to remain raw. In cases where there is a marked inclination in the dip of the pegmatite-sheet, it will be more economical in the long run to sink a shaft near the side of the quarry and reach the pegmatite by a cross-cut, or, where the dip is not far from the vertical, the shaft should be placed along the line of strike and the pegmatite worked along drives with over hand stoping in all cases.

The practice of sinking on the pegmatite—pursued both in the Bengal worm-like mines and in the Nellore quarries—is giving rise to a shocking destruction of good mica: a single blow with a pick, or a hole bored for blasting through a mica "book" an inch thick, may result in the loss of many rupees. It must be remembered that a "book" of mica only one inch thick and six inches square weighs over 3½ lbs. and may be worth Rs. 15 to Rs. 20. A hole through the centre of such a bundle would reduce its value to less than as many annas, and the writer has seen many instances where such damage has been done. Presumably every reasonable care is taken in the use of the pick and in drilling holes; but the present system of sinking on the pegmatite in which the mica is concealed by the inevitable rubbish, always wet, places the miner at a great disadvantage. With overhand stoping the miner is able to keep a clean and dry working face, on which the indications of a "book" are readily detected, and the mineral removed without damage. But in addition to this more careful treatment of the valuable mineral itself, there is a saving in necessary dead-work; for in blasting out the loose-textured pegmatite, the explosive is assisted by gravity; the waste material is more than sufficient for stowing the worked-out excavations, thus saving the cost of its haulage to surface and removing the necessity of permanent timbering in the winzes and rises; the work can also proceed continuously instead of being interrupted by a luxurious cessation at nights and during the monsoon, for water does not accumulate on the working face of a rise. Even, however, if overhand stoping were adopted, the destruction of mica through ignorance and carelessness will only be reduced to a minimum when a system of contracts like the "tribute" and "tutwork" in Cornish mines, or the system of "bargains" of the Welsh slate quarries, is adopted.

In the few Nellore mines where open quarrying is still possible, a considerable saving might be effected, notwithstanding the cheapness of labour, by simple machinery like the "Blondin" hauler of the Scotch stone quarries, and by using pumps or pulsometers for the removal of water. In opening new mines, however, it would be far more economical in the long run if the ordinary vertical shaft arrangements were adopted after the value of the pegmatite-vein has been tested by surface-working along its outcrop. Inikúrti has given rise to the idea that the pegmatites of Nellore form stock-like masses, irregular in shape and having no determinable disposition in the schists, whereas Inikúrti is an exceptional case; the lenticular masses are usually much flatter than this and are often best described as sheets with a strike and dip of fair constancy. Even Inikúrti might have been worked for a small fraction of what it has cost if, after its richness had been proved beyond question in 1891, a properly organized system of mining had been adopted by the judicious outlay of a little capital with underground instead of open workings. It must be remembered that the advice offered above by no means covers the whole art of mica mining. Every occurrence has its peculiarity, and requires, consequently, a special form of attack, and the most economical system of working will consist of a judicious selection from the great variety of recognised mining practices, modified, if necessary, by the ingenuity and common sense of the manager to suit the special local conditions.

There is still another form of economy which would be more easily accomplished if the mines were worked as larger concerns, and that is in the transport of the mica from the mines to the godowns. At present the mica is carried by coolies, and, besides the expense of mere transport, the practice affords an opportunity for theft, the general prevalence of which is shown by the existence in some centres of mica "producers" who possess mines from which mica, any expert knows, can only be extracted by miraculous means. This source of loss, and saving in transport, might be met by the employment of wire-rope tramways; but their use is hardly possible when there are so many petty miners working a very limited area. Large trusts have their evils, and in another direction complete isolation of interests has its drawbacks also. A certain amount of combination is absolutely necessary in some forms of mining, for which the smallest amount of capital possible for economical working generally exceeds that which an individual can afford to risk. With only one exception to my knowledge, the mica-mine owners in India are not able, or at least have considered it undesirable, to pay for a properly qualified mine manager, one reason being the smallness of the "venture." As a result, they are paying in many cases at least twice as much as they need do in mining expenses: there is an absence of system in attacking the deposits underground, due to ignorance of the geological conditions under which mica occurs, and a serious waste in surface management, due to ill-acquaintance with the methods which sharp competition has occasioned in more highly developed mining countries. Like all other forms of mining, mica has its crop of sad failures; but there is probably no other mineral which lends itself more to reduction of risks in the hands of the trained miner, and no other which more quickly brings the usual reward of false economy. Nevertheless, the fault is not entirely with the "adventurer," for the rules which have hitherto been in force permitted a maximum mining lease of five years only, a period barely sufficient for the development of the preliminary shafts and cross-cuts, and consequently utterly insufficient to obtain returns proportionate to the capital necessary for regular mining operations. However, it is hoped that these limitations, and the more serious insecurity of tenure, will shortly be removed as far as is consistent with other important interests.

The native system of mining naturally gives quicker returns, and has the advantage of requiring a small outlay of capital; but the mine worked by the native method has a total life (measured by output, not years) little longer than what would be considered merely the exploratory stage of a mine opened by recognised mining methods, and the latter (working a deposit of similar richness) will commence an indefinite period of steady and uniform returns when the former has reached its limit of remuneration. A single instance will neither completely confirm, nor will it disprove, this statement; for no form of mining is without its risks, either of unexpected variation in the mineral deposits, or of unforeseen errors in management. But those concerned in the mica-mining industry will nevertheless watch with interest the result of the operations now being undertaken by the Indian Mica Company, which is laying out capital under the advice and management of Mr. A. Mervyn Smith near Bendi in the Hazáribágh district, where they have departed from the old local custom, and are opening out a pegmatite-vein by systematic development of drives from vertical shafts. The work has scarcely as yet passed the exploratory stage, and the relations between the expenditure and returns are consequently not uniform; but the results so far obtained will nevertheless be instructive to other mica miners. The following details are extracted from a note by the manager, Mr. A. Mervyn Smith, who has, with the consent of his Directors, kindly given me all the information at his disposal:—

The vein now being worked at Lalki, near Bendi, has a strike of north-west – south-east and an average underlie of 45° E. to north-east. It cuts obliquely through the mica-schists of the country, and, as is generally the case with pegmatites which do not conform to the foliation-planes of the surrounding schists, it varies considerably in thickness, shape and direction, showing a tendency also to send off numerous apophyses. The underground workings, which do not go beyond a depth of 102 feet, communicate with the surface by three vertical shafts, and an incline of 1 in 6. Although carefully timbered and provided with proper ladder ways, the coolies objected to the vertical shafts, and the incline was primarily made as a concession to their prejudices; but it has also been found to be otherwise very useful. It is now provided with a tramway, served with a hauling engine and 3-feet twin drums, by which the excess of rubbish, not used for stowing in the mine, is brought to the surface. A double, 4½-inch, ram, Cameron pump keeps the mine dry at ordinary times, its work being supplemented during the rainy season by a self-filling water-truck run along the incline. Altogether 1,533 feet of drives and cross-cuts had been made up to July 1901. Last year's work cost R13,740 and included, in drivages and sinking, a total of 916 feet, which works out to the extremely low rate of R15 per foot, covering all except London charges. The material excavated in the overhand stopes is mined and removed to the surface at a cost of something less than 8 annas a ton. Common country-made gunpowder is found to be sufficiently effective in the stopes, and, being also much cheaper, is preferred to dynamite. An estimate made from the results of the last quarter's work shows a yield at the rate of 40lbs. of rough, or 10 lbs. of dressed mica, per ton of pegmatite stoped. The dressed mica was valued at an average price of 12 annas a pound; so each ton of pegmatite mined yielded dressed mica worth R7-8 *plus* waste worth about R1-14, a total of R9-6 per ton. The general characters of the pegmatite-vein being worked are now well established for a length of over 300 feet, showing an average thickness of 40 feet, with mica noticeably concentrated towards its selvages. It was formerly worked by natives who mined only on the foot-wall margin, as the much richer deposits, now proved by cross-cuts to occur near the hanging wall, were not noticed by them on account of this edge of the surface-outcrop being concealed by the overburden.

This last statement is the only one on which the writer feels at present free to offer comment. It illustrates the contention, iterated in preceding paragraphs, that the native method of mining does not turn the natural resources of the ground to full account, and, from the Government's point of view, this, in view of what we know of the limited nature of our mica resources, is a serious consideration. The owner of mineral rights, whether a Zemindar, Jaghirdar or the Government, naturally wishes to make the most of the minerals available, and the writer contends that the native method of mining not only results in the destruction of much good mica within reach, but is incapable of exploiting and working out the full resources of a pegmatite-vein. The principles of mining formulated in more highly developed countries are the result of sharp competition and experience; their proper observance consequently permits a lower average working charge at shallow depths, and, therefore, of profitable operations to greater depths. There is, of course, a judicious medium in this as in all thing , and whilst the present system is pernicious and wasteful in one direction, the writer would like to add to this advocacy of better organization, a warning against over-capitalizing a small industry, and against the danger of swamping a small market by large output. The latter, however, is a danger which ultimately brings its own cure, for a reduction in prices by abundance of supply will tend to suggest new uses for the mineral.

(2) Dressing.

The practice of splitting the "books" and dressing the mica sheets at the surface does not lend itself to the criticism which I have been forced to make with regard to the underground work. In Bengal the sheets are merely sickle-dressed by trimming off the broken and flawed edges by obliquely directed cuts with a large knife or sickle. The dressed sheets are left quite irregular in shape, and in this form are sent to the London market. A similar practice is adopted in many of the Nellore mines, and many of the managers stated that they have been instructed by London agents to supply the mica in these irregular pieces rather than in rectangles. Mr. E. H. Sargent, however, on opening the Inikúrti mines, instituted a practice of sending mica to the market only in the form of the largest possible rectangle, and he claimed that the system was more profitable. Rectangles are utilized with less waste than irregular sheets of the same grade, and they consequently bring a higher price, besides being more convenient to pack for safe carriage, and requiring less freight. The writer was formerly inclined to favour the system of cutting perfect rectangles before placing the mica on the market; but the advantage is probably not so great since mica of various shapes is required and the trimmings can be turned to account. There is now, however, another and much more important reason for sending mica to the *general* market in the roughly-trimmed (sickle-dressed) condition, and that is the outcome of a recent change in the import tariff of our largest customer, the United States. According to the Dingley Tariff Act, which came into force on July 24th 1897, mica imported into the United States was classified into (1) "unmanufactured," and (2) "cut or trimmed," the former class including the roughly cleaned or "thumb-trimmed" mica, as they call it in Canada. Both kinds are taxed with an *ad valorem* duty of 20 per cent.; but, whilst the "unmanufactured" material is charged with an additional 6 cents per lb., the "cut" mica is taxed with an extra 12 cents a pound. The effect of this law soon made itself manifest in a very natural way on the trade, not decreasing the total import, but completely changing the nature of the imported material: the lower grades became shut out by the prohibitive tariff, and, at the same time, amongst the higher grades roughly trimmed naturally became preferred to cut mica, the latter being imported to the States only when wanted for special purposes, and then bringing, of course, a special price of which the poundage forms a small fraction. The working of this law gave new life to many old mines in the States, the domestic production rising at once from 17,630 lbs. in 1896 to 118, 852 lbs. in 1897. At the same time, the tariff caused a severe shock to those mines in India which produced only second-rate material. There is, of course, a comparatively small demand for rectangular cut mica outside the United States, and English consumers naturally wish to see the market flooded with such material, not because they want rectangles only, but because the preparation of the mica in this form makes it, on account of the peculiar working of the Dingley tariff, less acceptable to American buyers whose competition is thus avoided. Of the sheet mica imported by the United States in 1900, that classed as "unmanufactured" amounted to 1,892,000 lbs., whilst the "cut or trimmed" mica reached only 64,391 lbs.

In the preparation of rectangles the mica sheets are, after the preliminary drying, splitting and cleaning, "scribed" with the help of

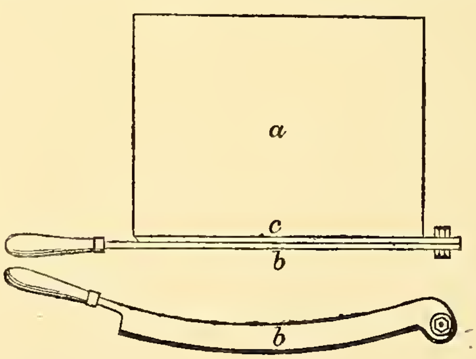

FIG. 19. *Table with knife for cutting large sheets of mica. Scale, 1 inch=2 feet.*

patterns of sheet zinc, tin or iron, to include the largest possible area of good mica; they are then cut along the ruled lines with a pair of ordinary garden shears, one handle of which is fixed to a log of wood in the ground with the cutting plane vertical (see plate I). A special form of cutting table is used for large thick sheets, too heavy for the shears. The table, 2 to 3 feet square (see plate I and figs. 19 and 20) is made of a 2 to 3-inch block of teak-wood, supported on firm legs and faced with a half-inch plate of steel (*c*), with the upper border made slightly acute to act as a cutting edge against the long, curved knife (*b*), also about half an inch thick, and hinged against the steel plate at the corner of the table.

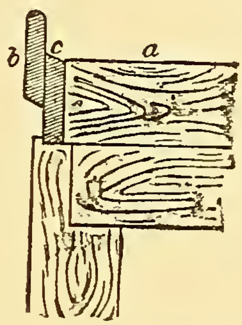

FIG. 20. *Section through the cutting edge of table shown in Fig. 19. Scale, one-fifth.*

An important part of the dressing operations consists of splitting the mica to remove damaged films or inclusions of foreign minerals which would, if allowed to remain, reduce the market value of the whole sheet, the slight loss of weight so incurred being more than compensated for by the higher price obtained for the residue. It is this part of the dressing which requires most judgment, and it is the part too often neglected by the managers, who do not fully appreciate its value.

(3) Quality and Price.

The mica sent to the market from India is practically all muscovite, which varies greatly in colour. The characteristic and favourite material raised in Bengal has a ruby-tint, a deep ruby-colour being the common intensity of the light transmitted through "books" half an inch thick. A greenish tinge more often characterizes the Nellore mica, but other colours are also found—smoky brown, pale amber, bright olive-green, and, more rarely, a bleached mica with silvery lustre. Formerly only transparent mica, free of stains, found a sale; but the objection to the presence of the well-known brown and black, iron-oxide, inter-laminar inclusions only holds for a limited portion of the uses to which the mica is put, and such material now brings a good price as long as it conforms to the desirable standard in toughness, cleavage, elasticity, freedom from pressure-figure flaws and evenness of surface.

With mica of the same quality, the price varies with the size of the sheets, according to which the product is graded. The grades are not, however, absolutely fixed, but the following list represents the usual grading:—

Specials,	over 36	square inches.
No. 1	24 to 36	"
No 2	15 " 24	"
No. 3	10 " 15	"
No. 4	6 " 10	"
No. 5	3 " 6	"

The maximum rectangle obtainable from any sheet of irregular shape is readily determined by placing it on a plate ruled into inch squares, the squares being numbered along the direction of the two co-ordinates from the left-hand lower corner. In addition to size, shape has an influence on the market price; amongst samples of mica of the same superficial area, long strips are in greater demand than square sheets, whilst pieces cut to a specially required shape naturally bring a special price, as they entail no waste.

When Mr. Mallet visited the Behar mines in 1873, the native miners recognised a series of grades, to which they gave the following special names:—

Karra,	about 50 to 100	square inches.
Rási,	" 30 " 50	"
Manjhla,	" 20 " 30	"
Sanjhla	" 12 " 20	"

Besides these, specially large sheets were distinguished as *admalla* and *urtha*; but the sizes appeared to vary at different mining centres. The writer was informed by Mr. W. H. Paschoud, Manager of the Singho division of Messrs. Chrestien & Co.'s mines, that the native miners still employ the terms *manjhla* and *sanjhla* for intermediate sizes, the ordinary adjective *bara* being used without special limitations for large specimens, whilst the smaller grades were merely known as *chhota*, and the waste, *raddi*.

Prices are extremely variable, and the market, being a comparatively small one, is sometimes subject to considerable artificial variations according to the wishes of the larger producers. The following quotations from recent sale reports of the Indian Mica Company will, however, give an approximate idea of the value of the mineral.

Report of a recent sale of sickle-dressed mica in Calcutta.

	Clear ruby.	Stained ruby.	
No. 1	Rs. 305	Rs. 185	per maund of 80 lbs.
„ 2	„ 190	„ 85	„ „
„ 3	„ 82	„ 43½	„ „
„ 4	„ 36	„ 24	„ „
„ 5	„ ...	„ 10	„ „

Special sale of small lots.

8″ × 8″,	Clear ruby,	18*s*.	per lb.
8″ × 8″,	Stained ruby,	13*s*. 6*d*.	„
6″ × 6″,	Clear ruby,	12*s*.	„
6″ × 6″,	Stained ruby,	9*s*. 6*d*.	„

Scrap mica.

No. 1 quality	(used for boiler and pipe-coverings)	13*s*. per cwt.
No. 2 „	(used for covering roofs) . .	7*s*. „

Recent London valuations of a consignment of stained, sickle-dressed, ruby mica.

Special.	3*s*. 6*d*.	to	4*s*. 6*d*.	per lb.
No. 1	2*s*. 6*d*.	„	3*s*. 6*d*.	„
„ 2	1*s*. 3*d*.	„	1*s*. 9*d*.	„
„ 3	9*d*.	„	10*d*.	„
„ 4	4½*d*.	„	5½*d*.	„
„ 5	2*d*.	„	2½*d*.	„

These prices are much lower than those which have been obtained for clear ruby mica of the best quality, of which the price varies too greatly to give a fair average. The lumping together of sheet mica with scrap prevents the use of export statistics as a test of the average value of sheet mica sent out of India; but in the tables of production for the United States the two kinds are estimated separately, and the following table gives the average value of sheet mica produced from 1893 to 1898. These are values estimated at the place of production, but they are in the country where most of the mica is consumed, and to compete with the American producer, the Indian miner must be able to meet his extra charges connected with freight and duty.

Production of sheet mica in the United States.

Year.	Quantity in lbs.	Value.	Average price per lb.
1893	6,500	£ 1,195	3*s.* 10*d.*
1894	9,900	£ 2,220	4*s.* 7*d.*
1895	6,200	£ 1,280	4*s.* 3*d.*
1896	17,630	£ 2,506	3*s.* 0*d.*
1897	118,852	£ 16,659	2*s.* 11*d.*
1898	110,928	£ 18,446	3*s.* 5*d.*
1899	97,586	£ 15,385	3*s.* 2*d.*
1900	127,241	£ 16,502	2*s.* 7*d.*

Scrap mica in the United States brings from 30*s.* to £ 2 a ton.

(4) Labour.

In both the principal mica-mining areas, Behar and Nellore, labour is fairly plentiful and cheap. In the Behar mines, Sonthals, Kols and other Kolarian tribes are employed, and the men earn from two to two and a half annas for a working day of eight hours, the women and children earning less. The number of coolies employed naturally varies according to the size of the mine, but they seldom exceed two hundred and fifty and the number in constant employment in the district is about five thousand.

In Nellore the miners are principally pariahs with a few ot the shepherd caste earning slightly higher wages than those working in the Behar mines.

(5) Production and Trade.

During the year 1900 there were 131 mines, employing 9,517 persons at work on mica. The total outturn amounted to 916 tons, slightly more than half of this amount being raised in the Nellore district which is now outstripping Bengal in the development of its mica resources. The returns for previous years are shown in the table below; but there is no doubt that, on account of the large production in zemindaris, the figures are quite incomplete. In fact, the import returns of other countries are in excess of these quantities.

	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.
					QUANTITY IN TONS.					
Bengal . . .	209	93	120	190	180	376	311	445	267	356
Burma . . .	...	...	...	...	...	1½	...	...	5¼	...
Madras . . .	100	137	2	4	3	23	22	246	151	262
Mysore . . .	...	...	...	2	2¼	3	2	2¾	2½	2½
					VALUE.					
	£	£	£	£	£	£	£	£	£	£
Bengal . . .	9,734	5,800	6,543	10,013	9,692	21,107	22,831	13,267	15,004	20,466
Burma . . .	2	...	...	...	...	11	...	...	18	...
Madras . . .	76	430	...	500	460	3,360	3,270	81,342	37,350	40,153
Mysore . . .	...	...	...	11	12	16	9	14	13	14

By far the largest quantity of Indian mica is sent to the United Kingdom which, however, is a market also for American buyers. Smaller quantities are sent direct to the United States, Germany and France, whilst casual shipments have been made at different times to the Straits, China, Austria, Mauritius and Natal. The only other countries which can be regarded at present as competing with India in the production of mica are the United States, which consumes the whole of its own production, Canada, which exports largely to the United States, besides consuming a portion of its own material, Argentina, Australia and Ceylon. Small quantities, mainly of scrap mica, have at times been raised in England, Norway, Russia and a few other countries; but India controls the market for the higher grades. The imports of sheet mica into the United Kingdom have been gradually rising during the past few years to the value £142, 371 in 1898. The estimated value of the mineral imported into the United States rose from £25,237 worth in 1894 to £30,020 in 1898, followed by a sudden rise to £55,185 in 1899 and to £63,912 in 1900. Of these amounts, Canada, which comes next to India as a producer, contributed mica worth £5,310 in 1894, £13,902 in 1898, with a jump to £29,648 in 1899. Canada may possibly be the origin of half the mica entering the United States, but the remainder, and most of that consumed in the United Kingdom, comes from India. Nevertheless, the mica-mining industry of Canada is making great strides, and its phlogopite is seriously competing with the muscovite of India.

(6)—Mica Mining Rules.

MADRAS.*

Prospecting.

1. *Applications.*—Licenses to prospect for mica in the classes of lands specified in paragraph 3 of Board's Standing Order No. 15 (of which the principal are reserved forests, reserved lands and unreserv-

* Government Order No. 125, Revenue, 13th February 1906.

ed lands at the disposal of Government) will be issued by the Collector to whom applications should be addressed.

In the case of the lands specified in clauses (*a*), (*b*) and (*c*) of paragraph 3 of the Standing Order, the prospector should make his own arrangements with the occupants of the land for the acquisition of the surface rights.

2. Each application should bear a court-fee stamp of annas 8 and be accompanied by a certificate of approval of Government under sections 10 and 11 (3) of the Government of India mining rules, and should contain the following particulars:—

(*a*) The name, residence and profession of the applicant.

(*b*) A description as accurate as possible, and illustrated by a sketch prepared to scale, of the situation, boundaries and area of the land with respect to which the licensee is required. The position of the plot required must be determined in the sketch with reference to known points.

3. *Period of License.*—The term for which the license shall be granted shall be one year or such shorter term as the applicant may desire. The license may be renewed by the Collector for a further term not exceeding two years whenever he is satisfied that the licensee has been prevented from completing his search of the land by any cause other than his own default.

4. *Fees.*—A surface rent equal to the land assessment in the case of all classified and assessed lands, and in other cases to the rate at which corresponding lands in the neighbourhood are assessed for land revenue, shall be paid for the land covered by the license, provided that the total rent levied annually under this clause on the lands covered by the license does not exceed the average rate of one rupee per acre.

5. The licensee will be allowed to remove free 1 cwt. of mica from the land covered by his license, and on all quantity removed in excess thereof a royalty of 5 per cent. *ad valorem* shall be levied.

6. *Size of Blocks, etc.*—A prospecting license will be restricted to such area as is reasonably required for *boná fide* prospecting purposes, the minimum extent being 10 acres. In determining the area to be granted the Collector will have regard to the means at the disposal of the prospector, but in cases in which the area to be granted exceeds 1 square mile, the Collector will make a reference to the Board before issuing the license.

Grants of licenses made by the Collector will be reported to Government through the Board of Revenue. Licenses are liable to be cancelled by the Board or Government if, on appeal from any of the parties affected by the Collector's order or otherwise, such a course is found necessary.

7. *Deposits.*—No application for the grant of a mica-mining lease will be taken into consideration unless the applicant deposits as security in respect of each lease such sum as the Collector may determine or gives security to the like amount to the satisfaction of the Collector, the maximum deposit in any case being Rs. 500. The security deposit will not be refunded until the licensee has, on the expiration or resignation of his license, filled in all pits excavated by him to the satisfaction of the Collector, and if he fails to do this himself within 6 months the work will be done at his expense. Should the licensee convert his prospecting license into a mining lease the deposit will, subject to such deduction as the Collector may order on account of damage done to the land, be credited as a mining deposit under paragraph 19.

8. No licensee shall cut or injure any tree on unoccupied and unreserved land or reserved forests without the permission of the Collector in writing. But it will be open to him to acquire any such trees at prices fixed by the Collector.

9. Neither the licensee nor any one claiming through or under him shall assign the license or transfer any right or interest thereunder without the previous consent in writing of the Local Government.

10. In case of any breach on the part of the licensee of any of the conditions of the license the Collector may summarily revoke the license and thereupon all rights conferred thereby or enjoyed thereunder shall cease.

Mining.

11. *Applications.*—Applications for the grant of mining leases in the classes of land specified in paragraph 3 of Board's Standing Order No. 15 should be presented to the Collector who will, if he sees no objection to granting them, submit them through the Board of Revenue for the orders of Government. In the case of lands specified in clauses (*a*), (*b*) and (*c*) of paragraph 3 of the Standing Order, the applicant should make his own arrangement with the occupants of the lands for the acquisition of surface rights.

12. Each application should bear a court-fee stamp of 8 annas and contain—

(*a*) the name, residence and profession of the applicant;

(*b*) a map of the area over which the proposed lease is to extend. The map should be prepared to scale and the position of the plot determined with reference to known points.

13. *Period of Lease.*—The maximum term for which a mining lease will be granted is 30 years.

14. *Fees—(i) Royalty.*—A royalty of 5 per cent. *ad valorem* shall be charged on all mica removed from any mine. Estimates of the value of mica, according to the size of the plates in which it is removed, will be framed from time to time, and each lessee shall be liable to pay the amount of royalty due as calculated on the assumption that all the mica removed from his mine is the best of its size and will fetch the estimated value; if any lessee prefers to defer payment of royalty until the actual sale price is known, he will be allowed to do so on furnishing a deposit sufficient to cover the amount of royalty payable at the schedule rates. If a lessee, who has paid royalty at the schedule rates, produces within one year from the date of despatch from the mine, a shipper's certificate in the prescribed form showing the actual receipts for sales of mica under each dimension, he will be allowed to recover any royalty paid in excess. Where the removals are in the first instance covered by deposits, royalty at the schedule rates will be levied if the certificate above referred to is not submitted within the prescribed period of one year.

On application being made to the Board any house of business of assured standing in the City of Madras will be authorised to grant shipper's certificates.

As a tentative measure royalty will be calculated on the scale drawn up by the Board.

15. *(ii) Dead-rent.*—The lessee shall also pay for every year after the first year an annual dead-rent of one rupee per acre provided that no lessee shall pay both royalty and dead-rent in respect of the same lease but only such one of them as may be the greater in amount.

16. *(iii) Surface rent.*—The lessee shall also pay for all land which he may take up, use, or occupy for the purpose of the mine a surface rent equal to the land assessment in the case of classified and assessed lands and a uniform rate of one rupee per acre in the case of unassessed and poramboke lands.

17. *Size of Blocks.*—The length of a block shall not be allowed to exceed 4 times its breadth nor shall its extent be less than 3 acres or more than half a square mile. A mining lease may be granted over one or more such blocks, provided that the total area held under mining leases by the lessee, or by those joint in interest with him, does not exceed ten square miles.

18. *Surrender of leases and applications for larger areas.*—It will be open to the Collector to allow a lessee to give up his original lease and take out a new one embracing a larger area, provided the prescribed limits as regards time and area are not exceeded.

On receipt of an application for prospecting or for mining over a plot lying within 200 yards of an area already granted to a different individual under a mining lease, the Collector may, if he sees no objection, give this original lessee an opportunity of extending his lease area, if the rules permit, so as to include the whole or a portion of the extent newly applied for.

19. *Deposits.*—No mining lease shall be issued unless the lessee shall before the lease is granted deposit as security in respect of each lease such sum as the Collector may determine or give security to the like amount to the satisfaction of the Collector, the maximum deposit in any case being Rs. 500. Each lessee shall be responsible for filling up pits excavated by him unless the royalty paid in respect of each excavation exceeds Rs. 200.

20. The following will be insisted on as necessary conditions of a lease:—

(*i*) The lessee shall at his own expense erect and at all times maintain and keep in repair boundary marks and pillars according to the demarcation to be shown in a plan annexed to his lease.

(*ii*) The lessee shall not cut or injure any tree on the land covered by his lease without the permission of the Collector in writing, but it will be open to him to acquire any such trees at prices fixed by the Collector.

(*iii*) Neither the lessee nor any one claiming through or under him shall assign the lease, or transfer any right or interest thereunder, or underlet the whole or any portion of the premises comprised in such lease, without the previous consent in writing of the Local Government.

(*iv*) The lessee shall commence operations within two years from the date of the execution of the lease, and shall thereafter carry them on effectually in a proper, skilful and mining-like manner unless prevented by unavoidable cause.

(*v*) The lessee shall allow any officer authorised by the Local Government in that behalf to enter upon the premises comprised in the lease for the purpose of inspecting the same.

(*vi*) The lessee shall not without the consent in writing of the Collector despatch any consignment of mica from the mines unless it shall have been inspected and its removal authorized by a Government officer appointed for the purpose. The dates on which the inspection will be made will be notified to the lessee by the Collector, but if the lessee desires to despatch the consignment on any other date, he shall give the Collector a fortnight's notice of such intention.

(*vii*) The lessee shall without delay send to the Collector a report of any accident which may occur at or in the said premises, and also the finding therein of any mineral not specified in the lease.

(*viii*) Should the royalty or rent reserved or made payable by the lease be not paid within two months next after the date fixed in the lease for the payment of the same, the Collector may enter upon the said premises and seize any minerals or movable property therein and may carry away or detain them until the rent or royalty due and all costs and expenses occasioned by the non-payment thereof shall be fully paid. If any rent or royalty remain at any time unpaid for six calendar months after the date on which it is due, the Collector may determine the lease and take possession of the premises comprised therein.

(*ix*) Any breach on the part of the lessee of the conditions of the lease renders the lease cancellable by Government.

21. In ordinary cases no mica operations will be permitted within a minimum distance of 70 yards of any irrigation source or channel. In the case of jungle streams, however, each case will be decided on its own merits. In any case 25 yards is however an irreducible minimum and that only on condition that no stone or earth is thrown into the course of the streams.

22. Should the applicant for a prospecting license or mining lease desire the Collector to prepare for him the sketch required by paragraph 2 (*b*) or the map required by paragraph 12 (*b*), the Collector may prepare the sketch or map required and recover the cost from the applicant at 4 annas per acre, or R3 per sketch or map, whichever is greater. All insufficient sketches will be rejected. The maximum sketch fee in respect of each mica mining block is R30. The sketch fee in the case of blocks exceeding 320 acres is calculated as follows:—

I. In excess of 320 acres but not exceeding 640 acres . .	R30+4 annas on every acre in excess of 320, the total being subject to a maximum of R60.

II. In excess of 640 acres but not exceeding 960 acres . .	R60+4 annas on every acre in excess of 640, the total being subject to a maximum of R90, and so on

23. *Forms of licenses and leases.*—The forms of licenses, leases and accounts are prescribed by Government.

An account with respect to each mine shall be kept in the Collector's office and on the 1st March and September of each year an account in a specially prescribed form will be forwarded to every lessee from whose mine mica has been allowed to be removed during the preceding half-year on the security of deposits. If the amount of royalty shown to be due under that account is not paid within the 15th of the month, the Collector will be at liberty to proceed to realize the amount by the adjustment of the deposit.

Schedule showing the scale of values to be adopted for the purpose of calculating royalty leviable on every pound of mica removed from the premises of a mine:—

Class.		Coloured mica.			White mica.		
		R	a.	p.	R	a.	p.
I.	4 square inches and under . . .	0	2	0	0	3	0
II.	above 4 square inches and not more than 8 .	0	4	0	0	6	0
III.	do. 8 do. 16 .	0	10	0	1	0	0
IV.	do. 16 do. 32 .	1	8	0	3	0	0
V.	do. 32 do. 48 .	3	0	0	5	0	0
VI.	do. 48 do. 64 .	4	8	0	7	0	0
VII.	do. 64 do. 80 .	6	0	0	9	0	0
VIII.	do. 80 do. 96 .	7	8	0	11	0	0
IX.	do. 96 do. 112 .	9	0	0	13	0	0
	and so on.						

NOTE.—The size of plates shall be calculated for assessment according to the greatest rectangular area the slabs will yield.

REVISED RULES FOR THE GRANT OF PROSPECTING LICENSES AND MINING LEASES FOR MICA IN BENGAL.

[Approved in Bengal Government Notification No. 142 T. R., dated the 23rd April 1902.]

In these rules, Collector means the Revenue Officer in charge of the district.

Prospecting Licenses.

1. (1) A license to prospect for mica, called hereinafter a prospecting license, shall confer on the licensee the sole right, subject to the conditions contained in the license, to mine, quarry, bore, dig and search for, win, work, and carry away mica lying or being within, under, or throughout the land specified in the license.

(2) A prospecting license shall only be granted with respect to land in which the mica mines, or mica, is the property of the Government, and shall apply only to the area described in the license.

NOTE.—A prospecting license should be restricted to such area as is reasonably required for *bonâ fide* prospecting purposes. The Collector's powers in this respect are made subject to the control of the Local Government, and it is accordingly directed that in cases in which a prospecting license is applied for over an area exceeding half a square mile, a previous reference to the Local Government should be made by the Collector.

2. No prospecting license shall be granted except to a person approved by the Government, and such person shall, before the license is granted, deposit as security in respect of each license such sum not being less than R100, as the Collector may determine, or give security to the like amount to the satisfaction of the Collector. Subject to such deduction on account of compensation for surface damage or otherwise as the Collector may order, the amount of any deposit made under this rule, should the depositor afterwards become the lessee of any mica-mining lease, will be carried to his credit as part of the rents payable under his lease, and should he decline or fail to obtain any such lease as aforesaid, will be returned to him.

3. (1) Every application for a prospecting license for mica shall, unless the Local Government shall in any case otherwise direct, be made to the Collector of the district in which the land or some part of the land with respect to which the license is required, is situate.

(2) Every such application shall bear a court-fee stamp of the value of eight annas and contain the following particulars, namely :—

(*a*) the name, residence and profession of the applicant;

(*b*) a description as accurate as possible, and illustrated by a rough sketch, of the situation, boundaries, and area of the land with respect to which the license is required.

(3) Every application shall be accompanied by a certificate of approval signed by a Secretary to the Local Government.

NOTE.—In granting a certificate of approval the Local Government should satisfy itself that the person intends to carry out *boná fide* prospecting work and has sufficient means at his disposal.

4. On receipt of any such application the Collector shall, as soon as practicable, enquire whether the grant of the license applied for is inexpedient either on the ground that the land described in the application is required for a public purpose, or otherwise.

5. (1) Should the Collector be of opinion that it is not expedient to grant the license, or should he find that the licensee has not been approved by the Local Government, he shall refuse to grant the license, and shall forthwith report the matter through the proper channel to the Local Government, which may pass such orders as it may think fit.

(2) Subject to the control of the Local Government, the Collector, if he finds that there is no objection to the grant of the license applied for, and if the applicant has been approved by the Local Government, may grant to the applicant a license in such form as may be prescribed, and shall report the matter to the Local Government or such other authority as the Local Government may direct.

NOTE.- Exploring and prospecting licenses are chargeable for stamp duty as agreements, *i.e.*, they must pay a stamp duty of 8 annas under article 5 (*b*) of Schedule I of the Indian Stamp Act, II of 1899. *Vide* Government of India's Circular in Revenue and Agricultural Department's No. 1677 S. R., dated 10th April 1902.

6. A register of applications for prospecting licenses shall be kept in English in the Collector's office, specifying—

(1) Number of application.
(2) Date.
(3) Name of applicant.
(4) Residence of applicant.
(5) Situation of the land.
(6) Boundaries.
(7) Estimated area.
(8) Date of certificate of approval of applicant by the Local Government.
(9) Date of license.
(10) Rent and royalty payable.
(11) Period for which granted.

7. Every prospecting license shall contain such conditions as may in any particular case seem necessary, and shall in all cases contain the following conditions :—

(i) The term for which the license shall be granted shall be one year or such shorter term as the applicant may desire. The license may be renewed by the Collector for a further term not exceeding two years, whenever he is satisfied that the licensee has been prevented from completing his search of the land by any cause other than his own default.

(ii) A moderate rent not exceeding one rupee per acre shall be paid for the land covered by the license.

(iii) The licensee shall pay a royalty at 5 per cent. of the value of the mica won and carried away over and above such quantity as the Collector, subject to the orders of the Local Government, may allow to be taken free for purpose of experiment.

(iv) No land in the occupation of any person shall be entered upon without the consent of the occupier, and no trees, standing crops, or other private property shall be cut or in any way injured without the consent of the owner thereof.

(v) The licensee shall make and pay reasonable satisfaction and compensation for all injury which may be done by him in exercise of the powers granted by the license, and shall indemnify the Government against all such claims which may be made by third parties in respect of any such damage or injury.

(vi) The licensee shall not cut or injure any tree on unoccupied and unreserved land without the permisssion of the Collector in writing.

(vii) Such license cannot be assigned nor can any right or interest thereunder be transferred without the consent of the Local Government.

Note.—The Local Government will, as a general rule, withhold sanction if no prospecting work has been done by the licensee, and there is reason to believe that he obtained the license solely with a view to immediately selling it out and out at a profit. On the other hand, sanction may with propriety be given if the licensee requires further resources, or proposes to associate other persons, by way of a partnership, Syndicate, or Joint Stock Company, with himself in the undertaking, if the assignment or transfer appears to be a *bonâ fide* arrangement, and if the transferee is a person or Company whom the Government would be willing to approve as a prospector. Hitherto the practice has been to unfavourably regard or absolutely prohibit transfers of prospecting licenses, on the ground that ordinarily there was nothing assured to transfer, that the transfer was proposed with the sole object of making money out of the public, and that, if the licensee was unable to work his concession, his proper course was to resign it. Under the new rules, the attitude of the Government will be less strict.

(viii) In case of any breach on the part of the licensee of any of the five last preceding clauses, the Collector may summarily revoke the license, and hereupon all rights conferred thereby or enjoyed thereunder shall cease.

(ix) The licensee shall, within six months next after the determination of the license or the date of the abandonment of the undertaking, whichever shall first occur, securely plug any bores and fill up or fence any holes or excavations that he may have made in the land to such extent as the Collector may require, and shall to the like extent restore the surface of the land and all buildings thereon which he may have damaged in the course of prospecting: Provided that this clause shall not apply to any land held under a mining lease.

(x) Should any question of dispute arise regarding the license, or any matter or thing connected therewith, or the powers of the licensee thereunder or the amount or payment of the rent or royalty made payable there by, the matter in difference shall be decided by the Local Government, whose decision shall be final.

Mining Leases.

8. On or before the determination of his prospecting license, the licensee shall have a right, subject to the rule hereinafter contained, and provided that the Local Government is satisfied that the prospecting has been of a *bonâ fide* character, to a mining lease in accordance with the terms contained in the rules for such leases.

Such lease may include an area not exceeding half a square mile, whether comprising the whole or part only of the area for which the prospecting license was granted.

9. (1) Every application for the grant of a mica-mining lease shall be presented to the Collector in whose district the land or some part of the land with respect to which the lease is applied for is situate. The Collector shall forward the application through the proper channel to the Local Government. The Local Government may by general or special order require a deposit of money not exceeding R500 to be made by the applicant in any case or class of cases before the application is taken into consideration.

(2) No mica-mining lease shall be granted otherwise than with respect to land in which the mine or mica is the property of Government or to any persons but approved capitalists who are willing to conduct operations on approved methods.

10. Every application for a mica-mining lease shall bear a court-fee stamp of the value of eight annas and contain—

(*a*) the name, residence, and profession of the applicant, and
(*b*) a map of the area over which the proposed lease is to extend.

11. On receipt of any such application the Local Government may, if the applicant is entitled to a lease under rule 8, or if it considers that the applicant should be granted a mining lease, grant the same in accordance with these rules over such one or more blocks, each not exceeding half a square mile in area, as the Local Government may think fit:

Provided that no mica-mining lease shall be granted by a Local Government under these rules so as to cause the total area held under mining leases by the lessee, or by those joint in interest with him, to exceed ten square miles.

No such lease shall be executed until it has been approved by the Legal Remembrancer or other legal adviser, if any, appointed for the Province.

NOTE.—The Local Government is empowered to grant to an applicant more than one block of land, if it considers this expedient. But the right of a prospector in respect of a mining lease is limited to one block. The granting of more than one block to him is entirely in the discretion of the Local Government. The number of blocks which may properly be granted under any one lease is a matter of importance and will vary with the resources at the command of the applicant, the area of mineralised land in the locality at the disposal of the Government, and the possibility of other capitalists being likely to engage in the same industry.

12. Without the previous sanction of the Governor-General in Council, the extent of each lot or block of land covered by a mica-mining lease shall not exceed half a square mile, and where the land follows the direction of a band or belt of mica, the length of the lot shall not exceed four miles.

13. The term for which a mica-mining lease shall be granted must not exceed thirty years, and no covenant for renewal shall be inserted in the lease without the previous sanction of the Governor-General in Council.

NOTE.—The Government of India would not be prepared to sanction a renewal clause in leases for purely speculative undertakings. On the other hand, they would be disposed to view with favour a proposal for a covenant for renewal where the existence of the mineral is ascertained beyond doubt where the enterprise is a substantial one, and where a large expenditure of capital is essential to the prosecution of the undertaking.

14. Every such lease shall contain such conditions and stipulations as the Government of Bengal may in each case consider necessary, but shall in every case contain the following conditions:—

(i) The lessee shall, during the currency of his lease, pay either a royalty of 5 per cent. *ad valorem* on all mica removed or won from his mine, or a yearly dead-rent at Re. 1 per acre, whichever may be the greater in amount. The royalty will be assessed on the sale value of the mica as shown in the books of the lessee, or as estimated by Government if, for any sufficient reason, the entries in the lessee's books be not accepted, after deducting therefrom the amount paid for freight and transit from the mine. The dead-rent shall be payable in equal half-yearly instalments, the first payment to be made on such date as may be agreed to under the terms of the lease.

(ii) The lessee shall have the power to relinquish his grant at any time during the currency of his lease on good and satisfactory reasons being shown to the Collector, and after paying in full the dead-rent for the year in which the grant is relinquished and for the next year. As an alternative a lessee may surrender his lease subject to the conditions specified in the rule appended to Government of India Circular in Revenue and Agricultural Department, No. 19—1-4, dated 10th April 1902, *i.e.*, by giving not less than 12 calendar months' notice in writing, and upon expiration of such notice, paying all rents, dues, royalty, compensation for damage, and other moneys which may then be due.

(iii) The lessee shall at his own expense erect and at all times maintain and keep in repair boundary marks and pillars according to the demarcations to be shown in a plan annexed to his lease.

(iv) Where the area leased lies within a Reserved or Protected Forest, the lessee shall at his own cost clear a line 30 feet in width all round the surface leased to him (but included in the leased area) of all trees, wood, grass, leaves, sheds, huts, and inflammable material generally. He shall maintain this line clear as above every year during the months of February, March, April, May, and June.

(v) No lessee of any block leased under these rules for mining purposes shall divert any road, path or bye-way on the block leased, or any water-course beyond the limits of the block leased to him, and all water running waste on such block shall be returned to its natural channel within the limits of the same block.

(vi) The lessee shall make and pay reasonable satisfaction and compensation for all injury which may be done by him in exercise of the powers granted by the lease, and shall indemnify the Government against all claims which may be made by third parties in respect of any such injury.

(vii) The lessee shall not cut or injure any tree reserved in the lease. Where the area leased lies within a Reserved or Protected Forest, the lessee shall at once give to the Forest Officer in charge of the forest a full description of any timber or tree destroyed or injured by him.

(viii) Neither the lessee nor any person claiming through or under him shall assign the lease or underlet the whole or any portion of the premises comprised in such lease, without the previous consent in writing of the Local Government.

NOTE.—Before granting sanction to the transfer or assignment of a mining lease as required by the rules, the Government should satisfy itself that the proposed transfer is a *bonâ fide* transaction, that the transferee is a person or Company of substance, and can be relied on to fulfil, in relation to the Government, the conditions and stipulations of the lease. It is not, however, intended that the Government should undertake responsibility towards the public for the accuracy of any prospectus which the transferees may intend to issue, or should closely examine the details for the proposed transfer or of the arrangements contemplated after it has taken effect. If in any particular case the Local Government feels a difficulty as to how its discretion should be exercised, a reference should be made to the Government of India.

(ix) The lessee shall commence operations within two years from the date of the execution of the lease, and shall thereafter carry them on effectually in a proper, skilful, and mining-like manner unless prevented by unavoidable cause.

(x) The lessee shall keep correct accounts showing the quantity and particulars of all mica obtained from the mine and the number of persons employed therein, and also complete plans of the mine, and shall allow any officer authorised by the Local Government in that behalf at any time to examine such accounts and plans, and shall furnish that Government with such information and returns in respect of the aforesaid matters as it may prescribe.* He shall also keep his accounts of the mica obtained from Government mines separate from those relating to mines in private lands if he has any such mines.

(xi) The lessee shall allow any officer authorised by the Local Government in that behalf to enter upon the premises comprised in the lease for the purpose of inspecting the same.

(xii) The lessee shall without delay send to the Collector a report of any accident which may occur at or in the said premises, and also the finding therein of any other mineral than mica.

(xiii) Should the royalty or rent reserved or made payable by the lease be not paid within two months next after the date fixed in the lease for the payment of the same, the Local Government may enter upon the said premises and distrain all or any of the minerals or moveable property therein, and may carry away or detain them until the rent or royalty due and all costs and expenses occasioned by the non-payment thereof shall be fully paid; and if any royalty or rent remain at any time unpaid for six calander months after the date on which it is due, the Local Government may determine the lease and take possession of the premises comprised therein.

(xiv) In case of any breach on the part of the lessee of any covenant contained in the lease, the Local Government may determine the lease and take possession of the said premises.

(xv) At the end or sooner determination of the lease, the lessee shall deliver up the said premises and all mines (if any) dug therein in a proper and workman-like state, save in respect of any working as to which the Local Government may have sanctioned abandonment.

(xvi) Should any question or dispute arise regarding the lease or any matter or thing connected with the mines and mica leased or the working or non-working thereof, or the amount or payment of the royalty or rent reserved or made payable by the lease, the matter in difference shall be decided by the Local Government, whose decision thereon shall be final.

* NOTE.—All information and returns obtained or furnished under this clause shall be treated as strictly confidential.

15. (1) All operations conducted under the authority of these rules within a Reserved Forest shall be subject to such conditions as the Local Government may by general or special order from time to time prescribe.

(2) It shall be a condition of every license granted under these rules that, before the commencement of prospecting within a Reserved Forest, notice shall be given to the District Forest Officer of the intention to commence operations, and that the operations shall be conducted subject to any conditions regarding the use of fire that he may prescribe: Provided that the licensee shall not enter on the land covered by the license, nor commence operations, without the written permission of the Collector.

(3) Every mining lease which includes any portion of a Reserved Forest shall, if it authorises the lessee to fell timber for mining purposes, specify the area within which or the quantity up to which, and the terms and conditions upon which, he may exercise that authority.

16. Should the applicant for a prospecting license or mining lease desire the Collector to prepare for him the sketch required by rule 3 (2) (*b*) or the map required by rule 10 (*b*), or should the sketch or map presented by the applicant be insufficient, the Collector may prepare the sketch or map required, and may, if he so order, recover the cost from the applicant at a rate not exceeding 4 annas per acre. If the Government of Bengal has prepared a map of a tract of country specially for the convenience of intending applicants for licenses and leases under these rules, and if any applicant makes use of such map for the sketch or map aforesaid, it will be open to that Government to recover as above such share of the cost of preparing the map as it may consider to be equitably due from such applicant.

17. If license or lease is not executed within six months after lease has been granted for it, the right of the applicant to such license or lease shall be held to have lapsed, unless the Local Government, for special reasons, consents to grant the same, notwithstanding the delay.

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Survey of India Offices, Calcutta, January, 1901.

MICA CUTTERS AT WORK,
BIRADAVOL, NELLORE DISTRICT.

Photographed by T. L. Walker.

T. H. Holland

Photogravure.

Survey of India Offices, Calcutta, January 1901.

FOLDED PEGMATITE-VEINS IN SCHIST.

SAKRI NADI, ABOVE BAGJANT, HAZARIBAGH DISTRICT.

Photographed by H. H. Hayden.

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

MASS OF QUARTZ IN A MICA QUARRY.
INIKURTI, NELLORE DISTRICT.
Photographed by T. H. Holland.

T. H. Holland

Photogravure

Survey of India Offices, Calcutta, January 1901.

ENTRANCE TO MICA MINE
KODERMA FOREST HAZARIBAGH DISTRICT.

Photographed by T. H. Holland.

T. H. Holland

Memoirs, Vol. XXXIV. Pl. V

Photogravure.

Survey of India Offices, Calcutta, January 1901.

BOOKS" OF MICA EXPOSED IN QUARRY.
INIKURTI, NELLORE DISTRICT.

Photographed by T. H. Holland.

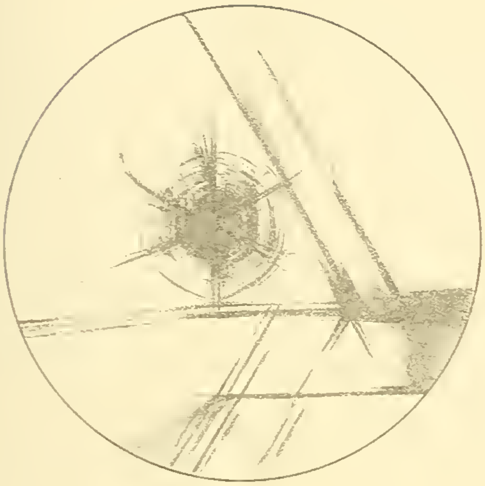

Fig. 1

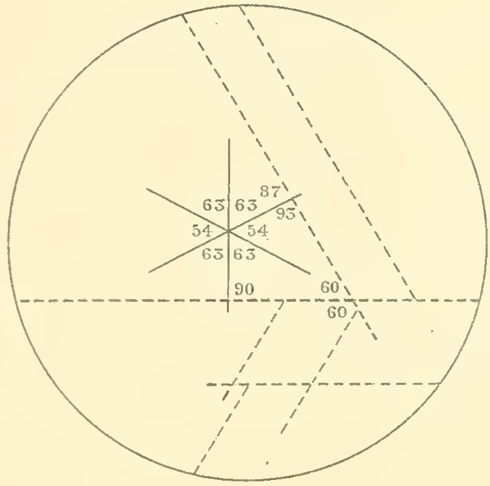

Fig. 1 a

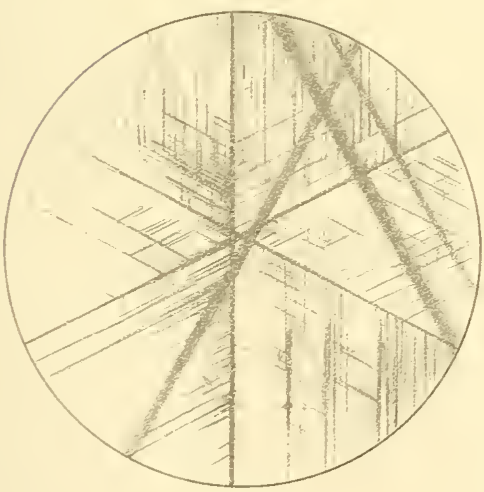

Fig. 2

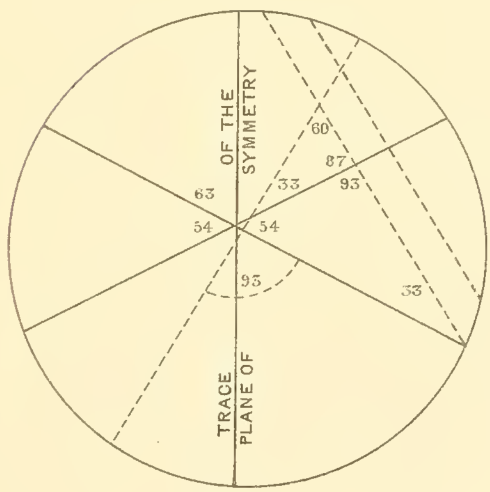

Fig. 2 a

From Photographs by T. H. Holland.

Lith., Geol. Surv. of India Office

PERCUSSION - AND PRESSURE - FIGURES IN MUSCOVITE.

Figures 1 and 2, from microphotographs magnified by 20 diameters.

Figures 1a and 2a, diagrams showing the angular relations of the cracks.

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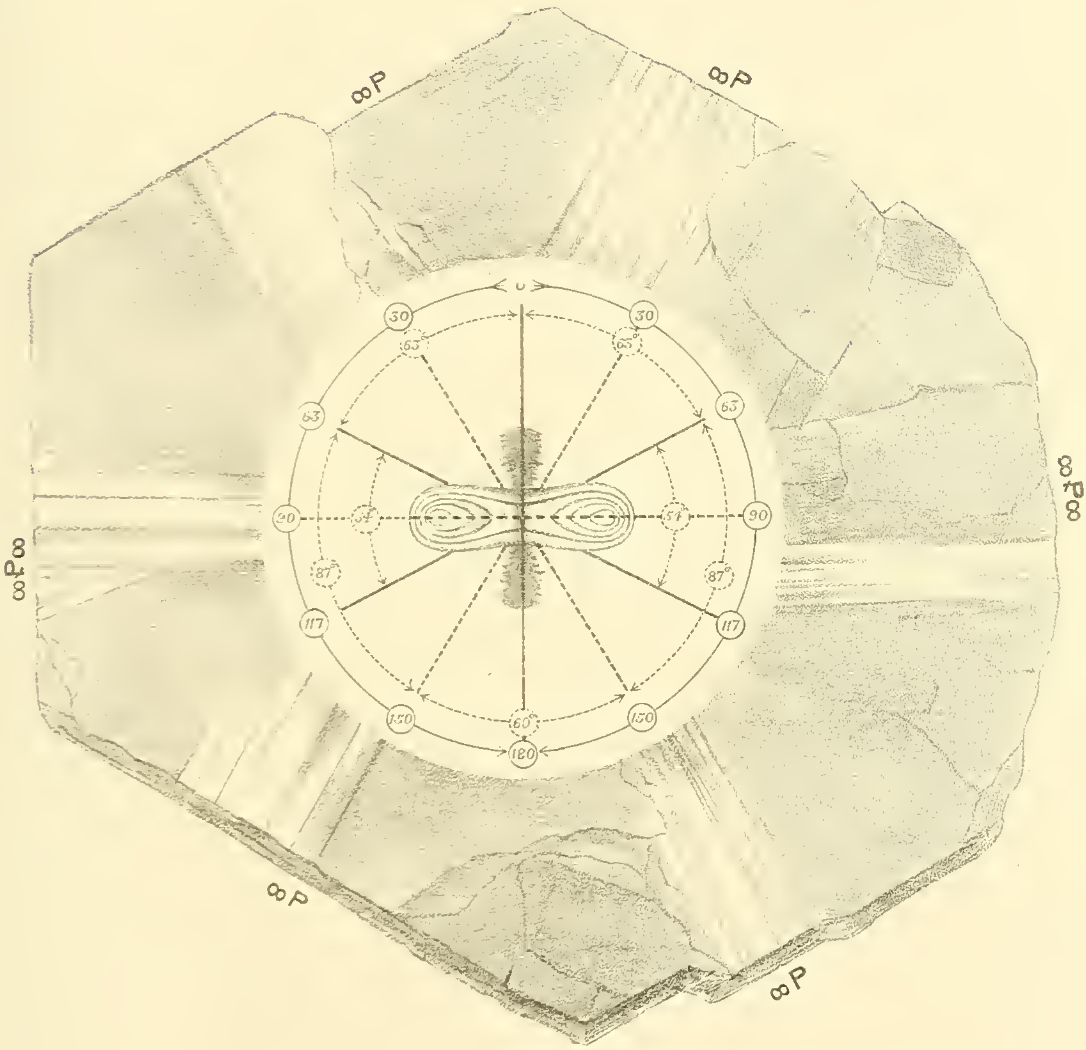


From a Drawing by T. H. Holland. Lith., Geol. Surv. of India Office

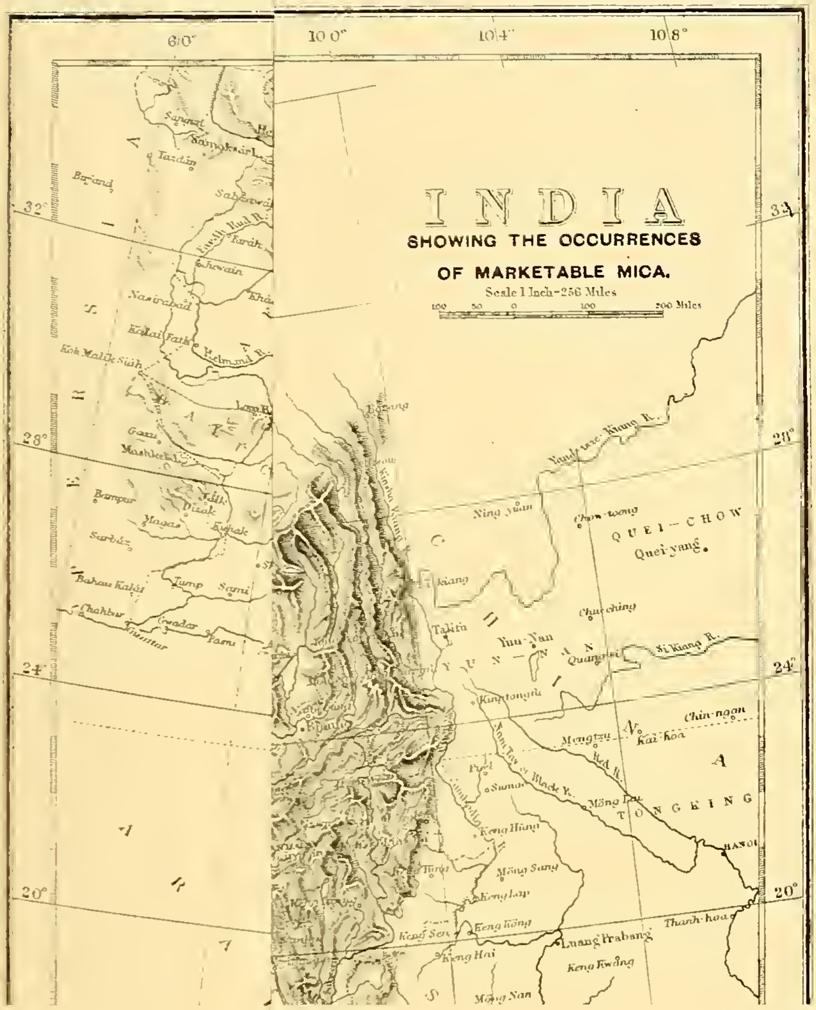
CRYSTAL OF MUSCOVITE,

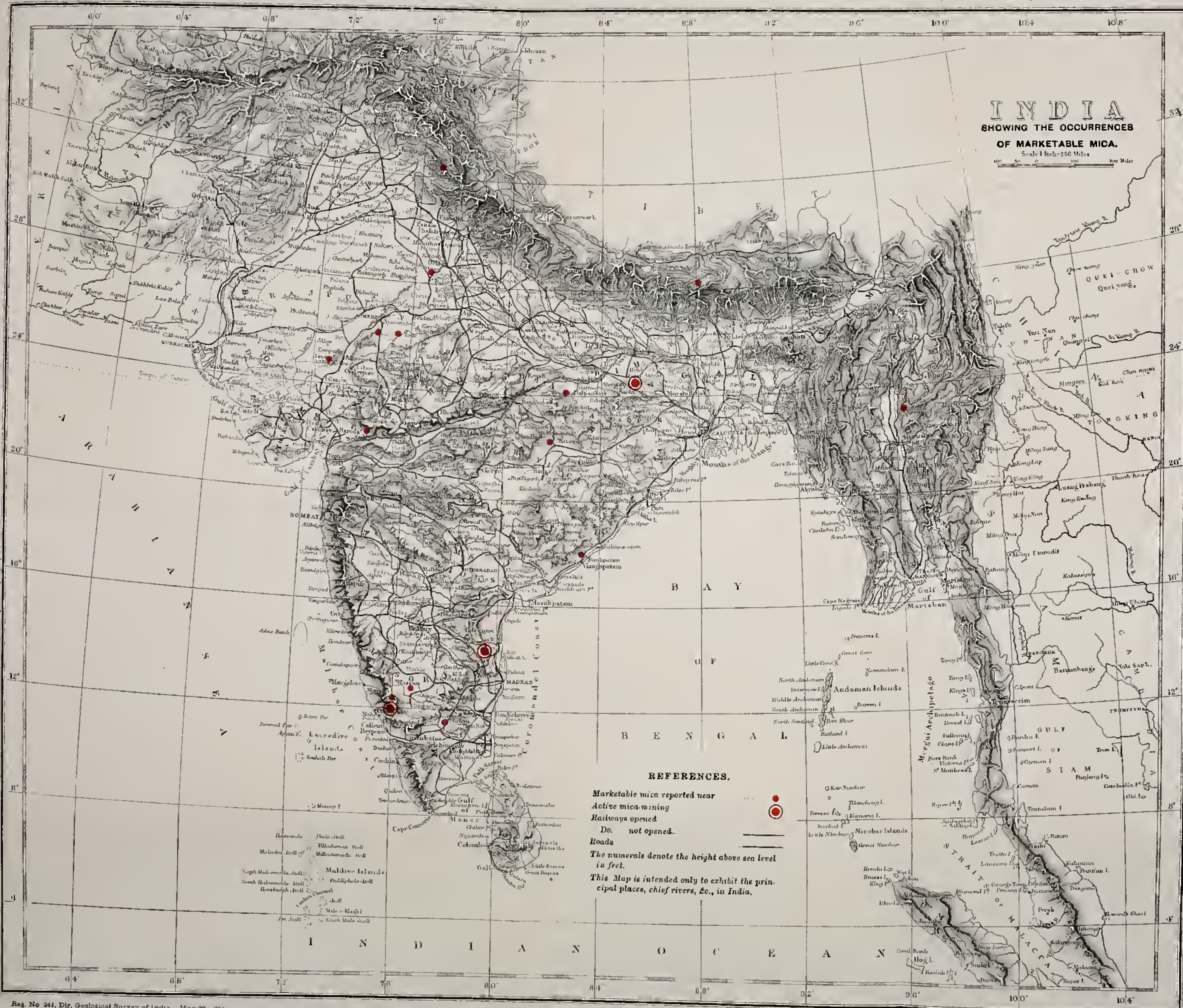
showing the symmetrical disposition of the optic axial plane, percussion-figure and natural pressure-figure.

Turpunpandla, Nellore district.

(Natural Size)

T. H. Holland moir, Vol. XXXIV, Pt. 2. Plate VIII.





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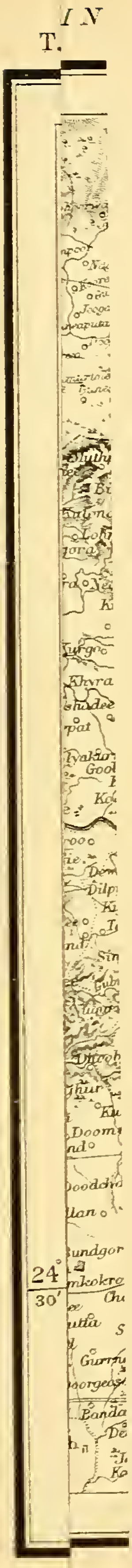
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Map
OF THE
BENGAL MICA MINING BELT
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MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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VOL. XXXIV, PART 1.

ON A PECULIAR FORM OF ALTERED PERIDOTITE IN THE MYSORE STATE, *by* THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Officiating Superintendent, Geological Survey of India.*

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I.—INTRODUCTION.

Attention has been frequently called to the peculiar nature of the secondary alteration exhibited by peridotites at various points in South India.[1]

The commonest instances of these peridotite exposures consist largely of dunites seamed with veins of magnesite, which vary in thickness from a few feet across to microscopic infillings of fissures, cutting through the olivine-rock in all directions, and accompanied sometimes by chalcedonic quartz and picrolite. As the result of weather denudation, these veins of magnesite stand out as ribs, and give the surface of the exposures a peculiar rough surface, made the more noticeable by the general absence of vegetation which characterises such areas, and for which of course such highly magnesian rocks, devoid practically of the common elements of plant-food, give rise to an unsuitable soil. Numerous, dazzling-white masses of

[1] Holland: "The comparative actions of subaërial and submarine agents in rock decomposition." *Rept. Brit. Assoc.*, 1898, p. 868; *Geol. Mag.*, Jan. 1899, p. 30. "A contribution to the discussion on rock-weathering and serpentinization." *Geol. Mag.*, December 1899, p. 540. "On the geology of the neighbourhood of Salem." *Mem. Geol. Surv. Ind.*, Vol. XXX, pt. 2

magnesite are constant characteristics of these peculiar exposures in South India, and have given rise to the name "Chalk Hills," applied locally to the best known occurrence near the town of Salem.

Whilst with a committee appointed to report in 1898 on the Marikanave irrigation project in the Mysore State, the writer met with the peculiar form of magnesian rock described in this note. The rock is, so far as known, unique, and only this occurrence of it has hitherto been recorded in South India.

Its exposure at Huliyar in the Mysore State is a mere hummock rising above the cultivated soil, which conceals its relationship to the crystalline schists around; but it is presumably part of a peridotite intrusion, differing from the many others known in South India by the peculiar form of alteration it has undergone. Like other peridotite intrusions in the same area, it is accompanied by masses of white quartz enclosing numerous cavities filled with carbonic acid, to which the writer has previously attributed the common formation of secondary magnesite in these peridotites.

The writer is very much indebted to Babu Baidya Nath Shaha, M.A., a former pupil in the Presidency College, for material assistance in the chemical work and for making the specific gravity determinations.

II.—PETROLOGICAL CHARACTERS.

It has already been stated that the magnesite is usually distributed as white veins through the altered peridotite. But in the present instance, the ferro-magnesian carbonate, which proves to be breunnerite, occurs as dark-grey, well crystallized, porphyritic crystals, measuring from half an inch to an inch across, lying in a dark-greenish-grey, fine-grained matrix of talc and picrolite. The rock has a most deceptive appearance in the field and in hand-specimens, and those who have handled the specimens have invariably been surprised when told the true nature of the porphyritic crystals and of the matrix. The iron-staining on weathered surfaces give the porphyritic crystals the appearance of pyroxenic or hornblendic crystals, and the greenish-grey matrix, being a good imitation of the diabase type of rock, completes the deception.

Although each phenocryst is shown in section and by cleavage to be a single large crystal, its outline is seen in microscopic section to be ragged and irregular where it abuts against the matrix. Magnetite, in the form of minute granules, or as dust gathered into patches and short bands, occurs in the breunnerite phenocrysts as well as in the matrix. Occasional shreds of talc and picrolite occur also as inclusions in the breunnerite.

The matrix consists of interlaced colourless talc and pale-green picrolite, together with numerous granules of rhombohedral carbonate, the magnetite-dust referred to above (with an occasional lump showing crystal outlines), and a few granules of pyrite. Analysis shows the presence of chromium, but I have not been able to detect with certainty the mineral chromite in any of the thin sections.

The specific gravity of a large specimen of the rock was found to be 2·95, whilst that of the matrix was 2·845, and of the breunnerite phenocrysts, 3·168. The matrix and breunnerite are thus in the proportion of—

Breunnerite	35 per cent.
Matrix	65 " "

The Breunnerite phenocrysts.

The phenocrysts which have been referred to as breunnerite contain numerous inclusions of magnetite-dust, talc and picrolite, all of which can be distinguished from the pure mineral by chemical analysis.

A piece of the mineral, having a specific gravity of 3·168, was selected for analysis, and gave the following results :—

Insoluble residue	1·57
Lime	trace
Magnesia	39·20
Ferrous oxide	8·27
Ferric oxide	2·93
Carbonic acid	47·01
	98·98

This is equivalent to—

Talc and picrolite	1·6
Magnesium carbonate	82·7
Ferrous carbonate	11·3
Magnetite	4·4
	100·0

The molecular ratio of $MgCO_3$ to $FeCO_3$ is thus 10 : 1, which is the ratio existing in the variety of these mixed carbonates to which Haidinger in 1825 gave the name *breunnerite*.[1]

The Matrix.

For an examination of the matrix, fragments having a specific gravity of 2·853 were crushed and analysed, with the following results :—

Silica	42·20
Iron oxide (calculated as Fe_3O_4)[2]	13·59
Magnesia	30·41
Carbonic acid	5·30
Water	7·73
Sulphur	0·11
	99·34

[1] Mohs' Treatise on Mineralogy, 1825, I, p. 411.

[2] Distinct reactions were obtained for chromium ; but the quantity was not estimated.

Assuming the carbonic acid to be present in the form of breunnerite, the sulphur as pyrite and the remainder of the iron mostly as magnetite, we get the following mineral composition of the matrix :—

Breunnerite	10·5
Pyrite	0·2
Magnetite	10·0 (approx.)
Talc and serpentine . . .	79·3 („)
	100·00

Bulk composition.

Combining these two analyses—that of the matrix with that of the breunnerite phenocrysts—in proper proportion, we obtain a bulk analysis for the rock of—

Silica	27·3
Iron oxide (Fe_3O_4) . . .	12·7
Magnesia	35·0
Carbonic acid	20·0
Water	5·0
	100·0

Assuming the rock to be the result of the alteration of an olivine (dunite) magma, on which carbonic acid and water have acted, we can, by the removal of these compounds, calculate the approximate proportions of the three main constituents of the dunite magma. Thus, removing the carbonic acid and water and calculating to 100, we obtain :—

Silica	36·4
Iron oxide (Fe_3O_4) . . .	16·9
Magnesia	46·7
	100·0

III.—ORIGIN OF THE ROCK.

The supposed composition of the magma, estimated by removing the carbonic acid and water from the bulk analysis of the rock, is sufficiently near that of a fresh dunite to render it highly probable that such was the original nature of the magma. The presence of chromium and absence of lime and alkalies are also in agreement with this idea.

In other areas in South India, where magnesite veins are abundant, we have direct evidence of their formation by the alteration of olivine-rock. Picrolite and talc are also found as secondary minerals in such areas; but, as previously pointed out, there is no general serpentinous alteration of the olivine-rocks.[1]

In the present instance, no unaltered relic of olivine-rock has been preserved, and but for the previous knowledge of such instances as the "Chalk Hills" near Salem, it is highly likely that one would not have suspected such a rock as that described in this note to be a direct product of the alteration of a dunite.

In the common case known to us in South India the magnesite is distributed along veins, which vary from microscopic infillings of the irregular cracks in an olivine crystal to thick veins a foot or two across. These have been referred to the action of carbonic acid from deep-seated sources attacking the olivine, and such action may have occurred at any time after the solidification of the rock. But the present instance is different and indicates a greater intimacy between the carbonic acid, water and olivine-rock magma; for the breunnerite crystals have grown outwards in the matrix in a way which indicates a certain degree of free molecular translation. One at first considers the possibility of the magma containing sufficient carbonic acid and water imprisoned so as to give rise in direct combination with the dunite material to a primary formation of these carbonates and hydrous magnesian silicates. Unfortunately

[1] Holland: Geology of the neighbourhood of Salem—the Magnesian Series of the "Chalk Hills." *Mem., Geol. Surv., Ind.*, XXX, p. 133.

for this idea the breunnerite contains shadowy bands of magnetite-dust distributed irregularly, suggesting its formation by excretion from a previously existing ferriferous mineral like olivine. These bands of magnetite-dust pass sometimes across the borders of the breunnerite crystals into the matrix as if both had been formed during the decomposition of the original ferro-magnesian mineral. Had the breunnerite been of primary origin we should expect to find the inclusions zoned, or at least to be distinct from the matrix.

It seems likely, therefore, that this rock has resulted from the alteration of a ferro-magnesian silicate rock near dunite, that the alteration was effected under conditions which permitted one of the products, breunnerite, to grow freely from definite crystal-centres, excluding the silica liberated during the process to form picrolite, and with the excess forming the more acid silicate, talc. Talcose masses are not uncommonly found in other magnesite areas in South India, but as a rule the silica liberated during the alteration of the olivine-rock to magnesite is separated in the form of a chalcedony or quartz.

In the remarkable instance under description, if the analyses are sufficiently representative, we have had a complete metamorphosis of the original rock to form a mineral aggregate which can be regarded as olivine-rock *plus* carbonic acid and water. The whole of the products have been retained within the rock-body to form new minerals instead of being separated as vein material or as special local concretions. The action must have occurred under conditions, as already stated, permitting a free translation of the molecules, and but for the evidence of the magnetite dust-bands, one would naturally imagine that the whole of these changes occurred during, and not subsequent to, the consolidation of the rock. Such an idea involves no greater theoretical difficulties than the idea of secondary alteration of an already-formed olivine-rock by the action of carbonic acid and water.

The use of the term secondary when applied to rock alteration is but relative. The minerals of early consolidation may be attacked and altered soon after their formation by the vapours originally included in the magma and excluded to the mother-liquor, or they may become attacked at a distinct and subsequent period. In the former case the processes of primary crystallization and secondary alteration are continuous and in reality phases of the same process. This explanation is not difficult to accept when the alteration is very limited in extent, as for instance, when the aqueo-igneous mother-liquor in a diabase-magma attacks the early-formed augite and changes it into biotite with concomitant excretion of magnetite.[1]

The extension of this idea to a complete alteration of the whole rock is a step one naturally hesitates to take, and, on account of the absence of recognisable stages in the process, one which is less easily proved. It is in this case, nevertheless, an explanation more satisfactory than either of the two alternative theories, namely, (*a*) primary consolidation of a dunite magma containing water and carbonic acid, or (*b*) alteration of a dunite after its consolidation by the secondary action of water and carbonic acid.

There is no doubt that the action of vapours originally contained in a magma has often been overlooked, and minerals like the zeolites epidote and serpentine have been thoughtlessly referred to secondary and independent processes such as weathering. We hope we are not now exaggerating the importance of these vapours in going to the other extreme and regarding the remarkable rock described above as the result of the complete alteration of the dunite by the vapours contained in its own magma. There is but a step from this conclusion to the idea of primary consolidation of an aqueo-igneous dunite magma charged with carbonic acid. For this last step, however, there is at present no direct support. To take it would involve the recognition of the water and carbonic acid as essential constituents and necessitate the distinçtion of the rock as a new type in the category of igneous species. Had the alteration taken place as a distinctly-

[1] *Cf.* Holland : *Quart. Journ. Geol. Soc.*, Vol. 53 (1897), p. 405 ; *Geol. Mag.*, December 1899, p. 543.

secondary phenomenon after the consolidation of the peridotite, we should not expect to find such a homogeneous result, but would, on the contrary probably find a certain amount of segregation of the products into veins, and stages in the alteration processes. Had the rock, on the contrary, crystallized in its present form as a primary rock, we should not expect the magnetite-dust to be distributed as bands through the breunnerite and the matrix alike, suggesting its excretion during the alteration of a previously existing ferro-magnesian silicate. The true explanation is probably somewhere between these two extremes, and the homogeneity of the resulting rock-mass is probably due to the fact that the water and carbonic acid which effected the change were originally included in, and uniformly distributed in sufficient quantity through, the magma.

The kind of alteration by which a simple dunite has been changed into this breunnerite-picrolite-talc rock would not be correctly described as secondary. The consolidation of the rock and its alteration were, if the phenomena have been correctly read, continuous, and are thus related to one another in a way similar to that by which a granite mass and its contemporaneous veins are formed—a series of phenomena in which a definite succession is essential, but which are all parts of one geological effort, and in that sense "contemporaneous." It is thus important to distinguish between "primary" or "contemporaneous" alteration, due to the action of vapours originally contained in the magma, and the "secondary" changes induced subsequently and unconnected with the processes of consolidation.

Part 3.—Note on the progress of the gold industry in Wynaad, Nilgiri district. Notes on the representatives of the Upper Gondwana series in Trichinopoly and Nellore-Kistna districts. Senarmontite from Sarawak.

Part 4.—On the geographical distribution of fossil organisms in India. Submerged forest on Bombay Island.

Vol. XII, 1879.

Part 1.—Annual report for 1878. Geology of Kashmir (third notice). Further notices of Siwalik mammalia. Notes on some Siwalik birds. Notes of a tour through Hangrang and Spiti. On a recent mud eruption in Ramri Island (Arakan). On Braunite, with Rhodonite, from near Nagpur, Central Provinces. Palæontological notes from the Satpura coal-basin. Statistics of coal importations into India.

Part 2.—On the Mohpani coal-field. On Pyrolusite with Psilomelane occurring at Gosalpur, Jabalpur district. A geological reconnaissance from the Indus at Kushalgarh to the Kurram at Thal on the Afghan frontier. Further notes on the geology of the Upper Punjab.

Part 3.—On the geological features of the northern part of Madura district, the Pudukota State, and the southern parts of the Tanjore and Trichinopoly districts included within the limits of sheet 80 of the Indian Atlas. Rough notes on the cretaceous fossils from Trichinopoly district, collected in 1877-78. Notes on the genus Sphenophyllum and other Equisetaceæ, with reference to the Indian form Trizygia Speciosa, Royle (Sphenophyllum Trizygia, Ung.). On Mysorin and Atacamite from the Nellore district. On corundum from the Khasi Hills. On the Joga neighbourhood and old mines on the Nerbudda.

Part 4.—On the 'Attock Slates' and their probable geological position. On a marginal bone of an undescribed tortoise, from the Upper Siwaliks, near Nila, in the Potwar, Punjab. Sketch of the geology of North Arcot district. On the continuation of the road section from Murree to Abbottabad.

Vol. XIII, 1880.

Part 1.—Annual report for 1879. Additional notes on the geology of the Upper Godavari basin in the neighbourhood of Sironcha. Geology of Ladak and neighbouring districts, being fourth notice of geology of Kashmir and neighbouring territories. Teeth of fossil fishes from Ramri Island and the Punjab. Note on the fossil genera Nöggerathia, Stbg., Nöggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia, and Australia. Notes on fossil plants from Kattywar, Shekh Budin, and Sirgujah. On volcanic foci of eruption in the Konkan.

Part 2.—Geological notes. Palæontological notes on the lower trias of the Himalayas. On the artesian wells at Pondicherry, and the possibility of finding such sources of water-supply at Madras.

Part 3.—The Kumaun lakes. On the discovery of a celt of palæolithic type in the Punjab. Palæontological notes from the Karharbari and South Rewah coal-fields. Further notes on the correlation of the Gondwana flora with other floras. Additional note on the artesian wells at Pondicherry. Salt in Rajputana. Record of gas and mud eruptions on the Arakan coast on 12th March 1879 and in June 1843.

Part 4.—On some pleistocene deposits of the Northern Punjab, and the evidence they afford of an extreme climate during a portion of that period. Useful minerals of the Arvali region. Further notes on the correlation of the Gondwana flora with that of the Australian coal-bearing system. Note on reh or alkali soils and saline well waters. The reh soils of Upper India. Note on the Naini Tal landslip, 18th September 1880.

Vol. XIV, 1881.

Part 1.—Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts, being fifth notice of the geology of Kashmir and neighbouring territories. Note on some Siwalik carnivora. The Siwalik group of the Sub-Himalayan region. On the South Rewah Gondwana basin. On the ferruginous beds associated with the basaltic rocks of north-eastern Ulster, in relation to Indian laterite. On some Rajmahal plants. Travelled blocks of the Punjab. Appendix to 'Palæontological notes on the lower trias of the Himalayas.' On some mammalian fossils from Perim Island, in the collection of the Bombay Branch of the Royal Asiatic Society.

Part 2.—The Nahan-Siwalik unconformity in the North-western Himalaya. On some Gondwana vertebrates. On the ossiferous beds of Hundes in Tibet. Notes on mining records, and the mining record office of Great Britain; and the Coal and Metalliferous Mines Acts of 1872 (England). On cobaltite and danaite from the Khetri mines, Rajputana; with some remarks on Jaipurite (Syepoorite). On the occurrence of zinc ore (Smithsonite and Blende) with barytes, in the Karnul district, Madras. Notice of a mud eruption in the island of Cheduba.

Part 3.—Artesian borings in India. On oligoclase granite at Wangtu on the Sutlej, North-west Himalayas. On a fish-palate from the Siwaliks. Palæontological notes from the Hazaribagh and Lohardagga districts. Undescribed fossil carnivora from the Siwalik hills in the collection of the British Museum.

Part 4.—Remarks on the unification of geological nomenclature and cartography. On the geology of the Arvali region, central and eastern. On a specimen of native antimony obtained at Pulo Obin, near Singapore. On Turgite from the neighbourhood of Juggiapett, Kistnah district, and on zinc carbonate from Karnul, Madras. Note on the section from Dalhousie to Pangi, *viâ* the Sach Pass. On the South Rewah Gondwana basin. Submerged forest on Bombay Island.

Vol. XV, 1882.

Part 1.—Annual report for 1881. Geology of North-west Kashmir and Khagan (being sixth notice of geology of Kashmir and neighbouring territories). On some Gondwana labyrinthodonts. On some Siwalik and Jamna mammals. The geology of Dalhousie, North-west Himalaya. On remains of palm leaves from the (tertiary) Murree and Kasauli beds in India. On Iridosmine from the Noa-Dibing river, Upper Assam, and on Platinum from Chutia Nagpur. On (1) a copper mine lately opened near Yongri hill, in the Darjiling district; (2) arsenical pyrites in the same neighbourhood; (3) kaolin at Darjiling (being 3rd appendix to a report on the geology and mineral resources of the Darjiling district and the Western Duars). Analyses of coal and fire-clay from the Makum coal-field, Upper Assam. Experiments on the coal of Pind Dadun Khan, Salt-range, with reference to the production of gas, made April 29th, 1881. Report on the proceedings and result of the International Geological Congress of Bologna.

Part 2.—General sketch of the geology of the Travancore State. The Warkilli beds and reported associated deposits at Quilon, in Travancore. Note on some Siwalik and Narbada fossils. On the Coal-bearing rocks of the valleys of the Upper Rer and the Mand rivers in Western Chutia Nagpur. On the Pench river coal-field in Chhindwara district, Central Provinces. On borings for coal at Engsein, British Burma. On sapphires recently discovered in the North-west Himalaya. Notice of a recent eruption from one of the mud volcanoes in Cheduba.

Part 3.—Note on the coal of Mach (Much) in the Bolan Pass, and of Sharag or Sharigh on the Harnai route between Sibi and Quetta. New faces observed on crystals of stilbite from the Western Ghâts, Bombay. On the traps of Darang and Mandi in the North-western Himalayas. Further note on the connexion between the Hazara and the Kashmir series. On the Umaria coal-field (South Rewah Gondwana basin). The Daranggiri coal-field, Garo Hills, Assam. On the outcrops of coal in the Myanoung division of the Henzada district.

Part 4.—On a traverse across some gold-fields of Mysore. Record of borings for coal at Beddadanol, Godavari district, in 1874. Note on the supposed occurrence of coal on the Kistna.

Vol. XVI, 1883.

Part 1.—Annual report for 1882. On the genus Richthofenia, Kays (Anomia Lawrenciana, Koninck). On the geology of South Travancore. On the geology of Chamba. On the basalts of Bombay.

Part 2.—Synopsis of the fossil vertebrata of India. On the Bijori Labyrinthodont. On a skull of Hippotherium antilopinum. On the iron ores, and subsidiary materials for the manufacture of iron, in the north-eastern part of the Jabalpur district. On laterite and other manganese ore occurring at Gosulpore, Jabalpur district. Further notes on the Umaria coal-field.

Part 3.—On the microscopic structure of some Dalhousie rocks. On the lavas of Aden. On the probable occurrence of Siwalik strata in China and Japan. On the occurrence of Mastodon angustidens in India. On a traverse between Almora and Mussooree made in October 1882. On the cretaceous coal-measures at Borsora, in the Khasia Hills, near Laour, in Sylhet.

Part 4.—Palæontological notes from the Daltonganj and Hutar coal-fields in Chota Nagpur. On the altered basalts of the Dalhousie region in the North-western Himalayas. On the microscopic structure of some Sub-Himalayan rocks of tertiary age. On the geology of Jaunsar and the Lower Himalayas. On a traverse through the Eastern Khasia, Jaintia, and North Cacbar Hills. On native lead from Maulmain and chromite from the Andaman Islands. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice.—Irrigation from wells in tbe North-Western Provinces and Oudh.

Vol. XVII, 1884.

Part 1.—Annual report for 1883. Considerations on the smooth-water anchorages or mud banks of Narrakal and Alleppy on the Travancore coast. Rough notes on Billa Surgam and other caves in the Kurnool district. On the geology of the Chuari and Sihunta parganas of Chamba. On the occurrence of the genus Lyttonia, Waagen, in the Kuling series of Kashmir.

Part 2.—Notes on the earthquake of 31st December 1881. On the microscopic structure of some Himalayan granites and gneissose granites. Report on the Choi coal exploration. On the re-discovery of certain localities for fossils in the Siwalik beds. On some of the mineral resources of the Andaman Islands in the neighbourhood of Port Blair. The intertrappean beds in the Deccan and tbe Laramie group in western North America.

Part 3.—On the miscroscopic structure of some Arvali rocks. Section along the Indus from the Peshawar Valley to the Salt-range. On the selection of sites for borings in the Raigarh-Hingir coal-field (first notice). Note on lignite near Raipore, Central Provinces. The Turquoise mines of Nishâpûr, Kborassan. Notice of a further fiery eruption from the Minbyin mud volcano of Cheduba Island, Arakan. Report on the Langrin coal-field, south-west Kbasia Hills. Additional notes on the Umaria coal-field.

Part 4.—On tbe Geology of part of the Gangasulan pargana of British Garhwal. On fragments of slates and schists imbedded in the gneissose granite and granite of the North-west Himalayas. On the geology of the Takht-i-Suleiman. On the smooth-water anchorages of the Travancore coast. On auriferous sands of the Subansiri river, Pondicherry lignite, and Pbosphatic rocks at Musuri. Work at the Billa Surgam caves.

Vol. XVIII, 1885.

Part 1.—Annual report for 1884. On the country between the Singareni coal-field and the Kistna river. Geological sketch of tbe country between the Singareni coal-field and Hyderabad. On coal and limestone in the Doigrung river, near Golaghat, Assam. Homotaxis, as illustrated from Indian formations. Afghan field-notes.

Part 2.—A fossiliferous series in the Lower Himalaya, Garhwal. On the probable age of the Mandhali series in the Lower Himalaya. On a second species of Siwalik camel (Camelus Antiqnus, nobis ex Fale. and Caut. MS.). On the Geology of Chamba. On the probability of obtaining water by means of artesian wells in the plains of Upper India. Further considerations upon artesian sources in the plains of Upper India. On the geology of the Aka Hills. On the alleged tendency of the Arakan mud vclcanoes to burst into eruption most frequently during the rains. Analyses of phosphatic nodules and rock from Mussooree.

Part 3.—On the Geology of the Andaman Islands. On a third species of Merycopotamus. Some observations on percolation as affected by current. Notice of the Pirthalla and Chandpur meteorites. Report on the oil-wells and coal in the Thayetmyo district, British Burma. On some antimony deposits in the Maulmain district. On the Kashmir earthquake of 30th May 1885. On the Bengal earthquake of 14th July 1885.

Part 4.—Geological work in the Chhattisgarh division of the Central Provinces. On the Bengal earthquake of July 14th, 1885. On tbe Kashmir earthquake of 30th May 1885. On the results of Mr. H. B. Foote's further excavations in the Billa Surgam caves. On the mineral hitherto known as Nepaulite. Notice of the Sabetmahet meteorite.

Vol. XIX, 1886.

Part 1.—Annual report for 1885. On the International Geological Congress of Berlin. On some Palæozoic Fossils recently collected by Dr. H. Warth, in the Olive group of the Salt-range. On the correlation of the Indian and Australian coal-bearing beds. Afghan and Persian Field notes. On the section from Simla to Wangtu, and on the petrological cbaracter of the Amphibolites and Quartz-Diorites of the Sutlej valley.

Part 2.—On the Geology of parts of Bellary and Anantapur districts. Geology of the Upper Dehing basin in the Singpho Hills. On the microscopic characters of some eruptive rocks from the Central Himalayas. Preliminary note on the Mammalia of the Karnul Caves. Memorandum on the prospects of finding coal in Western Rajputana. Note on the Olive Group of the Salt-range. On the discussion regarding the boulder-beds of the Salt-range. On the Gondwana Homotaxis.

Part 3.—Geological sketch of the Vizagapatam district, Madras. Preliminary note on the geology of Northern Jesalmer. On the microscopic structure of some specimens of the Malani rocks of the Arvali region. On the Malanjkhandi copper-ore in the Balaghat district, C. P.

Part 4.—On the occurrence of petroleum in India. On the petroleum exploration at Khátan. Boring exploration in the Chhattisgarh coal-fields. Field-notes from Afghanishtan: No. 3 Turkistan. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice of the Nammianthal aerolite. Analysis of gold dust from the Meza valley, Upper Burma.

Vol. XX, 1887.

Part 1.—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traverse through Jaunsar-Bawar and Tiri-G-arhwal. On the geology of the Garo Hills. On some Indian image-stones. On soundings recently taken off Barren Island and Narcondam. On a character of the Talchir boulder-beds. Analysis of Phosphatic Nodules from the Salt-range, Punjab.

Part 2.—The fossil vertebrata of India. On the Echinoidea of the cretaceous series of the Lower Narbada Valley, with remarks upon their geological age. Field-notes: No. 5—to accompany a geological sketch map of Afghanistan and North-eastern Khorassan. On the microscopic structure of some specimens of the Rajmahal and Deccan traps. On the Dolerite of the Chor. On the identity of the Olive series in the east with the speckled sandstone in the west of the Salt-range in the Punjab.

Part 3.—The retirement of Mr. Medlicott. Notice of J. B. Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section I. Preliminary sketch of the geology of Simla and Jutogh. Note on the 'Lalitpur' meteorite.

Part 4.—Note on some points in Himalayan geology. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section II. The iron industry of the western portion of the District of Raipur. Notes on Upper Burma. Boring exploration in the Chhattisgarh coal-fields. (Second notice.) Some remarks on Pressure Metamorphism with reference to the foliation of the Himalayan Gneissose-Granite. A list and index of papers on Himalayan Geology and Microscopic Petrology, published in the preceding volumes of the records of the Geological Survey of India.

Vol. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section III. The Birds'-nest or Elephant Island, Mergui Archipelago. Memorandum on the results of an exploration of Jessalmer, with a view to the discovery of coal. A facetted pebble from the boulder bed ('speckled sandstone') of Mount Chel in the Salt-range in the Punjab. Examination of nodular stones obtained by trawling off Colombo.

Part 2.—Award of the Wollaston Gold Medal, Geological Society of London, 1888. The Dharwar System, the chief auriferous rock series in South India. On the Igneous rocks of the districts of Raipur and Balaghat, Central Provinces. On the Sangar Marg and Mehowgale coal-fields, Kashmir.

Part 3.—The Manganese Iron and Manganese Ores of Jabalpur. 'The Carboniferous Glacial Period.' The sequence and correlation of the pre-tertiary sedimentary formations of the Simla region of the Lower Himalayas.

Part 4.—On Indian fossil vertebrates. On the geology of the North-west Himalayas. On blown-sand rock sculpture. Re-discovery of Nummulites in Zanskar. On some mica-traps from Barakar and Raniganj.

Vol. XXII, 1889.

Part 1.—Annual report for 1888. The Dharwar System, the chief auriferous rock-series in South India. (Second notice.) On the Wajra Karur diamonds, and on M. Chaper's alleged discovery of diamonds in pegmatite near that place. On the generic position of the so-called Plesiosaurus Indicus. On flexible sandstone or Itacolumite, with special reference to its nature and mode of occurrence in India, and the cause of its flexibility. On Siwalik and Narbada Chelonia.

Part 2.—Note on Indian Steatite. Distorted pebbles in the Siwalik conglomerate. 'The Carboniferous Glacial Period.' Notes on Dr. W. Waagen's 'Carboniferous Glacial Period.' On the oil-fields of Twingoung and Beme, Burma. The gypsum of the Nehal Nadi, Kumaun. On some of the materials for pottery obtainable in the neighbourhood of Jabalpur and of Umaria.

Part 3.—Abstract report on the coal outcrops in the Sharigh Valley, Baluchistan. On the discovery of Trilobites by Dr. H. Warth in the Neobolus beds of the Salt-range. Geological notes. On the Cberra Poonjee coal-field, in the Khasia Hills. On a Cobaltiferous Matt from Nepál. The President of the Geological Society of London on the International Geological Congress of 1888. Tin-mining in Mergui district.

Part 4.—On the land-tortoises of the Siwaliks. On the pelvis of a ruminant from the Siwaliks. Recent assays from the Sambhar Salt-Lake in Rajputana. The Manganiferous Iron and Manganese Ores of Jabalpur. On some Palagonite-bearing raps of the Rájmahál hills and Deccan. On tin-smelting in the Malay Peninsula. Provisional index of the local distribution of important minerals, miscellaneous minerals, gemstones, and quarry stones in the Indian Empire. Part 1.

Vol. XXIII, 1890.

Part 1.—Annual report for 1889. On the Lakadong coal-fields, Jaintia Hills. On the Pectoral and pelvic girdles and skull of the Indian Dicynodonts. On certain vertebrate remains from the Nagpur district (with description of a fish-skull). Crystalline and metamorphic rocks of the Lower Himalayas, Garhwál and Kumaun, Section IV. On the bivalves of tbe Olive-group, Salt-range. On the mud-banks of the Travancore coast.

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A NOTE ON THE SANDHILLS OF CLIFTON NEAR KARACHI, *by* R. D. OLDHAM, *Superintendent, Geological Survey of India*. (With 6 plates.)

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A NOTE ON THE SANDHILLS OF CLIFTON NEAR KARACHI, BY R. D. OLDHAM, *Superintendent, Geological Survey of India.* (With 6 plates.)

1.—INTRODUCTORY.

Between two and three miles from the town of Karachi, on a bluff looking over the sea, lies the suburb of Clifton. Here, in the hot weather, the inhabitants of Karachi find a cool and refreshing breeze blowing directly off the sea, and in the evening, when the sun sets behind the Manora Point and lights the quaintly shaped oyster rocks with its parting rays, the sunset effects are such as I have never seen surpassed and seldom equalled.

With these attractions it was at one time expected that Clifton would be the sanitarium, if not a suburb, of Karachi, and not a few houses have been built there. Of late years, however, the amenities of the place have been affected by an accumulation of sand on the sea face, and the growth of sandhills inland, which threaten to cut off all communication between Karachi and Clifton. In the following account it is proposed to give the result of observations made in October and December 1901 on the forms of the sandhills, as well as the results of an investigation into the cause of the accumulation of sand, and the source from which it is derived.

Previous to 1895 the approach to Clifton was by what is called the north approach road, that marked A. A. on the map, Plate IV. This crossed the hollow immediately behind Clifton by an embankment which, I am informed, was about 15 feet high. In 1895 sandhills first became conspicuously noticeable on the high ground and by 1898 this north

*

approach road was blocked by the advancing sand. The approach to Clifton then came to be by the east approach road and a cross road from it to the north approach road, marked B. B. on the map, but this too became blocked by sand, and in 1900 a new road was made, from the point where the cross road took off, leading direct to Clifton. This road is in no immediate danger of being blocked by sand, but the sandhills are already within 60 feet of the east road, and will certainly block it if left to themselves.

Meanwhile there had been an increase of land along the foreshore off Clifton, and between it and Karachi. A wooden pier, which runs down from the bluff at Clifton to the beach, had originally extended into the sea, but in 1891 it had to be lengthened by 400 feet, the then high-water mark being about 200 feet beyond the original extremity of the pier. In the ten years which have elapsed since the making of this extension, the foreshore has again advanced and the whole of the pier is dry at all stages of the tide, the sand has been heaped up till it is everywhere almost level with the plank flooring of the pier, and in places threatens to bury it, while the extreme limit of high tides now lies 50 feet to seaward of the outer end of the lengthened pier.

From this general account it will be seen that during the last 20 years there has been a steady and continuous accumulation of sand along the foreshore, and from this doubtless has been derived the sand which forms the sandhills behind Clifton. It is not easy to say whether there had been any considerable growth previous to this, but it must be recognised that what has taken place at Clifton is only part of what is taking place all along this coast; everywhere the action of waves and currents is smoothing the outline of the coast, in part by wearing away the headlands, but more largely by filling up the indentations and reducing the outline to a series of gently-rounded curves. As sand accumulates along the shore it is picked up by the winds and drifted inland to form sandhills on the land, and everywhere these sandhills are growing and extending inland.

The extension of sandhills at Clifton is, thus, only a part of a general phenomenon, not confined to that locality, but there still remains the question of whether the comparatively rapid extension, which has taken place in late years, is merely an incident in the normal course of affairs, or how far the works undertaken for the improvement of the harbour may have accelerated, or altered, the normal course of natural processes. For the solution of this question, which forms one of the principal objects of this memoir, it is necessary to commence with a consideration of the history of the Karachi harbour and the works undertaken for its improvement.

2.—The improvement of the Karachi harbour and its effect at Clifton.

The harbour of Karachi forms part of an extensive backwater which, at high tide, measures some 7 or 8 miles from NE. to SW. and about 4 miles in a direction transverse to this. It is shut off from the sea, firstly by a sand spit joining the land to the west with the rocky point of Manora, once doubtless an island; and secondly by the Keamari island, which appears to consist solely of sand, partly thrown up by the sea, partly blown up by the wind into sandhills. On either side of this island are the two original outlets of the harbour; the western, passing under Manora, being the principal one, while the eastern, known as the Chinna creek, between Keamari island and Clifton, was always a subsidiary one and is now completely closed.

Such was the condition of the harbour at the time of the conquest of Sind; this extensive backwater was filled and emptied at every tide and the channels formed by the scour had attained a certain amount of fixity, accompanied by frequent changes in detail, such as is found where the power developed by currents of water has been brought into equilibrium with the work to be done. The first of the works undertaken for the improvement of Karachi harbour was the connection of Keamari island, off which the deep-water anchorage lay, with the mainland by a continuous embankment, known as the Napier mole, which was completed in 1850. Before this mole was built ships had to lie off Keamari and unload into small boats, by which the cargo was brought up to Karachi at high tide, for the island of Keamari was only accessible at low tide by traversing a stretch of mud flats; the formation of embankment, the carrying a road across these mud flats, enabled cargo to be landed at Keamari, close to where the ships lay, and, at a later period, when jetties were built, to be landed without the intervention of boats or lighters.

Though increasing the convenience of the port, this continuous embankment cut off all the backwater to east of it, and so affected not only the force, but also the direction, of the currents of the tidal scour. The first effect of this was an immediate silting up of the deep-water anchorage off Keamari, but this effect was only temporary. After a while the currents adjusted themselves to the new state of affairs, and from 1854 to 1858 the channels became better defined, and the harbour improved, till it resumed a condition almost as good as before the building of the Napier mole.

Meanwhile another effect of this embankment was to increase the tidal scour through the eastern outlet of the harbour—that lying between the Keamari island and Clifton. All the water from the eastern backwater, which formerly flowed through the main entrance to the harbour, was now forced twice a day backwards and forwards through the subsidiary entrance. This entrance, consequently, scoured out, and a comparison of surveys made in 1856 and 1866 shows that the western side of this outlet was cut back 1,500 feet in the ten years, while the tidal scour from this creek kept the foreshore under Clifton comparatively free from sand.

Returning to the harbour proper, the further works carried out were a stone groyne running out from Keamari island, which was commenced in 1861 and completed in 1865, and a stone breakwater running out from the end of Manora Point, which was commenced in 1870 and completed in 1873. These works were intended to improve the navigability of the channel of access to the harbour and need not be considered here, as they do not directly affect the foreshore so far east as Clifton. In 1869, however, an opening was made in the Napier mole, which, with the subsequent developments of this new policy, had important results outside the harbour. In 1869, as has been said, an opening 175 feet wide was cut through the Napier mole, re-opening communication between the main harbour and the eastern breakwater;

in the following year this was supplemented by building a bank; rising 5 feet above low-water level, across the Chinna creek outlet; in 1871 this bank was raised to 6½ ft. above low water, and in 1873 the opening was completely closed and has remained so ever since. In the harbour the first effect of this was disappointing, for the currents of the tidal scour—which had attained a condition of equilibrium—were interfered with, and one of the first effects of the fresh scour set up was to form a deposit in the deep water of the harbour. But just as the currents soon worked out a fresh condition of comparative stability after the formation of the Napier mole, so the period of instability consequent on the opening of a passage through it soon passed away, the channels resumed a condition of equilibrium and the harbour experienced the effect of the increased tidal scour. At present the channels would be in a state of epuilibrium between force exerted and work to be done, and in a state of general stability accompanied by minor variations in detail, but for the fact that, as the channels so formed would not give sufficient accommodation, the harbour has to be kept open by continuous dredging, and the depth so maintained, being greater than that due to a condition of equilibrium, is constantly being reduced by silting up.

Outside the harbour the closing of the Chinna creek had the effect of putting an end to the tidal scour which had kept the Clifton foreshore free from sand, and a survey made in 1876[1] shows that all trace of the old tidal channel had been obliterated and the low-water mark bent round with an even curve in front of the old Chinna creek. Since then the foreshore has advanced, coming closer and closer to the final curve, along which the tidal and other currents will sweep the sand, neither eroding nor adding to the foreshore. At present the shore line lies nearly half a mile from the embankment across the Chinna creek and the backwater is separated from the sea by a tract of sanddunes, while the effect of the advance of the shore line is seen on either side, and extends—as has been mentioned—to beyond Clifton. The actual area which has been added to dry land cannot be

[1] See Plate V.

exactly estimated owing to the absence of recent surveys and the approximate nature of the older ones, but it is not far from 7,000,000 square feet, and this has without doubt formed the gathering ground, from which the material composing the sandhills has been derived.

Though this advance of the shore line is directly due to the closing of the Chinna creek, it must be clearly understood that there has been no interference with the natural course of events, beyond accelerating it. The constant easterly drift of sand along the coast would ultimately have closed the Chinna creek, and once this was closed the foreshore would have advanced in the same manner as it has done and will continue doing until it bends round in a regular and easy curve from the lee of Manora Point to the headland east of Clifton.

Besides the effect of closing the Chinna creek, the improvement of the harbour may have contributed to the growth of the sandhills in another way, and it is very generally believed in Karachi that their growth is largely, if not entirely, due to the practice of dropping the material dredged from the harbour in the neighbourhood of the oyster rocks, off Clifton. As will be shown, I do not think this factor one of great, if any, importance, but in view of the opinion being largely held, it is desirable to enquire how far the material of the sandhills may have been derived from the dredgings of the harbour.

For purposes of survey the Karachi Harbour is divided into seven sections as follows:—(1) Entrance; (2) Lower Harbour, sections 18 to 11; (3) Lower Harbour, sections 11 to 4, Eastern division; (4) Lower Harbour, sections 11 to 4, Western division; (5) Keamari anchorage; (6) New Channel, west of the Napier molé; (7) New Channel, east of the Napier mole. Of these the first five have been regularly surveyed each year since 1875, and the other two occasionally, and from these surveys are calculated the amount of natural scour and silt in each section and the results published, along with a return of the amount of dredging done, in the annual reports of the Port Trust. Summarising these returns I find that for the 25 years from 1875 to

1901 the totals are as follows, the quantities being expressed in millions of cubic feet:—

Section.	Scour.	Silt.	Dredging.
1	14·105	26·052	40·279
2	19·523	10·756	25·829
3	16·071	6·461	30·418
4	7·201	15·165	8·366
5	1·406	59·234	105·482
6	17·252	5·549	32·065
7	13·214	·750	......
TOTAL .	88·772	123·967	242·439

From this it appears that there has been a net enlargement of the capacity of the harbour of 207,244,000 cubic feet, and this represents the amount of material which has been removed from the harbour, and deposited somewhere outside.

If we now turn to the growth of land at Clifton, we find an increased area of about 7,000,000 square feet over which the deposit cannot be estimated at less than 15 feet on the average. There is also an area of about 1,750,000 square feet covered with sandhills, whose average depth may be taken as not less than 10 feet. These two together account for 122,500,000 cubic feet of material, and this estimate is a minimum one. To it must be added the deposit over some 4,000,000 square feet lying between the two areas, so that the accumulations at and near Clifton may be taken as amounting to, roughly, two-thirds of the total amount of material removed from the harbour, and to rather more than half of the amount of the dredgings which have been dumped in the sea off the Clifton shore.

At first sight this would seem to support the view of those who consider the growth of the sandhills to be entirely due to the dredging of the harbour, and this might be still further supported by the similarity between the material of which the dredgings are composed and that which forms the sandhills at Clifton. On a further examination of the question, however, this explanation falls. In the first place I have only estimated the material which has accumulated opposite and to the west of Clifton, and made no allowance for the great belt of sandhills east of Clifton or those which have been formed round Ghizri. If these were taken into consideration, it would be found that the amount of sand which has come ashore much exceeds what has been removed from the harbour of Karachi.

A second point is that, even if we assume that all the dredgings are washed ashore at Clifton, which is far from being the case, yet of the 207 millions of cubic feet removed from the harbour no less than 54 millions come from the entrance section, and this represents, practically in its entirety, material which has drifted round the Manora Point and of which quite half, as shown by the returns of silting in this section, has been merely helped on its way down the coast. If we add what may have drifted up the harbour with the tide, into the lower harbour, it becomes evident that quite one quarter of the material removed from the harbour is stuff which, in the natural state of affairs, would have drifted down the coast and reached the Clifton beach at most a few years later than it actually did.

From these considerations it is evident that the dredging has been quite a minor factor in the growth of the Clifton sandhills, for, if we may judge from the growth of land and shallowing of the sea to the eastward, it would seem that the amount of material removed from the Karachi harbour is quite insignificant in comparison with the amount of the natural drift along the coast. The effect of dredging the harbour and dropping the dredgings off Clifton may have slightly accelerated the growth of the sandhills, but if the Chinna creek had not been closed the foreshore would have been kept clear, and on the closing of this outlet it would have grown almost, if not quite, as rapidly as it has done.

So far, then, as the improvement of the harbour has affected Clifton, there is nothing which need be considered except this one work, but for it the dumping of dredgings off Clifton would have had no effect, with it the growth of foreshore and sandhill would at most have been a little slower had there been no dredging at all, or had the dredgings been carried further to sea.

3.—Distribution from a Growth of the Sandhills.

The stretch of land which has grown in front of the Clifton bluffs is the source from which the sand of the sandhills has been derived, but on it there are no conspicuous sandhills, though the surface is far from even. Each of the scattered shrubs and clumps of grass with which this area is dotted forms the nucleus of a small hillock of sand, but it appears to be only after the wind has travelled a certain distance over land that it is able to heap the sand into conspicuous and definite sandhills. Inland the sand has become heaped up against the high ground, and westward from the Clifton pier the bluff has become obliterated by the accumulation of sand. Behind the old bluff is a stretch of bare ground covered with small pebbles which have been heaped by the wind into ridges of an inch or so in height; on this stretch the finer-grained sand cannot come to rest, owing to the force of the wind, but inland of it scattered sandhills, separated by stony ground, commence. Behind the scattered sandhills comes the main mass of them, where the ground is completely covered by sand, while further east are more scattered sandhills.

Though the windward and leeward limits of the area covered by the sandhills behind Clifton resemble each other in the sandhills being smaller and more scattered than in the central area, they differ in the form of the sandhills. To leeward the sandhills dwindle in size, and the furthest of these are low round-topped heaps of sands, the incipient sandhills described further on. To windward this stage has been passed and the hills are all fully formed with well defined windward and leeward slopes.

Below the western end of Clifton the sand has banked up against the cliff, except where it has been removed artificially from in front of the sacred cave just east of the pier, and heaps of sand have accumulated behind the deserted houses on either side of the road. Still further east the sand has not yet banked against the cliff, but there is a high bank in front of the cliff, and separated from it by a hollow kept open by the scour of the wind along the face of the bluff. East of the termination of this bluff another series of sandhills stretches inland between New Clifton and Ghizri.

Such is the present distribution of the sandhills, and it appears inevitable that, in the absence of preventive measures, Clifton itself will become overwhelmed with sand, and the cliff on which it stands lost in a maze of sandhills. This fate can doubtless be prevented, but it seems doubtful whether it can be done except at a prohibitive cost and by spoiling those amenities which alone make its prevention desirable.

The sandhills of Clifton are of that crescentic form known to textbooks as burkhans or barchanes, and occur scattered, and separated from each other, near the boundaries of the area, but grouped together and coalesced in the central position. Though of the typical form found throughout the world, when loose sands are exposed to steady winds, I noticed one divergence from the ordinary diagrammatic representations of this type of sandhills. The usual diagrammatic representation of a burkhan is that shown in fig. 1, taken from a paper by Dr. Vaughan Cornish, in which he collates the

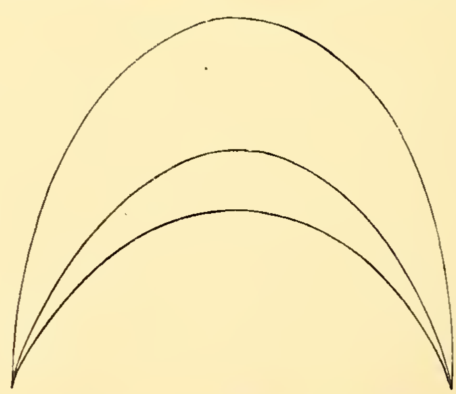

Fig. 1.—Diagram plan of barchane, after Vaughan Cornish.

accounts of sandhills known to him, and this representation is the more valuable from the present point of view in that it is not the result of independent observation, but of the impression left on the author's mind after a study of the descriptions of several observers.

In this diagram it will be seen that the cusps are represented as sharp pointed at their extremities, and the steep lee slope extends right up to the end of the cusp. When I first saw the Clifton sandhills, in October 1901, the easterly winds had not set in, and the sandhills retained the form that had been impressed on them by a long period of west-south-westerly winds, and this form was that represented in fig. 2, which is from an actual survey of a pair of isolated

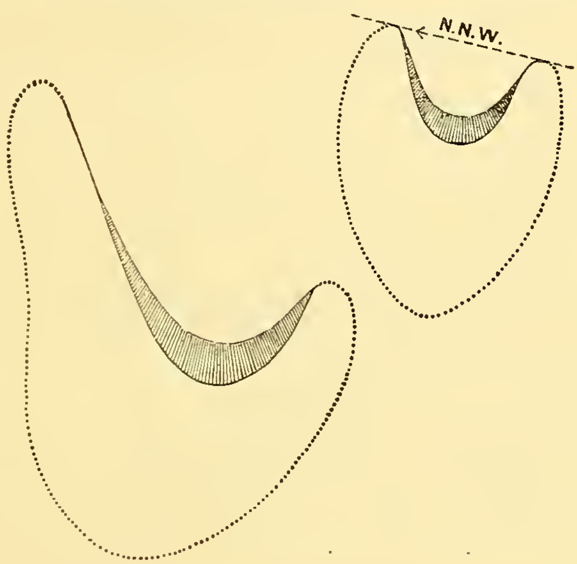

FIG. 2.—Plan of two sandhills near Clifton.

sandhills made in December. The sandhills had then been slightly modified by east-north-easterly winds, but not to any important extent, and the main features, especially the rounded outlines of the cusps and the restriction of the steep lee slope to the central portion of the sandhill, could easily be restored to what had been noted in October, when the opportunity of making a survey failed. If any confirmation were required of this statement it is to be found in the delineation of

Central Asian sandhills by v. Middendorff,[1] who first brought the term burkhan into geological literature; his figures are reproduced in Plate II, and it will be seen that he distinctly gives a rounded outline to the extremities of the cusps and shows them as dying out with a gentle slope in every direction.

The distinction is not merely an unessential refinement of detail, but has an important bearing on the theory of the cause of the crescentic form adopted by this type of sandhill. This is usually said to be due to the wings travelling faster than the central portion of the dune, on account of their lesser height and the consequently smaller amount of sand which has to be transported, but the explanation is only partial, and leaves much unexplained, especially the primary question of why one part of the dune should be higher than another.

The growth of the sandhills from their earliest beginnings to the typical barchane can be studied at Clifton. In the first instance a broad low patch of sand forms on the stony surface, six to ten feet in its longer diameter, which lies in the direction of the wind, and not much more than as many inches in thickness at the centre, from which the sand thins out on all sides and finally gives way to the ordinary stony surface without any well-defined margin. These patches of sand do not appear to owe their origin to any local obstacle, they lie to leeward, but not necessarily directly to leeward, of the fully formed sandhills and evidently owe their origin to an upward bend of the air currents, as indicated in fig. 3, by which a space of comparative calm is formed. In this space the sand, drifting along the surface by the

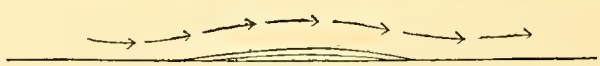

FIG. 3.—Longitudinal section of an incipient sandhill.

wind, comes to rest; in the earlier stages the supply of sand is sufficient to completely fill the space and its surface, following the stream lines of the air currents, has a smooth, gently-rounded outline from one end to the other.

The heap of sand, once formed, helps to accentuate the upward

[1] A. v. Middendorff: Mem. Acad. Imp. Sci. St. Petersbourg, XXIX, 29 (1881).

curve of the wind and grows both horizontally and vertically, as indicated in fig. 4, but as it grows the space to be filled by sand increases, till the supply drifted by the wind no longer suffices to fill the void, and, after drifting along and covering the windward

FIG. 4.—Longitudinal section of a sandhill further advanced in growth.

part of the sandhill, it forms a slope to leeward, down which the sand grains fall. In the hollow so produced an eddy of the wind is formed, which helps to keep the hollow open, and, as the sandhill grows in height, this eddy increases in force.

As the sandhill grows in height the volume of the space to be filled by sand increases, and in an increasing ratio; consequently the proportion of what may be regarded as the unfilled space in the hollow, under the upward bend of the wind, to the filled up portion increases as the sandhill grows; for the supply of sand may

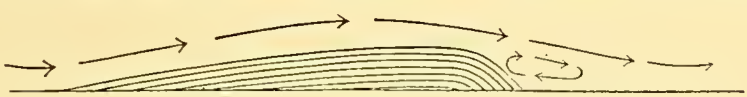

FIG. 5.—Longitudinal section of a fully developed sandhill.

be regarded as appreciably constant, the amount of space it will fill in a given time is constant, and the amount of unfilled space will vary from nothing in the incipient stage of the formation of the sandhill to quite one-third, on the central section, when the sandhill has reached a height of 10 or 12 feet and may be regarded as fully formed.

So far we have only considered the vertical section, along the direction of the wind and through the axis of the sandhill. We must now turn to what takes place on either side of this line. In the earliest stage the general form of the ground plan is shown in fig. 6.

FIG. 6.—Ground plan of incipient sandhill.

In the second stage a form like fig. 7 is attained, these ground plans being in both cases taken from actual sandhills seen near Clifton; here it will be seen that the generally oval outline is interrupted by a notch in the leeward end. At the centre of this notch, where the line drawn in the direction of the wind covers the highest point of the

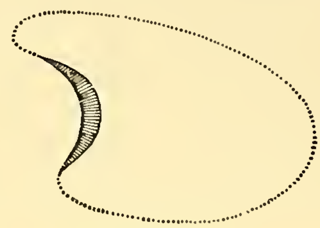

Fig. 7.—Ground plan of sandhill further advanced in growth.

sandheap, the section resembles that indicated in fig. 4, but on either side of this line the height of the heap grows gradually less, and the section approximates more and more to fig. 3, till finally we find the sand thinning off gradually to leeward as well as to windward. From one point of view the sandhill in this stage may be regarded as an imperfect form of a complete sandheap of oval outline, the imperfection being due to a lack of material; but this is only an incomplete statement of the case, as the notch, after its first establishment, is by no means solely due to a deficiency of material, but in part to a prolongation of the horns on either side of it.

At its commencement the notch in the leeward end of the sandheap appears to be due simply to a failure of material, sufficient in amount to fill in the whole of the space under the upcurving wind currents, but, once established, the effect of the eddy set up in it has to be reckoned with. This not only keeps the space within the notch clear, but appears to cause, or at any rate to assist in causing, an upward bend in the wind currents on either side, leading to the deposit of sand on either side in the same manner as the original accumulation, but further down wind. As the sandheap grows in size, and spreads laterally, there is doubtless some scouring out of the notch by the eddy set up in it, but apart from this, the horns continue to grow outwards and down wind, in a direction usually oblique to its direction, the obliquity being due not to a diversion of the direction of the wind, as assumed by v. Middendorff,[1] but to the fact that the upward diversion of the wind currents takes place more and more down wind than in the centre of the sandhill.

The growth of the horns on either side of the notch is seldom, if ever, symmetrical, one is longer than the other and occasionally one end of the sandhill gives origin to a long ridge of sand extending down wind and practically in the same direction as it. These long ridges seem to have much in common with the longitudinal sandhills, so conspicuously developed in the desert of Sind and Rajputana, but the scale of the two is so different that their origin is probably also different. Where one of the horns of the sandhill is extended in this manner the side slopes are steeper than those of the horns of normal proportion and usually markedly steeper on the inner side.

The manner in which the sandhills change their form under a change of wind is worthy of note. The principal winds seem to blow from west-south-west and east-north-east, the former prevailing for the greater part of the year, and to them the principal features of the sandhills are due, while the latter blow during the winter months, and cause a reverse slope and bank of sand to be formed, seen near the summit of the long gentle slope which faces the west-south-west winds. The formation of this reverse slope is accompanied by a good deal of scour of the original steep leeward slope, though in no case that I saw was this sufficient to cause a complete reversal of the shape of the sandhill. This shape, as will be remembered, is typically crescentic, with the horns pointing down wind ; on the reversal of the wind these horns come to point up wind, and the principal vertical displacement of the wind-currents takes place further down wind than the minor vertical displacements on either side. This again appears to be an unstable condition, and a modification soon occurs. I am not able to say for certain whether the reverse concavity of the lee side of the new sand ridge cuts off part of the original concavity and a hollow is so left, or, as seems more probable, the hollow is

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[1] *Loc. cit.*

scoured out by a wind eddy; but whichever be the origin, there is usually a hollow formed on the crest of the sandhill, to leeward of the new lee slope, a hollow which grows by removal of sand by the eddy set up in it, and corresponds on a small scale to the *fuljes* of the Arabian desert.

This hollow is very well shown on the crest of the sandhill represented in Plate I, and this photograph also shows the manner in which a change of form of the sandhill takes place, when it is attacked by a wind from a fresh direction. The sandhill in question was first shaped by west-south-west winds, then a period of east-north-east winds caused a partial modification of form, heaping up the sand from that side and forming the steep slope facing to left of the picture. These winds ceased for a while, and the sandhill was attacked by a south-west wind which has commenced to re-shape it, but this re-shaping does not in the first instance take place by a general and uniform removal of sand, but by the formation of notches in the crest, in which the wind is concentrated and increased in force, setting up a violent scour and excavating deep pits to leeward. In the photograph can be seen the ribbing of the sides of these notches, caused by the sand slipping down the sides as the notch is deepened by the scour, and it will be noticed that the furthest of these notches has been nearly cut down to the foot of the steep slope; in it downward scour is nearly at an end, the effect of the wind will be to widen the notch, and, as it and its fellows increase in size, the violence of the rush of air through them will diminish, its effect become more regular, and instead of the greatest scour being in the notches it will be on the pinnacles left between them, which will be gradually lowered till the crest is reduced to a smoothly-rounded outline.

4.—Composition of the Sand.

The laboratory of the Geological Survey is not equipped with apparatus for the complete physical analysis of soils, so a substitute was used, in the shape of a series of sieves of 10, 24, 50, 70, and 100 meshes to the inch, through which samples of sands from Clifton, and dredgings from the harbour, were passed.

The results of the analysis are as follows. Three samples of dredgings, obtained from Mr. E. Jackson, M.I.C.E., Port Engineer, Karachi :—

		Dredgings.			
Samples		No. 1.	No. 2.	No. 3.	Mean.
Left on sieve No.	10	6·0	9·0	...	5·0
,,	24	3·5	8·5	...	4·0
,,	50	10·0	24·5	6·0	13·5
,,	70	27·0	38·5	46·5	37·3
,,	100	34·5	18·0	37·0	29·8
Passed through	100	19·0	1·5	10·5	10·4

No information accompanied these samples as to the portion of the harbour from which each was derived, but they were sent as fair samples of the material dredged from the harbour, and the mean of the three may be taken to represent approximately the average composition of the dredgings removed from the harbour.

As may be seen from the analysis, the three vary considerably in nature. That numbered 2 appears to be from the outer harbour; the coarser fragments are all pieces of shell, and fragments of shell form the greater part even of the finer sand; this, and the absence of fine silt, point to its being material which has travelled round the Manora Point and been washed into the harbour.

The sample No. 1 is not very dissimilar to No. 2, but the fragments of shell do not seem so large, and a proportion of the coarser-grained material is composed of cinder and coal, showing that this sample was obtained from within the harbour, where ships can anchor and coal.

Number 3 is of a totally different character to the other two: it is comparatively free from shell-sand and is composed for three-quarters of its bulk of fine sand. It must be remembered that in the process of dredging there is a tendency for the finest-grained clayey matter to be washed out to a great extent, but this dredging contains lumps of fine-grained silt, evidently forming part of the original bottom of the harbour in the state in which it was before being dredged. It seems clear that, while the first two samples consist largely of matter drifted into the harbour, sample No. 3 consists of part of the original bed of the harbour, whether of tertiary or recent age, which has been dredged out to a greater depth than that which had been formed by natural scour.

A sample of sand collected from the shore at Clifton, just above high-water mark, had the following constitution:—

Left on sieve No.	24	1·0 per cent.
,,	50	16·0 ,,
,,	70	33·0 ,,
,,	100	39·5 ,,
Passed through	100	10·5 ,,

The constitution of this sample is not unlike that of the dredgings Nos. 1 and 2, the differences being easily accounted for by local circumstances. The sample was collected from just above high-water mark, and consists of material which has been blown up from the shore by the wind; hence the absence of the larger fragments of shell, which remain on that part of the shore reached by the waves.

It is from this that the sand composing the sandhills behind Clifton is derived. Two samples, one taken from the windward slope, the other from the steep lee slope of the principal sandhill, gave the following composition:—

		Windward slope.	Lee slope.
Left on sieve No.	50	1·0	0
,,	70	26·0	8·5
,,	100	56·0	78·0
Passed through	100	17·0	13·5

The sorting effect of the wind is well seen here, all the coarser fragments have been left behind, and disappeared, and those grains which pass through a sieve of 70 meshes to the inch, but not through one of 100, amount to more than half of the whole bulk; this sorting effect has been carried still further in the material forming the lee slope, where grains of this size form over three-quarters of the whole bulk.

The sands, both of the shore and of the sandhills, are composed to a large extent of fragments of shell. In the case of the sand from the shore this was found to amount to 66·25 per cent., and in the case of the sand of the sandhills, to 53·5 per cent. of the total weight. The shell-sand, moreover, comprises all the coarser-grained material, as may be seen from the following analysis :—

		Shore.	Sandhill.
Soluble in acid = shell-sand		66·25	53·5
Left on sieve No.	50	2·75	...
"	70	7·25	3·5
"	100	17·50	32·0
Passed through	100	6·25	11·0
		100·00	100·0

A few grains of coal and cinder were left on the 24-mesh sieve in the case of the shore sand.

An examination of the sands under the microscope shows that while the grains of the shell-sand are almost all smoothed and polished, those of the insoluble residue consist, even in the case of the sandhills, of angular fragments of clear quartz, mixed with a small proportion of other minerals, principally a green hornblende and small flakes of mica.

A sample of the dredgings, made of an equal mixture of each, was also treated with acid, and lost 60 per cent. of its weight; the residue was then washed clear of clayey matter, which prevented its being satisfactorily sieved, and lost a further 4 per cent., after which the remainder was sieved, with the following result :—

Soluble in acid = shell-sand		60·0
Clay and very fine silt		4·0
Left on sieve No.	24	0·8
"	50	1·5
"	70	5·9
"	100	16·2
Passed through	100	11·6
		100·0

5.—POSSIBLE MEASURES OF AMELIORATION.

Having described the mode of occurrence, form, and composition of the sandhills, there remains for consideration the question of whether and how far their further growth may be prevented, and the amenities of Clifton kept available to the residents of Karachi.

As has already been explained, the ground from which the sand is derived is the stretch of land which has grown in front of the old cliffs at Clifton, and of the old entrance to the Chinna creek. This land has formed on account of the stoppage of the tidal scour through and out of this inlet, and there can be no doubt that the re-opening of the Chinna creek would soon lead to a re-establishment of the old shore line, and the stoppage, or at any rate great restriction, of the supply of sand which goes to form the inland sandhills. While affording relief to Clifton, I doubt if this would have any great permanent effect on the main harbour of Karachi, though it would doubtless cause a temporary deterioration as all previous interference with existing conditions has done. As already explained, this part of the harbour has to be maintained at a greater depth than that which natural scour would give, and the cutting off of that portion of the scour due to the closing of the Chinna creek would have very little permanent influence.

But if the diminution of the tidal scour would have little permanent effect on the main harbour, it would have great effect on the entrance channel, on that part of the harbour above the main harbour or Keamari anchorage, which is known as the upper harbour, and on the channel leading up to the native jetty. In these parts of the harbour every bit of tidal water is of importance, and the interests of the harbour so far outweigh those of the watering place that there is no chance of the Chinna creek being re-opened.

Apart from this, a certain relief will result from the practice, now adopted, of carrying the dredgings well out to sea before dropping them; but, as has been explained, the dredgings only account for a part of the Clifton sands, and the further growth of the fore-shore and sandhills will not be stopped, though it may be retarded.

As it is impossible to attack the sand at its source, the alternative remains of dealing with it on land, and this again divides itself into two branches, firstly, the fixing of the sanddunes already formed and preventing them from advancing over the road to Clifton, and secondly, the stoppage of the inland drift of sand which results in their growth in size and number.

The management of sanddunes has been a pressing question along a large part of the western coast of Europe, where the experience of centuries has resulted in a very perfect knowledge of the way to fix, to prevent, and where desirable to cause, the formation of sand-hills. The results of this experience have lately been summarised in an exhaustive treatise.[1]

To a large extent they are inapplicable to the climatic conditions of Karachi, or of any other part of India, as the final aim in all cases is the establishment of a continuous cover of vegetation of some kind or other, and the details both of plants used, and method of planting are only adapted to the special climatic conditions of Europe. In part, however—that part which deals with the preliminary fixing of the loose sands—the principles are of world-wide application, and may be as profitably employed in India as in Europe.

The principle underlying the operations is in all cases the same, whatever may be the variation in details of application; it is the setting up of obstacles which will break the force of the wind, and prevent scouring of the loose sand, while causing a deposit of that which is blown along, or near, the surface, by the wind. In regard to this, the effect of an obstacle varies very largely with its nature. A solid obstacle, such as a wall or plank fence, causes a certain check in the wind currents and sand is deposited in front of the wall, but not in its immediate vicinity. Here a strong eddy is formed and not only is no sand deposited, but there may even be scour, as indicated

Fig. 8.—Diagram to illustrate the effect of a solid impermeable obstacle.

in fig. 8, and it is only when the heap of sand in front of the wall gradually rises to a greater height than it that this hollow fills up, and the wall is completely buried in sand.

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[1] *Handbuch des deutschen Dünenbaues*, by Paul Gerhardt, Johannes Abromeit, Paul Bock, and Alfred Jentzsch: Published by order of the Prussian Ministry of Public Works: Berlin, 1900.

The effect of an isolated, flexible, permeable obstacle, such as a clump of grass, is different; here the resistance to the wind is much less, there is no heap formed in front, nor any great scour. On the other hand, the wind which filters through the grass stems has its velocity reduced and sand is deposited behind the grass clump; as shown in fig. 9:—

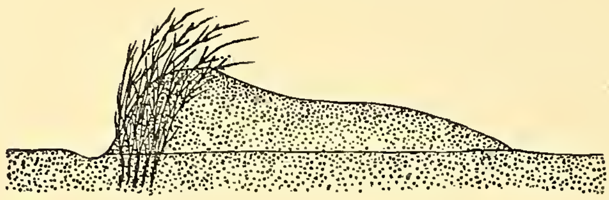


FIG. 9.—Diagram to illustrate the effect of a flexible permeable obstacle.

The effect of a rigid and permeable obstacle, such as an open fence, is a combination of the two; in front no eddy is formed, there is no scour, and the check in the velocity of the wind causes a deposit of sand both in front of and behind the obstacle as indicated in fig. 10:—

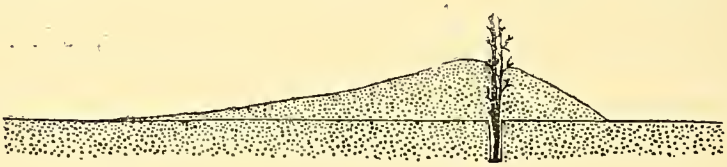


FIG. 10.—Diagram to illustrate the effect of a rigid permeable obstacle.

From a consideration of these three cases it will be seen that there is a certain degree of permeability of the open fence which will be most efficient, and it has been found that when the intention is to cause an accumulation of sand, this is best attained if the area blocked is about equal to that of the open spaces. The materials generally used are twigs and branches, as small as is compatible with sufficient strength to withstand the wind. Where the fence has a height of 4 feet or so a supporting framework is fixed to leeward of the twigs, as shown in fig. 11, but ordinarily

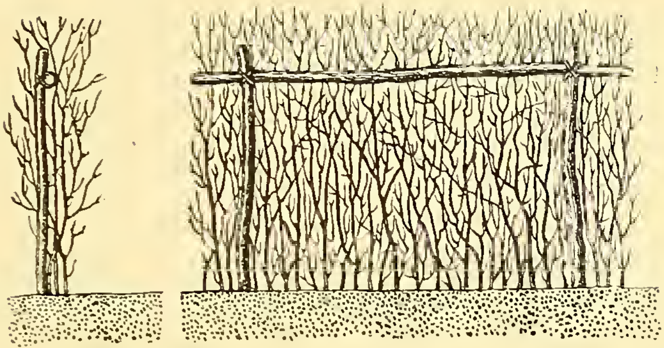


FIG. 11.—Diagram of fence intended to stop drift sand.

lower fences are used and this supporting framework is then omitted.

The mode of application, size, and distribution of the fences depends on the object to be attained. Where it is merely desired to fix loose moving sand, it has been found best to cover the surface with a network of low fences formed of twigs some 20 inches in length, of which about 8 inches are buried and 12 inches stand above ground. Planted in rows at right angles to each other and 4 yards apart, it is said that even strong winds will blow harmlessly over the loose sand.

This mode of protection is always applied to large areas, and the low fences arranged in straight lines, which are preferably arranged parallel and transverse to the direction of the prevailing wind, and it has been found that, on the coast of Prussia, 4 yards apart is sufficiently close; whether it would be sufficiently close in the case of the long-continued strong winds of Karachi may be doubted, and in any case it is necessary to place the fences closer on the steep sides of the dunes, which can be done, either by running diagonal fences across the squares, or by dividing them into smaller squares by halving the distance between the fences.

In the case of this protective fencing, when the object is not to cause an accumulation of sand but merely to stop its movement, the ratio of equality between solid twigs and interstices may be exceeded, and the spaces may be twice or even four times as much as the solid part of the fence, as in Plate III, fig. 2, which shows one of the applications of this method of protection. If, however, this method of fixing the sand were adopted at Clifton, the spacing would have to be closer, at any rate in the case of the sandhills near the road, where it is necessary not only to fix the sand already accumulated, but to catch the drifting sand which would otherwise form fresh sandhills further on.

The material used in Germany is usually pine twigs, from which the thinner parts have been cut away, but reeds are often used. These have not the strength of wood, but are used where it is only desired to fix the sand for a sufficient time to permit of a pine plantation establishing itself. They are cheaper than brushwood and have the advantage that, if sand accumulates, they are easily drawn up, and the fence re-established; owing to their greater weakness they must, however, be more closely planted than twigs. Plate III, fig. 1, shows fencing of this character formed of reeds.

The method of fixing loose sands has been described in some detail, as it may have a more extended application than merely to the Clifton sandhills, but it must be regarded merely as a means of fixing existing loose sand, not of preventing its accumulation; and even in this aspect it is, or should be, merely a temporary measure, to be followed as soon as possible by the planting of local grasses or other vegetation which will serve to permanently bind the sand.

The other object, of preventing the accession of sand, is attained by the building up of a continuous dam along the shore. The process is illustrated on Plate XII, taken from the same book as has been freely quoted above. The first step is the building of two parallel fences, of 28 and 36 inches in height, and a couple of yards apart. These fences are of the type represented in fig. 11, without the supporting framework if the material used is strong enough to enable it to be dispensed with. When sand has accumulated over these, another pair of fences is erected on the sand ridges, and when these have been buried the ridge is high enough and fixed enough to allow of grass being established on it. The grass having established itself, catches the drifting sand, and by degrees a broad sand ridge, with gently sloping sides, is built up. It would be possible to build up a sand ridge of this sort on the Clifton shore, which would prevent the inland drift of sand to a large extent, if not completely, but the ridge so formed would be an eyesore, and make Clifton no longer a desirable place of resort, and therefore would stultify the policy, and render useless the expense, of the works undertaken.

But if complete prevention is unattainable, or attainable only at the cost of what makes success undesirable, palliation is possible and inexpensive. Some attempts have been made at planting the sandhills in front of Clifton with a plant locally called goat's-foot creeper—*Ipomœa biloba.*, Forsk.,—but this is not the most suitable plant to use. It is an exotic and not a true desert plant, though almost one; in years of some rainfall it spreads rapidly over the surface of the ground, and I am informed that, up to three years ago, it spread over the sandy parts of Manora island and completely bound the sands there. During the last three years Karachi has had practically no rainfall and the creeper has died off the ground, leaving scattered root stocks which evidently preserve their vitality and are ready to sprout again when the climatic conditions become more favourable. Meanwhile the binding effect of the creeper has been lost, just when it would be most valuable.

Instead of incurring the expense of planting this exotic, a greater effect would be attained, at a less cost, by encouraging the growth of local grasses; these send out long suckers, which send down roots from every joint, and so bind the soil together. The effect of the grass is very visible on the new land at Clifton, for every clump of grass is the centre of a low hillock of sand, heaped up round it and retained by the binding action of its roots. In the past these grasses have been kept down by heavy grazing, but this has been stopped, the grass is now spreading, and if some of the water given to the goat's-foot creeper were devoted to these grass-clumps they would spread with greater rapidity than the creeper does, and more effectually bind the sand. Once a fairly continuous cover of grass was established on the sand, the greater part of the additions blown up from the shore would be stopped by it, the growth of the sandhills inland would be delayed, and, at a small expense, the amenities of Clifton preserved for many years to come.

Bemrose, Collo. Derby.

SANDHILL NEAR CLIFTON, SHOWING CHANGE OF FORM AND SCOUR BY WIND.

GROUND PLANS OF BURCHANS
(after v. Middendorf.)

Fig. 1.

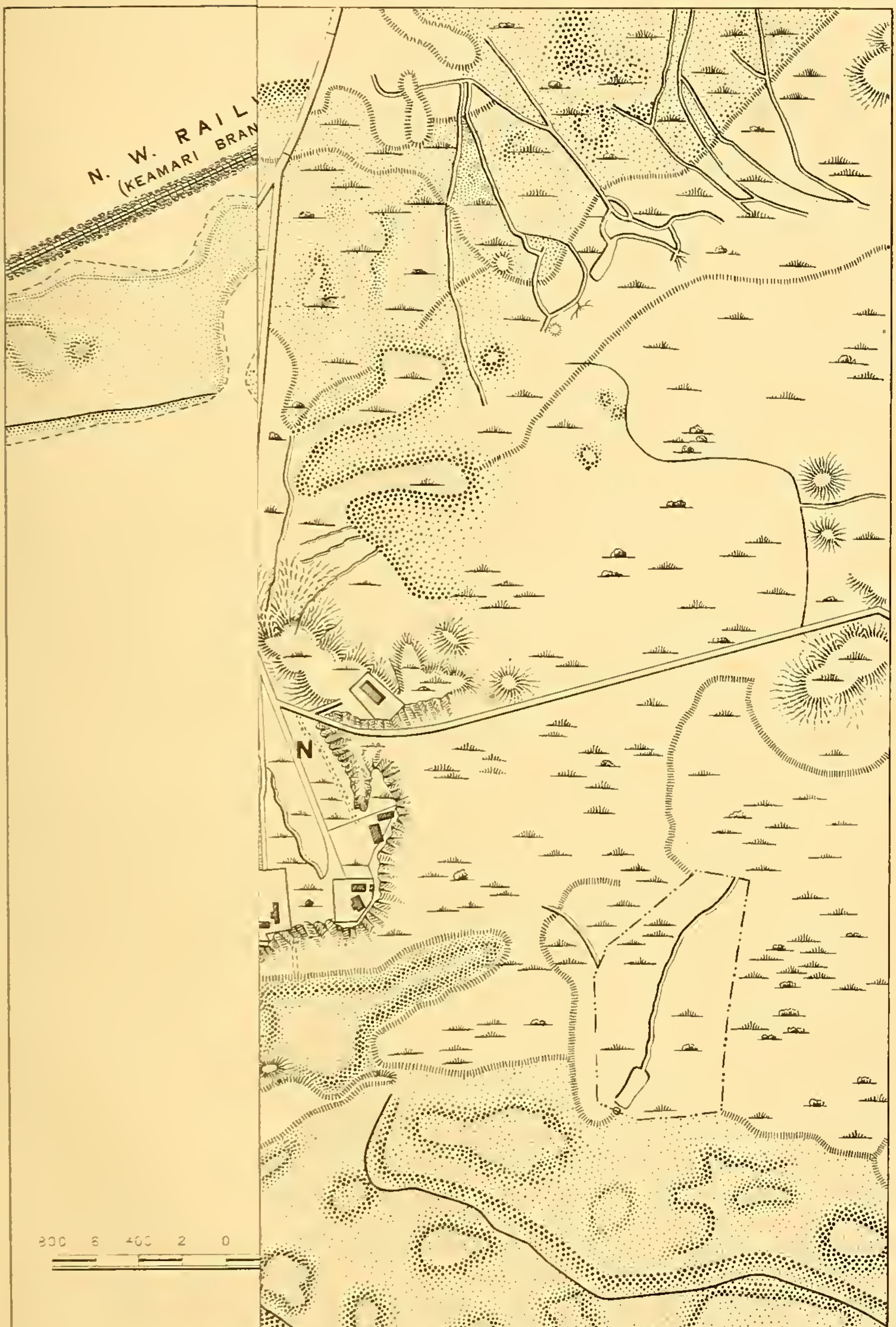
REED FENCING FOR FIXING LOOSE SAND

(after Gerhardt)

Fig. 2.

TWIG FENCING FOR FIXING LOOSE SAND

(after Gerhardt)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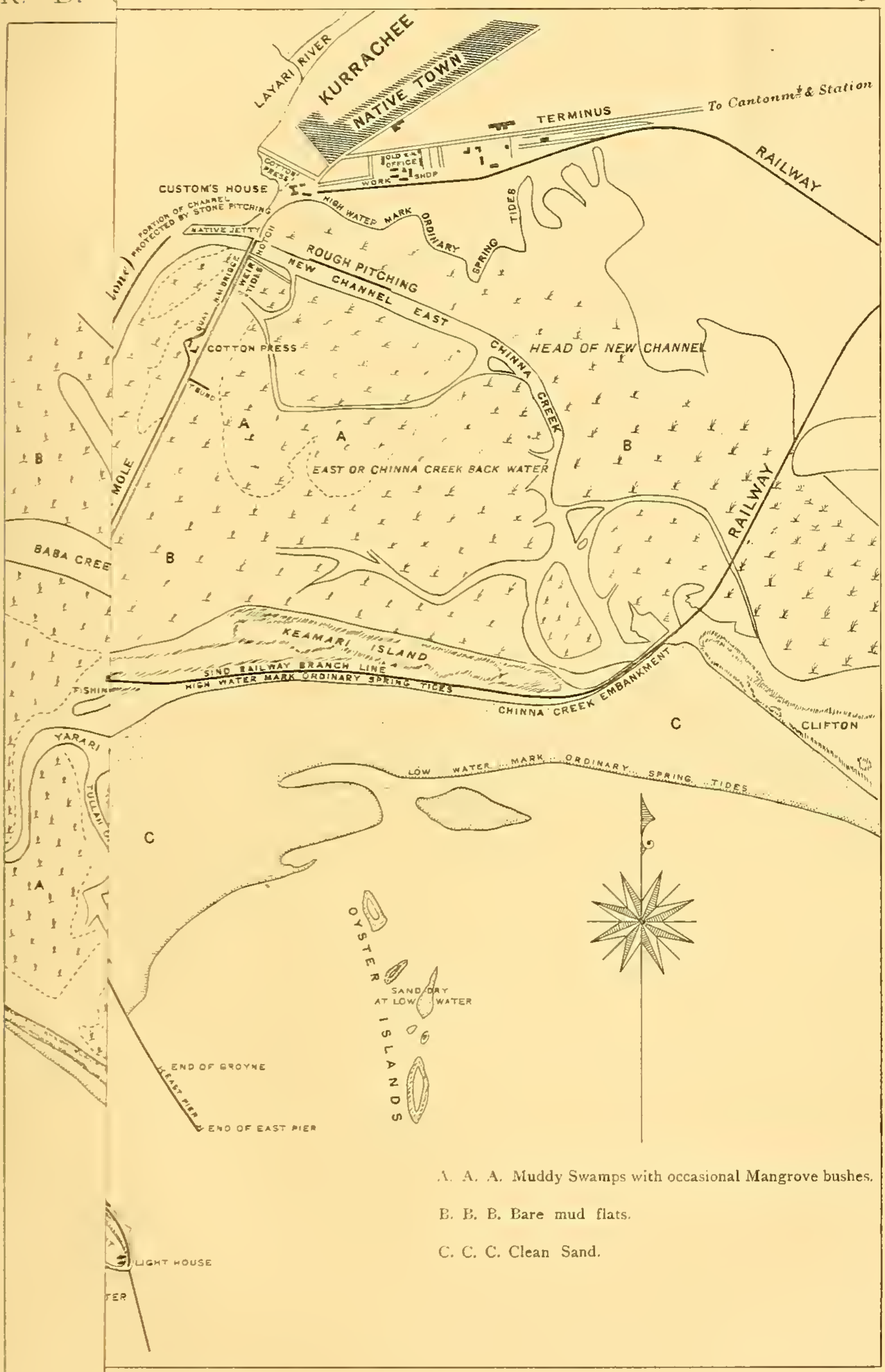
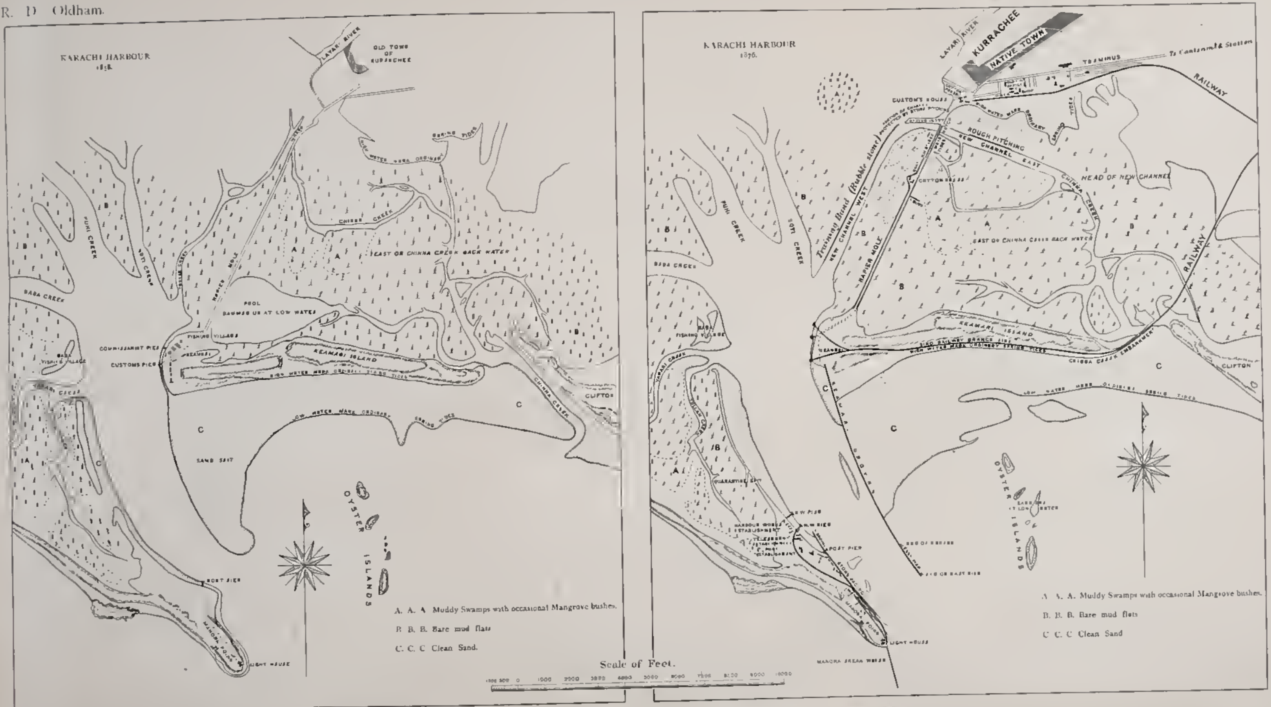
PLAN OF THE NEIGHBOURHOOD OF CLIFTON,

From the Survey of Lt. Col. G. A. Laughton B. S. C.

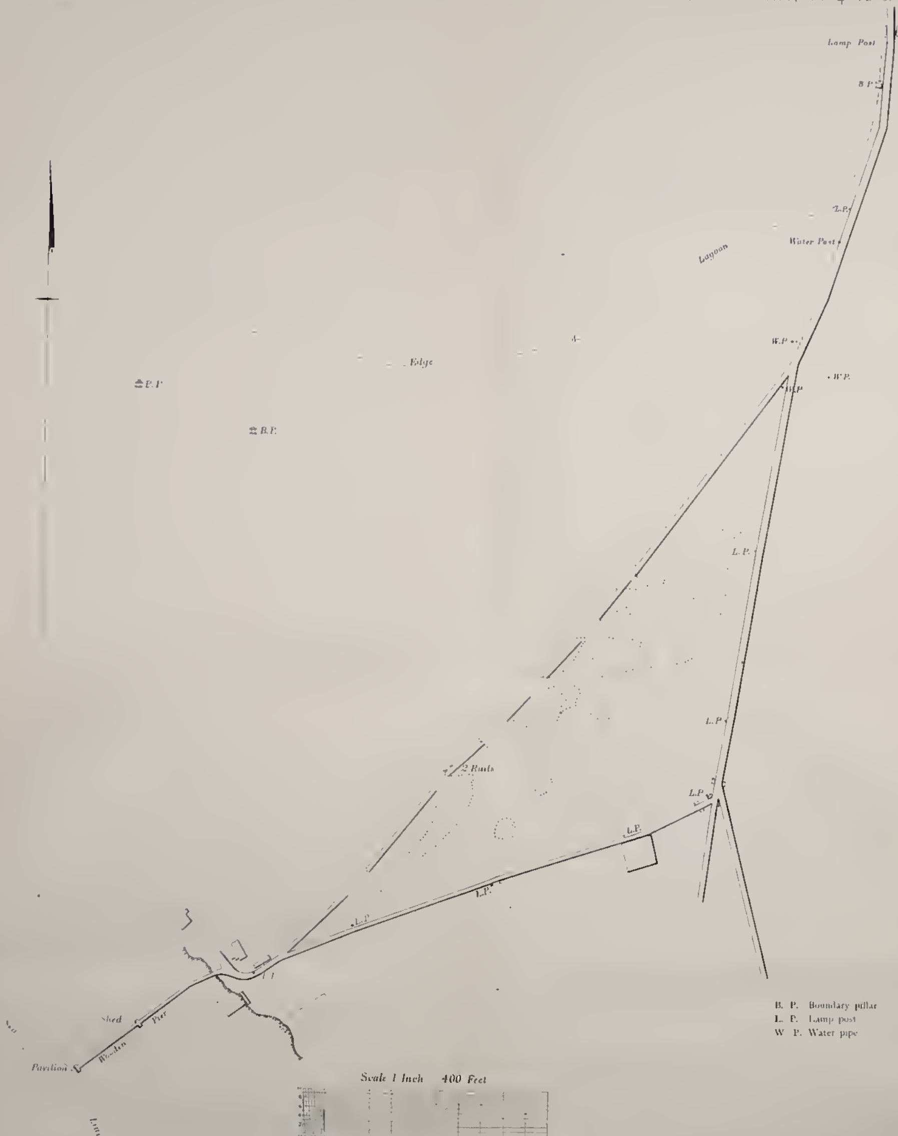

KURRACHEE
NATIVE TOWN
LAYARI RIVER
TERMINUS
To Cantonmt & Station
RAILWAY
CUSTOM'S HOUSE
PORTION OF CHANNEL PROTECTED BY STONE PITCHING
NATIVE JETTY
HIGH WATER MARK ORDINARY SPRING TIDES
ROUGH PITCHING
NEW CHANNEL EAST
CHINNA CREEK
HEAD OF NEW CHANNEL
COTTON PRESS
MOLE
EAST OR CHINNA CREEK BACK WATER
BABA CREE
KEAMARI ISLAND
SIND RAILWAY BRANCH LINE
HIGH WATER MARK ORDINARY SPRING TIDES
CHINNA CREEK EMBANKMENT
CLIFTON
LOW WATER MARK ORDINARY SPRING TIDES
YARARI
OYSTER ISLANDS
SAND DRY AT LOW WATER
END OF GROYNE
EAST PIER
END OF EAST PIER
LIGHT HOUSE
A. A. A. Muddy Swamps with occasional Mangrove bushes.
B. B. B. Bare mud flats.
C. C. C. Clean Sand.

& 1876.

R. D. Oldham.



MAPS SHOWING COMPARATIVE STATES OF HARBOUR IN 1858 & 1876.



EASTERN LIMIT OF SANDHILLS AT CLIFTON, KARACHI.

Surveyed Dec. 1901

Part 3.—Note on the progress of the gold industry in Wynaad, Nilgiri district. Notes on the representatives of the Upper Gondwana series in Trichinopoly and Nellore-Kistna districts. Senarmontite from Sarawak.

Part 4.—On the geographical distribution of fossil organisms in India. Submerged forest on Bombay Island.

VOL. XII, 1879.

Part 1.—Annual report for 1878. Geology of Kashmir (third notice). Further notices of Siwalik mammalia. Notes on some Siwalik birds. Notes of a tour through Hangrang and Spiti. On a recent mud eruption in Ramri Island (Arakan). On Braunite, with Rhodonite, from near Nagpur, Central Provinces. Palæontological notes from the Satpura coal-basin. Statistics of coal importations into India.

Part 2.—On the Mohpani coal-field. On Pyrolusite with Psilomelane occurring at Gosalpur, Jabalpur district. A geological reconnaissance from the Indus at Kushalgarh to the Kurram at Thal on the Afghan frontier. Further notes on the geology of the Upper Punjab.

Part 3.—On the geological features of the northern part of Madura district, the Pudukota State, and the southern parts of the Tanjore and Trichinopoly districts included within the limits of sheet 80 of the Indian Atlas. Rough notes on the cretaceous fossils from Trichinopoly district, collected in 1877-78. Notes on the genus Sphenophyllum and other Equisetaceæ, with reference to the Indian form Trizygia Speciosa, Royle (Sphenophyllum Trizygia, Ung.). On Mysorin and Atacamite from the Nellore district. On corundum from the Khasi Hills. On the Joga neighbourhood and old mines on the Nerbudda.

Part 4.—On the 'Attock Slates' and their probable geological position. On a marginal bone of an undescribed tortoise, from the Upper Siwaliks, near Nila, in the Potwar, Punjah. Sketch of the geology of North Arcot district. On the continuation of the road section from Murree to Abbottabad.

VOL. XIII, 1880.

Part 1.—Annual report for 1879. Additional notes on the geology of the Upper Godavari basin in the neighbourhood of Sironcha. Geology of Ladak and neighbouring districts, being fourth notice of geology of Kashmir and neighbouring territories. Teeth of fossil fishes from Ramri Island and the Punjab. Note on the fossil genera Nöggerathia, Stbg., Nöggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia, and Australia. Notes on fossil plants from Kattywar, Shekh Budin, and Sirgujah. On volcanic foci of eruption in the Konkan.

Part 2.—Geological notes. Palæontological notes on the lower trias of the Himalayas. On the artesian wells at Pondicherry, and the possibility of finding such sources of water-supply at Madras.

Part 3.—The Kumaun lakes. On the discovery of a celt of palæolithic type in the Punjab. Palæontological notes from the Karharbari and South Rewah coal-fields. Further notes on the correlation of the Gondwana flora with other floras. Additional note on the artesian wells at Pondicherry. Salt in Rajputana. Record of gas and mud eruptions on the Arakan coast on 12th March 1879 and in June 1843.

Part 4.—On some pleistocene deposits of the Northern Punjab, and the evidence they afford of an extreme climate during a portion of that period. Useful minerals of the Arvali region. Further notes on the correlation of the Gondwana flora with that of the Australian coal-bearing system. Note on reh or alkali soils and saline well waters. The reh soils of Upper India. Note on the Naini Tal landslip, 18th September 1880.

VOL. XIV, 1881.

Part 1.—Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts, being fifth notice of the geology of Kashmir and neighbouring territories. Note on some Siwalik carnivora. The Siwalik group of the Sub-Himalayan region. On the South Rewah Gondwana basin. On the ferruginous beds associated with the basaltic rocks of north-eastern Ulster, in relation to Indian laterite. On some Rajmahal plants. Travelled blocks of the Punjab. Appendix to 'Palæontological notes on the lower trias of the Himalayas.' On some mammalian fossils from Perim Island, in the collection of the Bombay Branch of the Royal Asiatic Society.

Part 2.—The Nahan-Siwalik unconformity in the North-western Himalaya. On some Gondwana vertebrates. On the ossiferous beds of Hundes in Tibet. Notes on mining records, and the mining record office of Great Britain ; and the Coal and Metalliferous Mines Acts of 1872 (England). On cobaltite and danaite from the Khetri mines, Rajputana ; with some remarks on Jaipurite (Syepoorite). On the occurrence of zinc ore (Smithsonite and Blende) with barytes, in the Karnul district, Madras. Notice of a mud eruption in the island of Cheduba.

Part 3.—Artesian borings in India. On oligoclase granite at Wangtu on the Sutlej, North-west Himalayas. On a fish-palate from the Siwaliks. Palæontological notes from the Hazaribagh and Lohardagga districts. Undescribed fossil carnivora from the Siwalik hills in the collection of the British Museum.

Part 4.—Remarks on the unification of geological nomenclature and cartography. On the geology of the Arvali region, central and eastern. On a specimen of native antimony obtained at Pulo Obin, near Singapore. On Turgite from the neighbourhood of Juggiapett, Kistnah district, and on zinc carbonate from Karnul, Madras. Note on the section from Dalhousie to Pangi, *viâ* the Sach Pass. On the South Rewah Gondwana basin. Submerged forest on Bombay Island.

Vol. XV, 1882.

Part 1.—Annual report for 1881. Geology of North-west Kashmir and Khagan (being sixth notice of geology of Kashmir and neighbouring territories). On some Gondwana labyrinthodonts. On some Siwalik and Jamna mammals. The geology of Dalhousie, North-west Himalaya. On remains of palm leaves from the (tertiary) Murree and Kasauli beds in India. On Iridosmine from the Noa-Dibing river, Upper Assam, and on Platinum from Chutia Nagpur. On (1) a copper mine lately opened near Yongri hill, in the Darjiling district ; (2) arsenical pyrites in the same neighbourhood ; (3) kaolin at Darjiling (being 3rd appendix to a report on the geology and mineral resources of the Darjiling district and the Western Duars). Analyses of coal and fire-clay from the Makum coal-field, Upper Assam. Experiments on the coal of Pind Dadun Khan, Salt-range, with reference to the production of gas, made April 29th, 1881. Report on the proceedings and result of the International Geological Congress of Bologna.

Part 2.—General sketch of the geology of the Travancore State. The Warkilli beds and reported associated deposits at Quilon, in Travancore. Note on some Siwalik and Narbada fossils. On the Coal-bearing rocks of the valleys of the Upper Rer and the Mand rivers in Western Chutia Nagpur. On the Pench river coal-field in Chhindwara district, Central Provinces. On borings for coal at Engsein, British Burma. On sapphires recently discovered in the North-west Himalaya. Notice of a recent eruption from one of the mud volcanoes in Cheduba.

Part 3.—Note on the coal of Mach (Much) in the Bolan Pass, and of Sharag or Sharigh on the Harnai route between Sibi and Quetta. New faces observed on crystals of stilbite from the Western Ghâts, Bombay. On the traps of Darang and Mandi in the North-western Himalayas. Further note on the connexion between the Hazara and the Kashmir series. On the Umaria coal-field (South Rewah Gondwana basin). The Daranggiri coal-field, Garo Hills, Assam. On the outcrops of coal in the Myanoung division of the Henzada district.

Part 4.—On a traverse across some gold-fields of Mysore. Record of borings for coal at Beddadanol, Godavari district, in 1874. Note on the supposed occurrence of coal on the Kistna.

Vol. XVI, 1883.

Part 1.—Annual report for 1882. On the genus Richthofenia, Kays (Anomia Lawrenciana, Koninck). On the geology of South Travancore. On the geology of Chamba. On the basalts of Bombay.

Part 2.—Synopsis of the fossil vertebrata of India. On the Bijori Labyrinthodont. On a skull of Hippotherium antilopinum. On the iron ores, and subsidiary materials for the manufacture of iron, in the north-eastern part of the Jabalpur district. On laterite and other manganese ore occurring at Gosulpore, Jabalpur district. Further notes on the Umaria coal-field.

Part 3.—On the microscopic structure of some Dalhousie rocks. On the lavas of Aden. On the probable occurrence of Siwalik strata in China and Japan. On the occurrence of Mastodon angustidens in India. On a traverse between Almora and Mussooree made in October 1882. On the cretaceous coal-measures at Borsora, in the Khasia Hills, near Laour, in Sylhet.

Part 4.—Palæontological notes from the Daltonganj and Hutar coal-fields in Chota Nagpur. On the altered basalts of the Dalhousie region in the North-western Himalayas. On the microscopic structure of some Sub-Himalayan rocks of tertiary age. On the geology of Jaunsar and the Lower Himalayas. On a traverse through the Eastern Khasia, Jaintia, and North Cachar Hills. On native lead from Maulmain and chromite from the Andaman Islands. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice.—Irrigation from wells in the North-Western Provinces and Oudh.

Vol. XVII, 1884.

Part 1.—Annual report for 1883. Considerations on the smooth-water anchorages or mud banks of Narrakal and Alleppy on the Travancore coast. Rough notes on Billa Surgam and other caves in the Kurnool district. On the geology of the Chuari and Sihunta parganas of Chamba. On the occurrence of the genus Lyttonia, Waagen, in the Kuling series of Kashmir.

Part 2.—Notes on the earthquake of 31st December 1881. On the microscopic structure of some Himalayan granites and gneissose granites. Report on the Choi coal exploration. On the re-discovery of certain localities for fossils in the Siwalik beds. On some of the mineral resources of the Andaman Islands in the neighbourhood of Port Blair. The intertrappean beds in the Deccan and the Laramie group in western North America.

Part 3.—On the miscroscopic structure of some Arvali rocks. Section along the Indus from the Peshawar Valley to the Salt-range. On the selection of sites for borings in the Raigarh-Hingir coal-field (first notice). Note on lignite near Raipore, Central Provinces. The Turquoise mines of Nishâpûr, Khorassan. Notice of a further fiery eruption from the Minbyin mud volcano of Cheduba Island, Arakan. Report on the Langrin coal-field, south-west Khasia Hills. Additional notes on the Umaria coal-field.

Part 4.—On the Geology of part of the Gangasulan pargana of British Garhwal. On fragments of slates and schists imbedded in the gneissose granite and granite of the North-west Himalayas. On the geology of the Takht-i-Suleiman. On the smooth-water anchorages of the Travancore coast. On auriferous sands of the Subansiri river, Pondicherry lignite, and phosphatic rocks at Musuri. Work at the Billa Surgam caves.

Vol. XVIII, 1885.

Part 1.—Annual report for 1884. On the country between the Singareni coal-field and the Kistna river. Geological sketch of the country between the Singareni coal-field and Hyderabad. On coal and limestone in the Doigrung river, near Golaghat, Assam. Homotaxis, as illustrated from Indian formations. Afghan field notes.

Part 2.—A fossiliferous series in the Lower Himalaya, Garhwal. On the probable age of the Mandhali series in the Lower Himalaya. On a second species of Siwalik camel (Camelus Antiquus, nobis ex Fale. and Caut. MS.). On the Geology of Chamba. On the probability of obtaining water by means of artesian wells in the plains of Upper India. Further considerations upon artesian sources in the plains of Upper India. On the geology of the Aka Hills. On the alleged tendency of the Arakan mud volcanoes to burst into eruption most frequently during the rains. Analyses of phosphatic nodules and rock from Mussooree.

Part 3.—On the Geology of the Andaman Islands. On a third species of Merycopotamus. Some observations on percolation as affected by current. Notice of the Pirthalla and Chandpur meteorites. Report on the oil-wells and coal in the Thayetmyo district, British Burma. On some antimony deposits in the Maulmain district. On the Kashmir earthquake of 30th May 1885. On the Bengal earthquake of 14th July 1885.

Part 4.—Geological work in the Chhattisgarh division of the Central Provinces. On the Bengal earthquake of July 14th 1885. On the Kashmir earthquake of 30th May 1885. On the results of Mr. H. B. Foote's further excavations in the Billa Surgam caves. On the mineral hitherto known as Nepaulite. Notice of the Sabetmahet meteorite.

Vol. XIX, 1886.

Part 1.—Annual report for 1885. On the International Geological Congress of Berlin. On some Palæozoic Fossils recently collected by Dr. H. Warth, in the Olive group of the Salt-range. On the correlation of the Indian and Australian coal-bearing beds. Afghan and Persian Field notes. On the section from Simla to Wangtu, and on the petrological character of the Amphibolites and Quartz Diorites of the Sutlej valley.

Part 2.—On the Geology of parts of Bellary and Anantapur districts. Geology of the Upper Dehing basin in the Singpho Hills. On the microscopic characters of some eruptive rocks from the Central Himalayas. Preliminary note on the Mammalia of the Karnul Caves. Memorandum on the prospects of finding coal in Western Rajputana. Note on the Olive group of the Salt-range. On the discussion regarding the boulder-beds of the Salt-range. On the Gondwana Homotaxis.

Part 3.—Geological sketch of the Vizagapatam district, Madras. Preliminary note on the geology of Northern Jesalmer. On the microscopic structure of some specimens of the Malani rocks of the Arvali region. On the Malanjkhandi copper-ore in the Balaghat district, C. P.

Part 4.—On the occurrence of petroleum in India. On the petroleum exploration at Khátan. Boring exploration in the Chhattisgarh coal-fields. Field-notes from Afghanistan: No. 3, Turkistan. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice of the Nammianthal aerolite. Analysis of gold dust from the Mezà valley, Upper Burma.

Vol. XX, 1887.

Part 1.—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traverse through Jaunsar-Bawar and Tiri-Garhwal. On the geology of the Garo Hills. On some Indian image-stones. On soundings recently taken off Barren Island and Narcondam. On a character of the Talchir boulder-beds. Analysis of Phosphatic Nodules from the Salt-range, Punjab.

Part 2.—The fossil vertebrata of India. On the Echinoidea of the cretaceous series of the Lower Narbada Valley, with remarks upon their geological age. Field-notes: No. 5—to accompany a geological sketch map of Afghanistan and North-eastern Khorassan. On the microscopic structure of some specimens of the Rajmahal and Deccan traps. On the Dolerite of the Chor. On the identity of the Olive series in the east with the speckled sandstone in the west of the Salt-range in the Punjab.

Part 3.—The retirement of Mr. Medlicott. Notice of J. B Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section I. Preliminary sketch of the geology of Simla and Jutogh. Note on the 'Lalitpur' meteorite.

Part 4.—Note on some points in Himalayan geology. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section II. The iron industry of the western portion of the District of Raipur. Notes on Upper Burma. Boring exploration in the Chhattisgarh coal-fields. (Second notice.) Some remarks on Pressure Metamorphism, with reference to the foliation of the Himalayan Gneissose-Granite. A list and index of papers on Himalayan Geology and Microscopic Petrology, published in the preceding volumes of the records of the Geological Survey of India.

Vol. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section III. The Birds'-nest or Elephant Island, Mergui Archipelago. Memorandum on the results of an exploration of Jessalmer, with a view to the discovery of coal. A facetted pebble from the boulder bed ('speckled sandstone') of Mount Chel in the Salt-range in the Punjab. Examination of uodular stones obtained by trawling off Colombo.

Part 2.—Award of the Wollaston Gold Medal, Geological Society of London, 1888. The Dharwar System, the chief auriferous rock series in South India. On the Igneous rocks of the districts of Raipur and Balaghat, Central Provinces. On the Sangar Marg and Mehowgale coal-fields, Kashmir.

Part 3.—The Manganese Iron and Manganese Ores of Jabalpur. 'The Carboniferous Glacial Period.' The sequence and correlation of the pre-tertiary sedimentary formations of the Simla region of the Lower Himalayas.

Part 4.—On Indian fossil vertebrates. On the geology of the North-west Himalayas. On blown-sand rock sculpture. Re-discovery of Nummulites in Zanskar. On some mica traps from Barakar and Raniganj.

Vol. XXII, 1889.

Part 1.—Annual report for 1888. The Dharwar System, the chief auriferous rock-series in South India. (Second notice.) On the Wajra Karur diamonds, and on M. Chaper's alleged discovery of diamonds in pegmatite near that place. On the generic position of the so-called Plesiosaurus Indicus. On flexible sandstone or Itacolumite, with special reference to its nature and mode of occurrence in India, and the cause of its flexibility. On Siwalik and Narbada Chelonia.

Part 2.—Note on Indian Steatite. Distorted pebbles in the Siwalik conglomerate. 'The Carboniferous Glacial Period.' Notes on Dr. W. Waagen's 'Carboniferous Glacial Period.' On the oil-fields of Twingoung and Beme, Burma. The gypsum of the Nehal Nadi, Kumaun. On some of the materials for pottery obtainable in the neighbourhood of Jabalpur and of Umaria.

Part 3.—Abstract report on the coal outcrops in the Sharigh Valley, Baluchistan. On the discovery of Trilobites by Dr. H. Warth in the Neobolus beds of the Salt-range. Geological notes. On the Cherra Poonjee coal-field, in the Khasia Hills. On a Cobaltiferous Matt from Nepál. The President of the Geological Society of London on the International Geological Congress of 1888. Tin-mining in Mergui district.

Part 4.—On the land-tortoises of the Siwaliks. On the pelvis of a ruminant from the Siwaliks. Recent assays from the Sambhar Salt-Lake in Rajputana. The Manganiferous Iron and Manganese Ores of Jabalpur. On some Palagonite-bearing traps of the Ráj-mahál hills and Deccan. On tin-smelting in the Malay Peninsula. Provisional index of the local distribution of important minerals, miscellaneous minerals, gemstones, and quarry stones in the Indian Empire. Part 1.

Vol. XXIII, 1890.

Part 1.—Annual report for 1889. On the Lakadong coal-fields, Jaintia Hills. On the Pectoral and pelvic girdles and skull of the Indian Dicynodonts. On certain vertebrate remains from the Nagpur district (with description of a fish-skull). Crystalline and metamorphic rocks of the Lower Himalayas, Garhwál and Kumaun, Section IV. On the bivalves of the Olive-group, Salt-range. On the mud-banks of the Travancore coast.

Part 2.—On the most favourable sites for Petroleum explorations in the Harnai district, Baluchistan. The Sapphire Mines of Kashmir. The supposed Matrix of the Diamond at Wajra Karur, Madras. The Sonapet Gold-field. Field Notes from the Shan Hills, (Upper Burma). A description of some new species of Syringosphæridæ, with remarks upon their structures, &c.

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Vol. XXV, 1892.

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