REPORTS

ON

THE MAGNESITE AREAS NEAR SALEM AND ON SOME CORUNDUM LOCALITIES

IN THE SALEM AND COIMBATORE DISTRICTS.

BY

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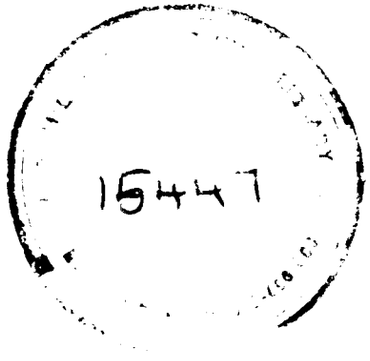
1895.



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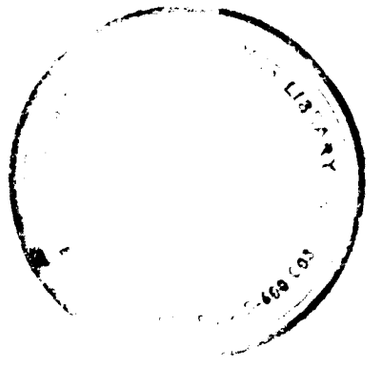

REPORT ON THE MAGNESITE AREAS OF THE CHALK HILLS AND OTHER LOCALITIES NEAR SALEM.

Introduction.

About the middle of November last I received a communication from the Madras Government asking me to examine the above areas (G.O., dated 12th November 1894). Accordingly a good part of the cold-weather season of 1894–95 was spent in their study.

The main results of my examination are embodied in this report which deals with—

(1) The two areas of the Chalk hills.
(2) That of the north-west end of the Kanjamallai hill.
(3) That near Valaiyapatti in the Námakkal taluk.

Of these three areas the first is by far the most important. They will be taken for description in the above order.

(1) Chalk Hills.

The two areas embraced under the above name have been described by Messrs. King and Foote in their Memoir (*Mem. G. S. of India*, vol. IV, pt. 2, 1864). The same areas were cursorily examined by Mr. Holland quite recently, and described (*Records G. S. of India*, vol. XXV, p. 135, 1892).

Whilst the two former observers gave a fairly detailed description of the mode of occurrence of the magnesite, with remarks on the accompanying minerals, the latter was able to come to more definite and accurate conclusions regarding the mode of origin of the magnesite, chromite, etc.—conclusions which have been abundantly confirmed and illustrated by my own visit.

In taking up work myself on these extremely interesting rocks, it was clear (considering that a generally descriptive account, and an up-to-date theory of them existed already) that any advance that I could make on the work of my predecessors must be in the direction of greater accuracy as regards detailed surveying of the minerals and rocks of the area. My line of action was therefore clear, and the first step towards it was to obtain a detailed topographical map. This I found not

to exist; and so, as the shortest way out of the difficulty, I set to work and plane-tabled the two magnesite areas of the Chalk hills myself on the scale of 6 inches to 1 mile, showing sketched contours of 10 feet. A tracing of the map, geologically coloured, accompanies this report.

It will be seen, therefore, that the apparently simple request of the Madras Government for further information about the magnesite of these hills was really a call of a more serious nature than would appear at first sight—if I were to see anything and report anything beyond what was already known and published.

Position and area.

The Chalk hills lie a few miles north of Salem town. They comprise two areas, a smaller one to the south, through which at its south-west end the Madras Railway and the road to Omalur pass, and a larger one to the north-east of the latter, and which keeps a position to the east of the railway and road. The former contains about $1\frac{1}{4}$ square miles and the latter (so far as shown in my map) about $3\frac{1}{2}$ square miles. It extends, however, further away in a north-easterly direction.

Orography.

The hills rise gently from the plains, and expose a set of low undulating surfaces, generally bare of vegetation and without water. They are streaked with white, owing to the veins of magnesite (carbonate of magnesia) from which (erroneously) the name Chalk hills is taken.

General Geological structure.

The structure of the two magnesite areas may be summarised as follows:—

(1) The plains surrounding the Chalk hills are composed of an ancient gneissic series, wrapped into folds with a N.E.—S.W. strike.

(2) The two areas of the Chalk hills are essentially two great intrusive masses of olivine-chromite rock, and other olivine-bearing rocks, which, from their containing little or no felspar or quartz, belong to the peridotite, or ultra basic group of rocks, such as dunites, picrites, etc. These rocks, owing to the unstable mineral olivine, have undergone enormous mineral change, whereby, first the dunite became serpentinised more or less completely, and secondly, the serpentinised product was further altered with the formation of magnesite, chalcedony, etc.

The Dunite and its contained mineral Chromite.

Mr. Holland was the first to detect the presence of dunite in the specimens which he collected in the Chalk hills and north-west of Kanjanallai hill—see foot-note at p. 114 of Mr. Holland's paper.

This rock, first known from the Dun mountain, New Zealand, is composed entirely of olivine and chromite, and as such, in an unaltered condition, it is found at many places in the Chalk hills where the rock has resisted the metamorphic influences tending to convert it into serpentine. The top of "J" hill and of "Tent" hill, and the western end of the south area are examples of places where the rock, of a grey or greenish-grey colour, may be observed. The grey rock (colourless in thin section), such as is found on the summit of "J" hill and near "KK" hill, might be at first sight mistaken for a quartzite until the high specific gravity arouses suspicion.

The microscope shows the rock to be composed almost entirely of a coarsely crystalline aggregate of olivine, felted together, and with minute black crystalline grains of chromite dotted through it.

A chemical analysis of the "J" hill specimen No. 10·189, made in the survey laboratory by Mr. Blyth, gave—

Silica	39·10
Magnesia	48·26
	87·36
Iron, alumina	12·64
Manganese	
Chromium	
Moisture, etc.	
	100·00
The specific gravity was	3·176

I give below, for comparison, an analysis of the dunite of the Dun mountain (Von Hochstetter)—

Silica	42·80
Magnesia	47·38
FeO.	9·40

(after the chromite had been removed).

I next give that of oriental olivine, taken from Dana's Mineralogy:—

Silica	39·73
Magnesia	50·43
FeO.	9·19
The specific gravity being	3·351

There can be no doubt that originally nearly the whole of the Chalk hills area was composed of this extreme form of peridotite known as dunite. But mineral changes rapidly set in, and the two first of these changes that must be noticed are (*a*) the alteration, partially or wholly, of the olivine into

serpentine, and (*b*) the segregation of the chromite into nodules and veins. With regard to the change of olivine into serpentine, I need say very little. It can be followed most perfectly under the microscope by a series of transitional sections showing, first, a few veins of the latter anastomosing among and penetrating the crystals of olivine, afterwards breaking them up, then separating them into isolated small grains set like islands in a sea of serpentine, and which at last become very small and finally disappear. The subsequent changes which brought about the conversion of much of the serpentine into magnesite have effectually destroyed any ornamental qualities it might have possessed, by giving it a dull earthy appearance. Only here and there do there occur a few minute veins, a finger thick, of a pale apple-green serpentine, which might, if they had been on a larger scale, have been of economic use. Pierolite or fibrous serpentine, is also found in veins here and there.

Coming to the chromite, originally discovered by Mr. Heath, and worked by the Porto Novo Company, the only observations we have as to its mode of occurrence are those made a long time ago by Newbold, and those of recent date by Holland. The former found the mineral in very thin veins, either lying among the magnesite of the veins or between it and the walls of the veins. The observations were drawn from an examination of the mines near the chimney on the accompanying map. Holland corroborated Newbold's observations in this respect — see *Journal Roy. Asiatic Soc.*, vol. VII, 1843, pp. 167—171. Of the three shafts marked on my map, the middle one is the largest, and though I explored this carefully, I could find no trace of the mineral left in the crumbling rock-walls of the shaft.

In some small pits sunk along the position of the red line on the map (some of which appear to have been enlarged lately), I was able to see the position of several veins of the chromite. Three vertical parallel veins a quarter of an inch, 1 inch, and $\frac{1}{2}$ inch wide respectively, and separated by a few inches of serpentinised matrix, occur striking E. 20° N. at a position on the map N.W. 5° N. from the chimney, and distant about 650 yards (see pl. I, fig. 1). Nearly horizontal magnesite veins may be seen interrupting and cutting across both the matrix and the chromite veins. In one place a vein of magnesite, has not only interrupted, but also displaced, the middle vein of chromite, showing that the magnesite was, in this case, the last to form.

What is undoubtedly a continuation of the same vein towards the E. 20° N. is to be seen at several points between

900 and 1,000 yards off. At no other places in this north area was chromite found *in situ*.

It will be seen from the map, however, that in this area a little east of the chimney there is a space of country from which six stream-beds radiate in different directions. In every one of these stream-beds, and especially in their higher parts, chromite, in lumps, varying from one foot to one inch or even less across, may be picked up (the places where such have been found are indicated on the map by red dots).

It is clear, therefore, that the area drained by these streams is penetrated by chromite veins. Unfortunately, my data are too scanty for any attempt to estimate the amount of chromite available to the miner; nothing but a practical test within the area of, say, 1,000 yards radius from the chimney would settle this all-important question. Geology has gone as far as it can, unaided, in the matter.

In the southern area of the Chalk hills the map similarly shows, by means of red dots, the places where chromite has been picked up at the surface. No chromite, actually *in situ*, is known in this area; but the indications of it in the stream between "Tent" hill and "Green bush" hill, and in the one to the south-west of "Tent" hill, show that the centre of this area is approximately the true location of the chromite. No mines have been worked in the area, but I have no doubt that if extensive quarrying of the magnesite is ever carried out, chromite veins will in due course be laid bare.

As for the quality of the ore, the nodules and lumps as picked up among the hills show that it is practically a granular-crystalline aggregate of the pure mineral, chromate of iron, the theoretical composition of which, as given by Dana, is—

Chromium sesquioxide	68·0
Iron protoxide	32·0
	100·0

but chromite varies much in the amount of the sesquioxide present, 50 per cent. being considered a very good quality of ore.

The actual analysis of the ore, as found in the north area of the Chalk hills, is given in Newbold's paper referred to above. It was made by Mr. E. Solly, and gave—

Chromium sesquioxide	49·00 per cent.
Which is about equivalent to chromic acid	57·09 "

Or to cent. per cent. of chromate of potash."

The following description of the method of working and transporting the ore to the coast is taken from Newbold's report:—

"The ore is separated from the rock by means of pickaxes, chisels, "wedges, and hammers; sorted and piled up into little heaps on the "ground in front of the huts occupied by the superintendents, where "it remains until the Cauvery becomes navigable—that is, from the end "of June till the end of September. It is then sent down by land to "Moganoor, a place on the river about 40 miles southerly from Salem, "whence it is boated to Porto Novo on the Coromandel coast. Thence "it is shipped to Europe by the Porto Novo Iron Company."

About 100 tons are said to have been extracted from the mines, one block of which weighed two tons, but it was found that the export of the crude ore to England did not pay owing to the quantities available from Scotland, Styria, etc. At a depth of 50 or 60 feet from the surface water was met with, and it is not impossible that it was this difficulty which helped largely to stop the work, inasmuch as no better means of removing the water were used than buckets and ropes.

Other Ultra-Basic and Basic rocks of the Chalk hills.

Besides the dunite, and its more immediately derived serpentine and chromite veins, there occur, somewhat sparingly, examples of other less basic rocks. They are generally black or of dark colour, and stand out in rounded lumps, having escaped the great alteration which the dunite has suffered. They are represented on the map by a purple colour. Many of these in the north area are situated round the margins of the dunite intrusion. One remarkable one is found to the east of "Green bush" hill in the south area. All these rocks contain olivine, but not to the exclusion of everything else. They also contain green pyroxene, and sometimes black mica. Some also contain a small amount of plagioclase felspar, thus linking the ultra-basic rocks with the basic.

It is not absolutely certain how these rocks made their appearance in this area, but one reasonable hypothesis is that, lying as they do at the outer edge of the great dunite intrusion, they represent the lighter portions of the molten magma which separated at the surface, whilst the more basic elements of it tended to sink by their higher specific gravity and so occupy what is now a more central portion of the Chalk hills areas. But, as the study of these rocks is of more petrological interest than of economic importance, I do not propose to do more here in the way of describing them, but to confine myself to stating that, as they hint at an increasing basicity of the rocks as we travel inwards and downwards from the outer edges of the two

areas, they point to the possibility of the heavier minerals, *e.g.*, chromite, being found in greater abundance at greater depths.

Another set of hornblende-garnet rocks which form the high ridge "IIIII" between the north and south areas will similarly be neglected in this report.

The Magnesite veins.

I come now to the mineral which is most abundantly represented in the Chalk hills, that is, the magnesite, or carbonate of magnesia. Its general characteristics, mode of occurrence, and appearance have been described by many observers, among whom may be mentioned Newbold (*Journal Roy. Asiatic Soc.*, vol. VII, p. 161, 1842), King and Foote in their memoir cited above, and lastly Holland. The descriptions of the earlier observers stand good at the present day, if we simply substitute the more correct mineralogical descriptions of the rocks from which it was originally derived in the place of the hornblende schists, micaceous and massive talcose schists, basalts, etc., of these observers. The mistake made by them (perfectly intelligible before the microscope was regularly employed for the examination of rocks by means of thin sections) was of a simple nature. They looked upon the area of the Chalk hills as primarily a focus of metamorphism, brought about by a locally intense extravasation of hot acid waters or vapours, which were sufficient to change the otherwise stable minerals in the gneissic rocks surrounding the area. Mr. Holland's and my own researches, on the other hand, have simplified the matter considerably by the discovery that the rock forming the groundwork of the Chalk hills areas is entirely different from the surrounding gneissic rocks; that it is in fact, as has been described above, a nearly pure olivine rock in various stages of alteration. The fact of such an olivine rock having at one time been erupted into the older gneisses in this part of the country is in itself sufficient to account for the secondary masses of serpentine and veins of magnesite, without having recourse to hot acid waters emerging at particular places; inasmuch as it is the nature of olivine rocks to rapidly undergo changes into serpentine and magnesite. The mineral is of such an unstable nature as to readily lend itself to these changes under normal subterranean or surface conditions (without calling into play any special metamorphosing agents), whilst the ordinary gneisses of the country, and the less basic rocks surrounding the area, remained practically unaltered.

I need say very little, therefore, as to the general occurrence of the magnesite here, except that it appears in veins, which although they have, in places, a tendency to a particular

alignment, along what were probably originally joint planes in the dunite, are nevertheless as a rule completely irregular in their disposition. The number of veins, and the corresponding quantity of the magnesite, were points to which I particularly directed my attention; and which I have endeavoured to represent on the accompanying map. The pale wash of blue, which covers the whole area where the dunite is found, stands for that in which the magnesite is least in evidence or absent altogether. The cross-shaded portion is that in which there is a fair amount of the magnesite; whilst the deep-blue wash represents the parts richest in magnesite. I have been compelled for diagrammatic purposes to draw the boundaries of the different areas as sharp, but I need scarcely remark that in nature there are no such hard and fast lines; the richer and the poorer rock grading into each other.

(1) The richest areas (coloured blue) are, generally speaking, the western end of the north area, and the south side of the south area. I estimate that the proportion, by volume, of magnesite in the rock in these richest parts is about one-half or one-third of the whole rock.

(2) The moderately rich area (cross-shaded) occupies generally the more central parts of the Chalk hills; and I estimate that the proportion, by volume, of magnesite here is only from one-sixth to one-tenth, or even less, of the whole rock.

(3) The poorest area (coloured pale blue) merely shows a few thin veins and patches of the magnesite here and there, and impossible of estimation.

The total area embraced under heading No. (1) above, in the two parts of the Chalk hills taken together, amounts to about 620,000 square yards, that under heading No. (2) amounts to about 5,536,000 square yards.

Considered altogether, the amount of magnesite in these hills is practically unlimited. The richest portions (as visible at the surface) stand up in rough lumpy hillocks, sometimes, as in the case of the hills at the western end of the north area, rising as much as 100 to 140 feet above the plains, whilst in other parts, as the south edge of the south area, they rise only to 30, 40 or 60 feet above the plains. Hence the mineral (if any demand for it ever does arise) can be worked in open quarries, and taken away to the rail. The quarries could all be reached by a light tramway, or by carts.

Two outline views of the two areas are appended to this report to show the configuration of the country, and two photographs to illustrate the surface appearance of the magnesite veins.

(2) KANJAMALLAI AREA.

Mr. Holland (*Rec. G. S. of India*, vol. XXV, p. 142) was the first, I believe, to draw attention to the presence of ultra-basic rocks and magnesite in small amount at the north-west end of the Kanjamallai hill in a depression at the head of a little stream running down to Sithaswaran kovil (temple). Therein also he remarks on the possibility of finding chromite associated with the magnesite.

On visiting this part myself last season, I found the rocks as described by Mr. Holland. But the amount of the purer olivine-chromite ultra-basic intrusive rock (dunite) as found at the surface was, however, extremely small. It is of a pale greenish-yellow colour and crumbles easily. Veins of magnesite run through it. In close relation with it was a brilliant dark-green rock composed of enstatite and a bright-green pyroxene (diopside), a rock which is also found in the extreme north-east parts of the north magnesite area of the Chalk hills, on the east side of the double-peaked Nagramallai hill (not represented on the map).

Mr. Holland's prediction as to the possible finding of chromite here was verified by my coming upon a band of it about 4 inches thick among the magnesite and decomposed ultra-basic rock. It was only exposed for the short distance of about 3 yards.

The whole exposed area of these rocks in this locality is in length not more than $\frac{3}{4}$ mile and in breadth $\frac{1}{4}$ mile. It appears to follow round the eastern end of the depression at the north-west end of Kanjamallai in the angle formed by the main ridge and the low continuation of it south of Sithaswaran kovil (temple). I could not find any trace of it anywhere else on the Kanjamallai ridge.

To the south of Kanjamallai hill, and running parallel to, and north of, the Salem, Sankaridrug road, there is a little row of hills composed chiefly of talcose schists and dunite, with a mere trace of magnesite among them. The talcose rock was locally worked as pot-stone for making rude vessels (feeding troughs for cattle, etc.).

Both these two areas are too small to be considered as of any importance from the magnesite they contain; but the chromite of the former, and the pot-stone of the latter, may be considered as of some economic value. The chromite is in close proximity to a thick bed of magnetite.

This paper does not profess to deal with the iron ores of Kanjamallai, but I may mention that a few average specimens

from the lowest and thickest band of magnetiteschist at the south foot of Kanjamallai were analysed in the Survey laboratory by Mr. Blyth and gave :—

No. 10·212 (a fine-grained, almost aphanitic rock, a large specimen of which I sent to the Madras Museum)—

Specific gravity	3·365
Per cent. of iron	35·09

No. 10·243—

Specific gravity	3·531
Per cent. of iron	34·390

No. 10·239 (a coarsely crystalline quartz-magnetite rock)—

Specific gravity	3·538
Per cent. of iron	36·06

(3) The Valaiyapatti area.

This locality is one of those described by Foote and King in their Memoir cited above, p. 96. The amount of magnesite present is extremely small. The ultra-basic rocks which have given rise to the magnesite are the same as those last described from north-west end of Kanjamallai hill, but I did not find any of the pure olivine rock analogous to the dunite of the Chalk hills.

The actual locality is a little south (from half to one mile) of Palappatti of the one-inch map of the Namakkal taluk (Madras Survey). The magnesite is exposed over an area of one mile by half a mile, and it is developed among rocks which contain a considerable quantity of enstatite, with green pyroxene (diopside).

Besides this particular area there is, actually at Valaiyapatti, another occurrence of similar rocks, which stretch away in a long narrow band east and west of the town. They form little hills rising sometimes steeply, and forming a discontinuous chain. With them east of the town occurs a rock of an extremely acid type, a very coarse red or pink and white pegmatoid rock or graphic granite, composed of quartz and felspar, which have crystallised together simultaneously.

From the point of view of this report I need not make any further remarks concerning this occurrence.

These are all the localities with magnesite that I have so far visited. The first is the only one in which the mineral is developed in sufficient force to be of any practical use.

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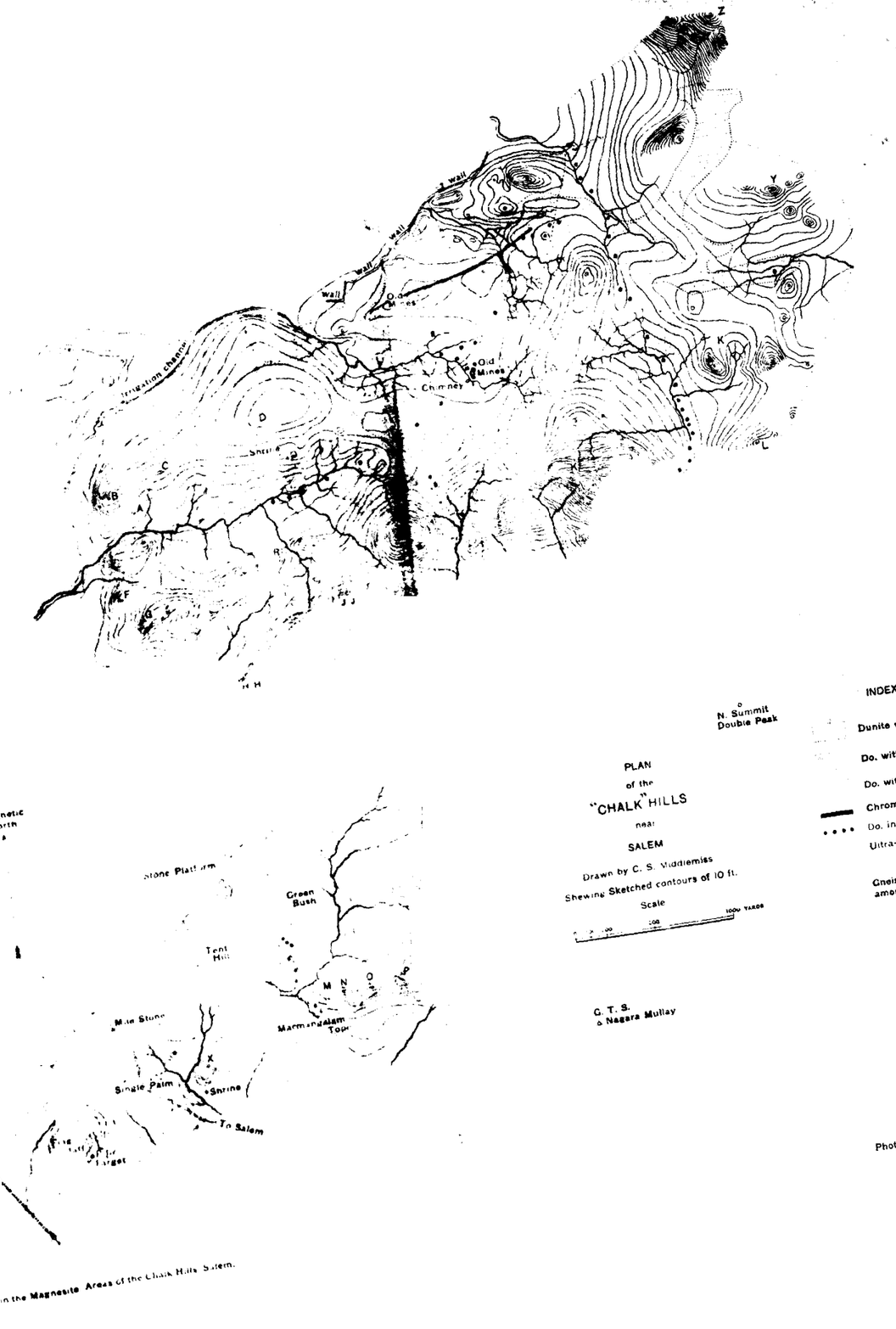
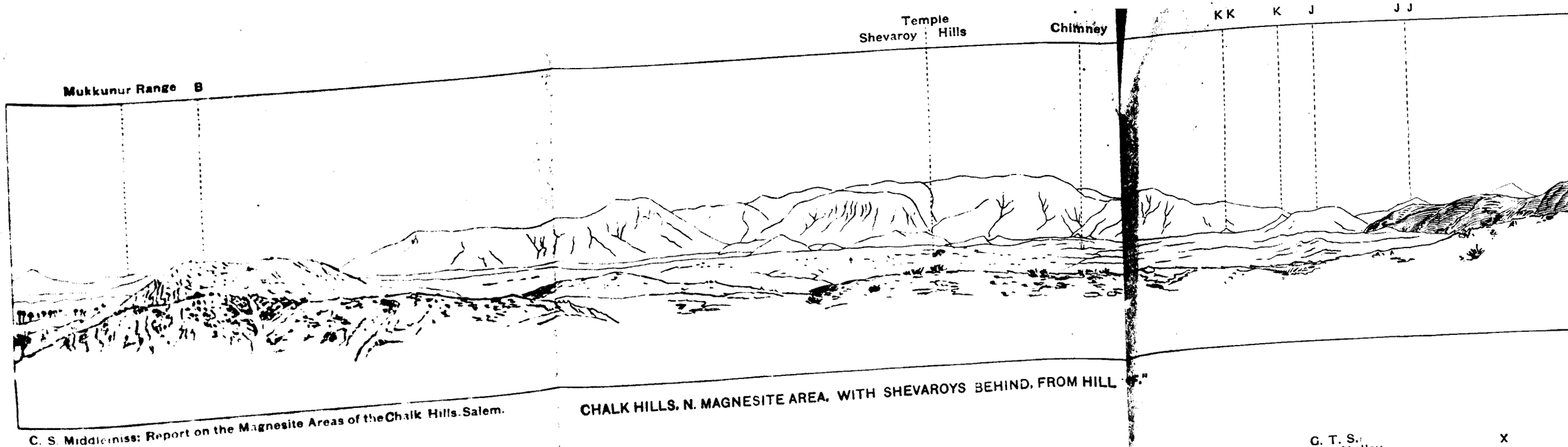
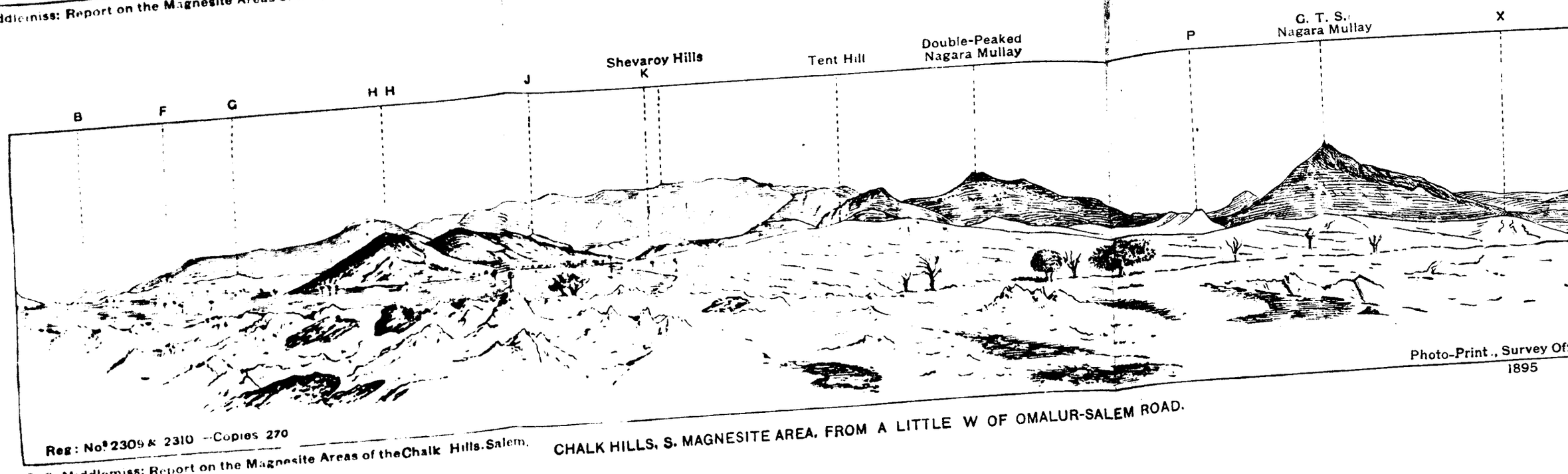




C. S. Middlemiss: Report on the Magnesite Areas of the Chalk Hills. Salem.

CHALK HILLS, N. MAGNESITE AREA, WITH SHEVAROYS BEHIND, FROM HILL "F."



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CHALK HILLS, S. MAGNESITE AREA, FROM A LITTLE W OF OMALUR-SALEM ROAD.

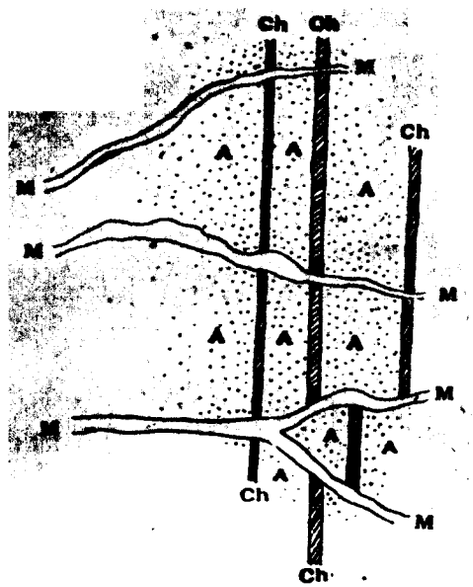

FIG. 1.

A = Serpentinised Dunite.
Ch = Veins of Chromite.
M = Do.: Magnesite.

Scale

0 3 6 12 inches

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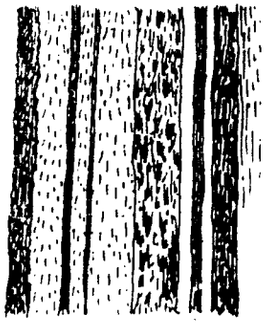

FIG. 1

BANDED ANORTHITE HORNBLENDE GNEISS

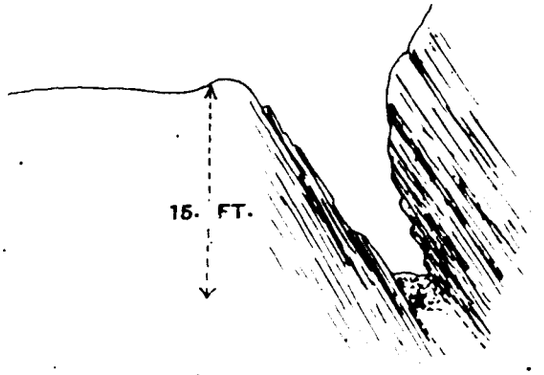

FIG. 2

RED CORUNDUM MINE

(Section across)

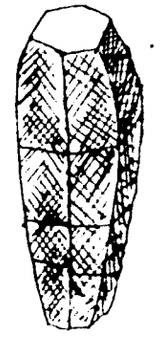

FIG. 3

CRYSTAL OF CORUNDUM

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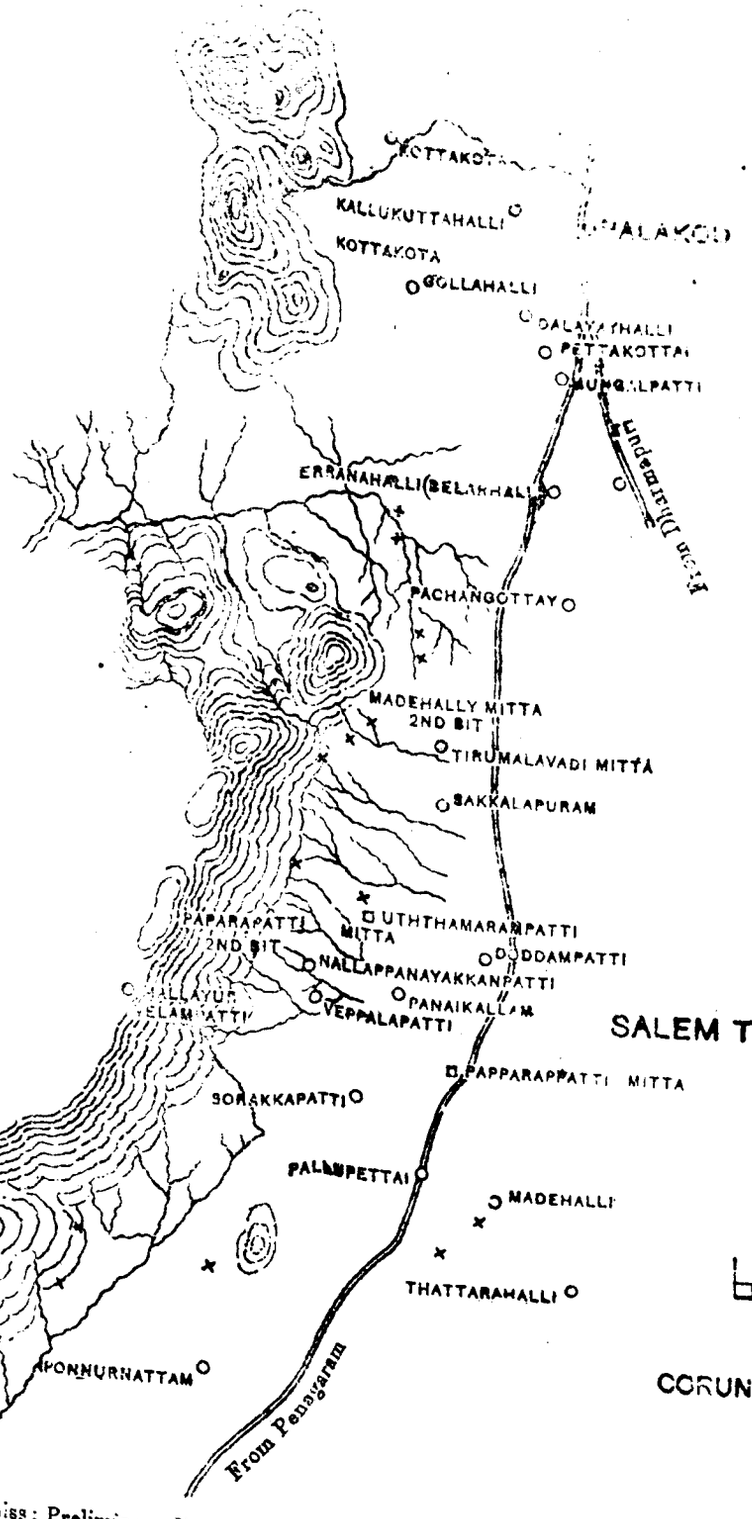

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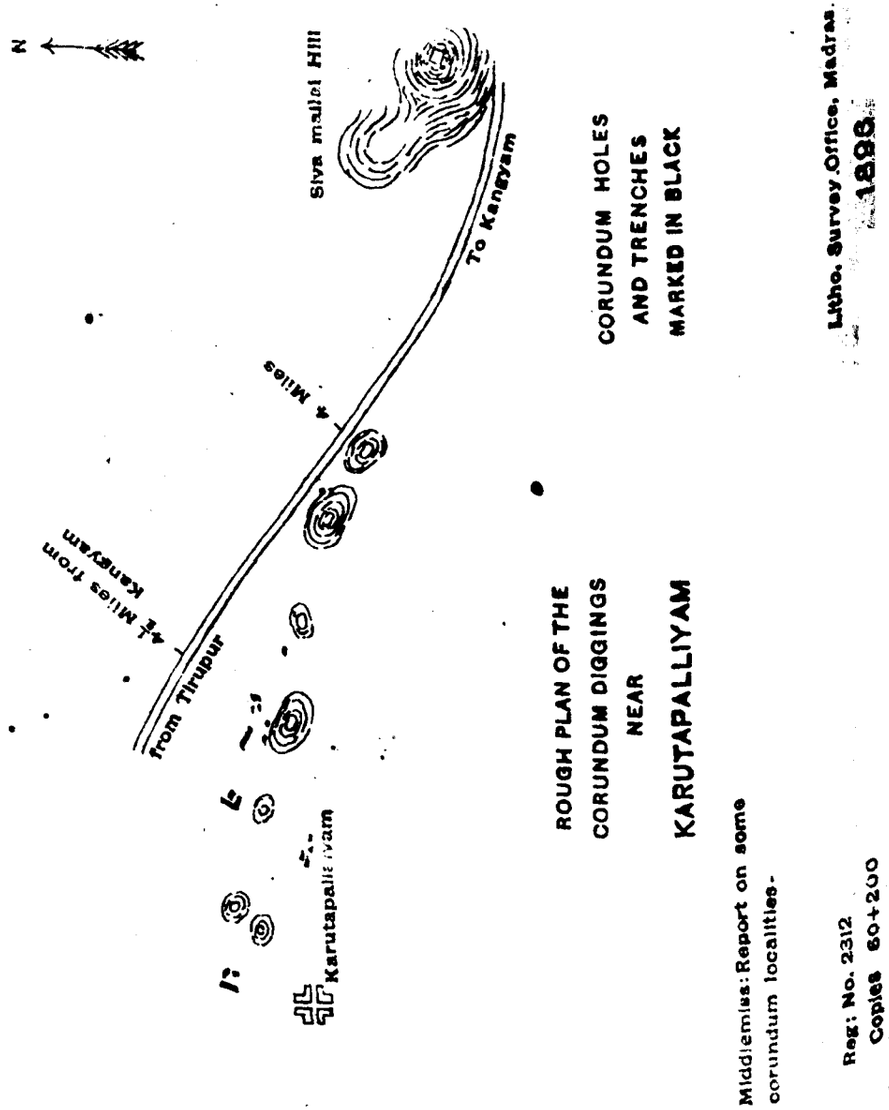

PRELIMINARY REPORT ON SOME CORUNDUM LOCALITIES IN THE SALEM AND COIMBATORE DISTRICTS.

Introduction.

In this report I shall merely endeavour to give a concise account of such facts as to the distribution and occurrence of corundum in the districts referred to under the above heading, as have up to the present been investigated by me. All discussion of theoretical questions arising from them, except in so far as such questions bear on the distribution of the mineral, will be left for a future more complete report, when these investigations have been brought to a close.

A few remarks of a general nature have already been made by me in my progress report for the working season 1893–94, and reproduced in substance in the annual report of the Geological Survey for the year 1894 (*Rec. G. S. of India*, vol. XXVIII, pt. 1, p. 3), and in two letters to the Government of Madras; one dated 7th August 1894, and one dated 5th October 1894. I need not do more here than refer to them, as all important details contained therein will be embodied in the present report.

Corundum localities visited by me.

The following is a list of the localities where corundum has been examined by me :—

(1) Sithampundi or Sittampundi, near Solasiramani (Sholasigamani), Námakkal taluk, Salem district.
(2) Paparapatti and neighbourhood, Dharmapuri taluk, Salem district.
(3) Rengopuram, Dharmapuri taluk, Salem district.
(4) Road from Dharmapuri to Morappur.
(5) Selangapalaiyam, Bhaváni taluk, Coimbatore district.
(6) Gopichettipalaiyam, Coimbatore district.
(7) Karutapalaiyam, Coimbatore district.

The following localities, though they have been quoted as corundum localities, have proved not to contain corundum in

some cases, or else local information on the subject was found to be wanting:—

(1) Yellagiri hills, near Jalarpet.
(2) Neringipet, Coimbatore district.
(3) Chinnamallai, Coimbatore district.
(4) Kanjikovil, Coimbatore district.

Descriptions of the Localities.

(1) *Sittampundi area.*

This locality lies a little east of the Cauvery river, and about five miles to the south of the boundary dividing the Tiruchengódu taluk from the Námakkal taluk. It has apparently been known for a very long time. Specimens of corundum and of the enclosing rock from it were described by Count de Bournon (*Phil. Trans. Roy. Socy.*, 1802, p. 282), and the place was visited by Captain Newbold and reported on by him (*Journal Roy. Asiatic Socy.*, vol. VII, p. 224). Lastly Dr. Warth of the Geological Survey visited and reported on it in two letters to the Madras Government, Nos. 540 and 606, dated 24th June and 16th July 1892, respectively.

Area.

The size of the area productive in corundum was given by Dr. Warth as 771 acres, but the village officers gave 1,000 acres as the estimated amount. It was also stated to be about four miles long and two miles broad in its widest part.

The part examined by me was about two miles long and varied in width from 100 yards to 1,000 yards. It lies south-west, south, and south-east of Sittampundi village, occupying a slightly elevated bit of rising ground running with its long axis west-north-west, east-south-east, at distances varying, according to the position, of from 1 mile to ½ mile from the village.

It was in December 1893 that I began my corundum investigations in the district at this place first on account of its being the one about which most information was obtainable. The following summary is based on the observations then made in the field, and on the subsequent examination of the rocks and minerals in the laboratory.

Rocks of the neighbourhood.

The rocks to the north of the corundum area consist generally of a great series of biotite gneissic rocks, covering large areas, and with bosses and veins of a coarse reddish granite bursting through them and often forming picturesque crags and precipitous hills, such as that at Tiruchengódu town, and the similar hills in the vicinity.

Actual matrix of the corundum.

But the actual rock present at the corundum workings differs from the above in being a gneiss or gneissic rock, of a pale silvery or pearly grey colour, streaked with black and consisting of anorthite (Indianite) and hornblende, chiefly, with accessory minerals garnet, and minute quantities of chondrodite (?). In structure the rock is a crystalline granular aggregate of anorthite, with rather elongated prisms of hornblende, sparsely or numerously arranged with their long axes roughly parallel to the foliation.

The rock is well foliated in bands which generally run perfectly straight, and which differ in the relative amounts of the pale mineral (anorthite) and of the dark mineral (hornblende) present. (See Fig. 1).

In some places the hornblende, in others the anorthite, make up nearly the whole rock. Garnets also become locally very numerous. The specific gravity of a specimen with but little hornblende and garnet was found to be 2·824. In this respect it closely resembles anorthite, the specific gravity being a little higher than that of the latter on account of the hornblende.

It is among this gneiss that the corundum appears, dotted about at random among it like porphyritic crystals of orthoclase in a granite. The mineralogical composition, structure, and general appearance of the rock-matrix here is plainly the same as that recorded by Count de Bournon from the Salem district, and named "Indianite" by him. The microscopical examination of the two rocks shows them to be practically identical.

Other minerals associated with the gneiss.

In some sort of association with the anorthite gneiss, which is not disclosed by any exposures on the ground, there must occur a very coarse binary granite consisting of quartz and pink or flesh-coloured orthoclase felspar, inasmuch as large pieces of the latter, and beautifully clear smaller fragments of the former are found scattered over the ground in perfectly fresh lumps and showing no trace of rolling by the action of water.

On each side of the *in situ* gneiss, which forms the rising ground, there are gentle slopes of the same rocks, partly or wholly buried under surface material formed of the broken-up gneiss, and with here and there a recent calcareous pisolitic tufa, derived no doubt from the decomposition of the lime-felspar (anorthite).

The corundum of the area.

The corundum occurs in two ways in the area:—

(1) In the bed-rock as described above.
(2) In the gentle slope of debris along with the weathered pieces of the bed-rock.

It is of a pale greenish-grey, rarely flesh colour, and occurs sparsely distributed among the parts of the gneiss which are richer in anorthite. It takes the form of irregular lumps averaging from one-fourth to one inch in diameter. They do not, as a rule, show the prismatic and pyramidal faces, though some specimens from this locality in the Survey Museum are in the form of short six-sided prisms, characteristic of corundum. They exhibit, however, rhombohedral cleavage, which may be detected as fine and very regular lines crossing one another at an angle of about 95 degrees, and ruled as it were at fairly regular intervals. These fine lines crossing one another in this distinct way are a good practical distinction in the field between this mineral and pieces of orthoclase, or other felspar, especially in the case of the flesh-coloured corundum, which at first sight may be easily confounded with the flesh-coloured felspar referred to in the previous paragraph. It is possible that some of the lines may indicate repeated twinning, but the difficulty of cutting microscope sections or of getting sufficiently thin cleavage flakes of the mineral, make it at present impossible to decide this point.

Nearly all these pieces of the mineral are surrounded by a shell of calcite, from one-fourth to one-eighth inch thick, in which they lie among the matrix. This shell appears to be left by the crystallising out of the alumina (corundum) from the lime-bearing felspar (anorthite).

The corundum found in the debris slopes is the same as that of the matrix rock inasmuch as the former is simply derived from the latter by weathering.

Red corundum or ruby of the area.

Besides the grey corundum noted above, and the flesh-coloured variety into which it passes, there are to be found fragments, generally minute, of red corundum, which very locally pass into ruby. The brighter coloured pieces of these, which are but seldom larger than one-fourth inch in diameter, were found by me only in the more hornblendic layers of the gneiss; and they lie in it surrounded by a shell of anorthite partly converted into calcite. These pieces are not generally transparent, but dull and opaque, and of a red-currant colour. But here and there minute points of a fairly translucent red colour may be detected, and I have no doubt that occasionally

rubies of value have been extracted from these rocks, as is reported traditionally and by Newbold (*Journal Roy. Asiatic Socy.*, vol. VII, p. 224).

Old corundum workings.

The grey and the flesh-coloured corundum are found all over the area to the south-west, south, and south-east of Sittampundi, referred to in page 12. The native workers have in some cases taken the trouble to break up the rock-matrix along the more rocky parts of the rising ground, and so to extract the mineral from its shell of carbonate of lime. But more generally it has been gathered by merely grubbing among the debris between the *in situ* outcrops and along the slopes. Shallow excavations of this sort a foot or two deep are to be met with all over the area. Women chiefly, but men also, take part in the search, which they conduct with the help of a small digging implement and a basket. The searchers pick about among the talus until they find traces of corundum. They then set to work to dig out a basketful of the material which is then gone over by hand, the fragments of corundum being selected readily and with certainty by those accustomed to the work.

I was informed that the grey corundum was sold locally at the rate of eight seers for the rupee, and that a man can collect that much in about fifteen days. The red corundum with occasional clear ruby particles is more locally distributed, and I only know of one set of small workings and pits at a point one and a half miles south-east by east of Sittampundi and south 8° (degrees) east of Anagherry hill. There are several openings along one line of strike running north-west by west and extending for about 100 yards, but most of them have since been filled up by the falling-in of the sides. One mine was about fifteen feet deep, cut out along the strike, and from two to three feet wide. It had been much deeper (several yards I was told) but had subsequently been partly filled in with rubbish from above. Two years ago, I was told, this mine was worked, and the red corundum sold in Tiruchengódu for 1, 2, 3 and 4 rupees, according to the colour, transparency, and size of the pieces. Figure 2 is a rough sketch section of the mine.

Emery.

A piece of emery was picked up by me at the surface of the ground south-west of Sittampundi, but the rock was not found *in situ* anywhere.

Uses of the corundum.

There seems to be no doubt about the practical uses to which corundum can be put as an abrading and polishing agent by armourers and lapidaries in the country. Mr. Ball surmises (*Manual of*

the Geol. of India, pt. II), that the consumption of corundum in India must be considerable, though, possibly it was larger formerly than now, as the trade of the armourer is possibly not so active now as it used to be.

Quantity of corundum available.

It is not possible without making some careful test experiments on a fairly large scale to say how much corundum, relative to the matrix, there is present. I was only able to make the following experiments with a few coolies in collecting the mineral from the surface—

9 coolies working 6 hours gathered 4 lbs. (size of pieces that of fine gravel.)
Therefore 1 coolie „ 8 „ „ 0·6 lb.

Another experiment gave these results—

10 men working 8 hours got 8 lbs. or
1 man „ 8 „ „ ¾ lb.

Another trial gave—

5 men working 8 hours got 5·5 lbs. or
1 man „ 8 „ „ 1·1 lb.

From these an average of about ½ lb. for one coolie working one day can be deduced.

Mining on a large scale.

If mining on a large scale in the bed-rock be ever undertaken and found profitable, we might expect a gradual extension of the productive area by the laying bare of rocks along the same strike, and by enlarging the present area of solid rock exposed after the surface debris had been cleared away. Hence my remarks in my letter to the Government of Madras of 25th October 1894, recommending that all facilities should be given to the leasing of the mines, so that their productiveness may be tested and data be obtained for future guidance. Inasmuch as the ordinary corundum occurs distributed in the bed-rock in the manner I have indicated, and not in veins or lodes in small and restricted places, there is no probability that the mineral will suffer a rapid exhaustion; because it is certain that the part now visible above the alluvium is only a fraction of what lies hidden beneath it.

(2) *Paparapatti area.*

Paparapatti lies ten miles north-west of Dharmapuri town. In a direct line, one and a half miles away to the west-north-west is a range of rugged hills, and between the two there stretches an alluvial plain with rock out-cropping here and there. Most of this plain is taken up with cultivation. The

corundum is widely distributed over the area. As an indication of what is already known of its distribution, I have traced an outline map from the one inch Survey map and marked with red crosses the places where corundum has been actually seen and found by me. It does not follow that this represents the limit of this corundum locality, but no information as to the extension of the areas could be obtained at the time of my visit, which was cut somewhat short by a pressing demand from the Madras Government to visit the magnesite area of the Chalk hills near Salem.

Nature of the neighbouring rock.

As in the Sittampundi area, the surrounding rocks of this neighbourhood are gneisses, or gneissic rocks with biotite as the dark mineral present. They are well foliated, with a foliation-strike approximately N.N.E.—W.S.W., that is to say, agreeing with the general trend of the hill-range to the west of Paparapatti. At the actual corundum localities there is, however, no appearance of a hornblende-anorthite rock such as is the matrix at Sittampundi. The rock, a biotite gneiss still, continues the same in character over the whole area, with the exception of a very local change, to be alluded to presently. Veins of a very coarse granite with red felspar and clear white quartz penetrate the gneiss, as well as veins of a closer-textured purplish granite. There are other intrusive veins of a dark compact trap.

The matrix of the corundum.

The actual matrix of the corundum in this area is apparently an altered form of the biotite gneiss. Elliptical (in section) or lenticular portions of the gneiss appear to have had their minerals re-arranged and altered; the dark mineral biotite segregates into an outer layer surrounding the lenticular portion, whilst the central parts of it remain more purely formed of deep flesh-coloured orthoclase (finely crystalline, and showing under the microscope a fine micro-perthitic intergrowth of possibly plagioclase) the amount of which varies with the amount of corundum present. Along with this changed appearance of the gneiss the foliation of the rock in these lenticular patches becomes much less pronounced and occasionally disappears altogether.

The size of these patches is sometimes as much as 3 or 4 feet long by 6 inches or a foot across where actually seen in the rock; but that they are in some parts much larger is shown by the huge lumps of the changed rock found lying on the hill-side.

On the hill-sides W.N.W. of Paparapatti the *in situ* gneiss containing these presumably altered lenticles, with corundum developed additionally, may be seen but rarely. Even then the hill-side is so completely broken up and weathered into loose, tumbled blocks that it is quite impossible to get any approach to a natural section showing the true relation between the areas of altered and unaltered rock.

The corundum itself.

The corundum here differs entirely in appearance from that of Sittampundi. It is of a deep purplish-brown or sometimes dark greenish-grey colour, and it is always regularly crystallised into hexagonal prisms with a great number of variously inclined pyramidal faces imperfectly developed, and so giving the prism an elongated barrel, or even spindle shape (see fig. 3). These elongated prisms lie towards the central parts of the lenticular patches of changed gneiss last described, arranged in any direction, but generally with a tendency to an imperfect parallelism of their long axes with the long direction of the lenticle, which itself again is roughly parallel to the foliation of the surrounding gneiss.

The size of the corundum crystals, cleavage, &c.

In size they vary from extremely minute grains and crystals, only visible in a microscopic section, to large crystals several inches long and from $\frac{1}{4}$ to 1 inch in diameter. The characteristic rhombohedral cleavage is easily made manifest by breaking the crystals and sometimes as in the crystal figured (fig. 3) traces of the cleavage planes are visible on the prism faces. Occasionally also a combination of the rhombohedron and prism may be seen in a single crystal.

Shell of Orthoclase round the corundum.

Besides the generally altered rock in which the corundum is embedded, each crystal is immediately surrounded by a shell of more compact orthoclase, generally flesh-coloured but sometimes white, having a thickness of from $\frac{1}{4}$ to $\frac{1}{8}$ inch. When a corundum crystal has been broken out or has dropped out from the rock, the place where it lay can always be distinctly recognised by this shell which remains behind.

Arrangement of the corundum-bearing rock in lines.

It is clear from the map that the outcrops of the rock in which corundum occurs lie in successive lines, roughly parallel to the strike of the gneiss, namely, N.N.E—S.S.W. This seems to show that the particular bed, or band, of the gneiss fruitful in corundum, is repeated by the foldings of the rocks, so that it appears several times at the surface. Should this

tentative conclusion be correct, it has a practical bearing on the amount of corundum in the locality, because it makes it very probable that the lines of fruitful rock which have continued as far as shown on the map will also continue further in the same direction in either continuous or broken outcrop.

Native ways of obtaining the mineral.

There are two ways of getting the mineral here corresponding to the case of Sittampundi, viz., (1) by working the bed-rock and (2) by digging in the talus of debris at the foot of the hills and slopes. No extensive working of the bed-rock has been practised; but the richer lumps have been broken up, when not too hard or too large for demolition by hand. Numerous shallow pits in the debris and half-decomposed rock have been made. In general, it may be said that the mineral is gathered in an unsystematic, casual way, not as a regular pursuit, but only during the hot weather or at times when the soil from an agricultural point of view requires no attention; also during times of scarcity. A good deal is also gathered at ploughing times and at any time, especially after rain, by being picked up when met with without special search. By these means at certain times the mineral is accumulated and sold in the market as a regular article of commerce. Merchants from Madras and Bombay, it is said, buy large quantities of it at intervals when the local collections have accumulated.

Working on a large scale systematically.

As in the case of Sittampundi, it is impossible to say whether working the mineral systematically would pay. Such a question can only be decided by actual experiment carried on in such a way that the correct average percentage of corundum obtainable from a given amount of rock may be deduced. Towards the south-west of the corundum-bearing area there is a stream of water which is said to be perennial. This could be turned to account in sifting the more finely distributed particles of corundum in the matrix, after breaking up and gentle pounding. These minute grains, at present overlooked, are as valuable as, or possibly more so, than the larger fragments, volume for volume; inasmuch as the corundum must first be reduced to the granular form before it can be used as an abrading agent.

The area as a whole.

On the whole this area near Paparapatti is a decidedly promising one. The amount of corundum present in the rock appears to be sometimes considerable, and the area of known outcrops is a large one.

(3) *Rengopuram.*

Locality limited.

So far as I know personally, and also by report, this locality is an isolated and limited one. At the same time it should be remembered that negative evidence goes for very little in such a matter as the recognizing of small pieces of corundum, and especially in uncultivated forest land, where the soil is never disturbed.

The actual place of the corundum is two miles N. by E. of Rengopuram, a village on the outskirts of the forest land near Penagaram.

Two pits.

Here are to be seen two pits a few yards apart. The newer of the two is about 15 feet long by 8 feet broad, and 5–8 feet deep, and is sunk through a rock composed of alternate layers of a felspathic rock and a hornblende gneiss. I could find no corundum in the rock itself, although I made a careful and prolonged search. The villagers and servants with me were equally unsuccessful. The mineral was, however, abundant in the surface debris overlying the edges of the mine. It is possible that this surface material may have come from a more distant point by a movement of soil-cap down the slope. The difficulty was to account for the mine which had been carried down some distance into the bed-rock.

The corundum colour, form, &c.

The corundum here is of a greenish-grey colour and is very much rounded and waterworn into holes, and even slightly honey-combed (facts supporting the belief that it came from some distance). Hexagonal short prisms were the prevailing forms which it assumed, and most of these showed a tendency to break up parallel to the basal plane, thus forming irregular plates. There is no good basal cleavage, however, the rhombohedral cleavage being the only noticeable one.

(4) *Road from Dharmapuri to Morappur near 6th milestone.*

The first of the two localities embraced under the above heading lies one mile south of the 6th milestone from Dharmapuri, at the foot of a low hill a little west of the foot-path. The nature of the rock and the mode of occurrence of the corundum resemble entirely those of the Paparapatti area. The exposure shows signs of having been worked within a radius of a few yards. I could not find, nor hear of any other exposures of the same rock in the neighbourhood. The low hill-range west of the Mukkunur range and that range itself are petrologically of different constitution. Here as before, however, negative evidence counts for very little. A band of the corundum-bearing rock may continue from this outcrop, though hidden from view at present.

The other locality is two miles north of the same milestone. There is no good exposure of the rock. A few fragments in a field alone reveal a few bits of corundum of a dark grey colour set in a very fine-grained fissile rock almost resembling a phyllite or schist.

(5) *Selangapalaiyam.*

Locality.

The first locality I visited in Coimbatore district was the above. The corundum occurs scattered in fragments and rolled pieces in a field extending from near Chinnanayakkanur to Selangapalaiyam.

Nature of the enclosing rock.

The solid rock of the neighbourhood is very imperfectly seen. There are no rocky masses and no quarries. So far as one can gather from fragmentary observations, the rock of the country here is a muscovite-biotite gneiss, with wavy foliation, and with veins of a coarse binary pinkish graphic-granite penetrating it irregularly.

The corundum, and mode of gathering.

The fragments of corundum are of a pale greyish-green colour, sometimes brown outside. It has no crystalline form, but is in irregular lumps varying in size from $\frac{1}{4}$ inch across to 1 and 2 inches across. Nearly all are rolled, but the rhombohedral cleavage is generally distinguishable.

The village karnam of Selangapalaiyam informed me that it was not gathered systematically, but picked up from the fields, chiefly by women, during the rains. Perhaps 25 or 30 maunds were gathered annually.

(6) *Gopichettipalaiyam.*

Locality.

This is a limited locality like the last and is simply a field, from the surface of which the mineral is gathered. The village magistrate owns the field, No. 94, which is about half mile north of the travellers' bungalow.

Bed-rock : Corundum.

The only rock seen *in situ* was a disintegrated and much altered hornblende gneiss. The corundum is of a dark brown colour, more nearly resembling that of Paparapatti than anything else. There was a fairly large quantity of it scattered over the field, the few of us present easily picking up pieces of the size of

walnuts. Old picked-over heaps of rubbish lined the edge of the field. The Revenue Inspector informed me that this was the only field near in which the mineral was found; that a contractor from Madras came annually and took away all the corundum he could find; that the latter employed 30 or 40 coolie women who worked for three months last year (1894) and collected altogether two large cart-loads; that each woman could collect ½ to 1 Madras measure (= Rs. 80 weight) every day.

This field struck me as being singularly productive. The rock beneath is probably very rich.

(7) *Karutapallaiyam.*

Locality.

The above village lies about two miles W.N.W. of Sivamallai, a prominent temple-crowned hill in the Kangyam taluk. Between the village and the hill there stretches a row of six or seven small rocky hillocks composed of the same gneiss as the hill itself. The hillocks in fact are structurally a W.N.W. continuation of the Sivamallai mass.

The neighbouring rocks.

Two rocks of different composition and structure are connected with the appearance of corundum at this place. The one is the pale grey gneiss of the Sivamallai hill, and the other a coarse granite intruded as veins into the gneiss.

The former is a very felspathic rock which in appearance resembles the anorthite rock of Sittampundi. It is composed almost wholly of plagioclase felspar and microcline in a granular condition. A small quantity of biotite or of hornblende and iron-oxide, with another minute mineral in small octohedra, zircon (?), occur as accessories. The last was brought to me as corundum by some of the Sivamallai villagers.

The whole rock weathers into large pale ochre-coloured blocks forming small tors.

Along the northern foot of these hillocks, between Karutapallaiyam and the Tiruppúr-Kangyam road and extending for a distance of one mile, there are a series of holes and trenches made by the owners of the lands, which reveal the coarse granite alluded to above. It is a dark red, white, and black non-foliated rock, composed of red or deep flesh-coloured felspar which is a form of orthoclase with minute intergrowths of probably plagioclase, quartz in sometimes very clear lumps, and biotite in large nests of small plates.

The corundum occurring in the coarse granite.

It is in this extremely coarse red granite that the corundum is found as large well-preserved six-sided crystals of a dark or light greenish-grey colour. The mineral appears in this completely unaltered rock as if it were a normal mineralogical constituent, or at least accessory, of the granite. It possesses no shell of any other mineral as in the case of the Sittampundi and other localities where the corundum is found in its matrix. There is nothing to suggest in this case that the corundum was formed subsequently to the matrix in which it lies; nothing to suggest a secondary origin for it.

This area is still under investigation, but in the meanwhile it is noteworthy that the corundum is dug chiefly in the granite along the line of contact (or very near it) with the gneiss.

This is not the place to introduce theories; but should the mineral be afterwards shown to be a contact phenomenon, then its presence in the gneiss at Sittampundi as a secondary mineral, and its presence in the granite of Sivamallai as one of the same age as its matrix, would be explained.

Mining the corundum: numerous holes and trenches.

The mining or digging out of the corundum near Karutapallaiyam is quite an active industry (1895) on a small scale. The fields on the northern side of the row of rocky hillocks of waste land have been taken up, not for the purpose of cultivation, but for corundum mining. There are a number of irregular holes and some few regular trenches, the latter following W. by N.—E. by S. (the direction of strike of the gneiss and of the intrusive veins of the granite) or at right angles to this direction. One of these was 30 yards long, 2 yards wide, and 20 feet deep. Another trench was dug along a direction N.E. by E. for 15 yards. It was 20 feet deep and 2 yards wide, and it followed the junction of the granite with the gneiss which here dipped 60° N.W. The largest and most productive working was close to the village of Karutapallaiyam. Here were obtained some very large crystals of corundum 6–8 inches across. I was shown a basketful of the mineral weighing about 14 seers (28 lb.) gathered during the day of eight hours by four men, their wives and little children.

A past generation are reported to have made a very good thing out of the corundum of this place, when the stuff sold for Rs. 40 per podi = 192 Madras measures. Now, I was told, only Rs. 30 would be obtained for the same amount; I cannot say how much confidence is to be placed in these figures.

On the whole I think this locality is perhaps the most promising that I have so far seen. It is the only one I saw in private land that was in active working.

Other localities near this place.

At Padyur, Shigrispalaiyam and Kundyankovil in the vicinity the mineral is reported. They will be visited in due course.

Summary and General Remarks.

From the preceding account, it is clear that the corundum deposits of Salem and Coimbatore, so far as they have been at present examined, are not confined to one well-marked stratum of rock, of a constant composition and definite horizon. The matrix may be, as we have seen, (1) anorthite gneiss, (2) orthoclase gneiss, (3) a fine grained schist, (4) a coarse graphic-granite.

Varied matrix of the corundum.

Thus the nature of the bed-rock of any area would not be a guide as to whether corundum might be found there or not.

It seems possible, however, that the presence in or near of a coarse granite, intrusive among the bed-rock, does represent a condition without which corundum fails to appear. Further discussion of this point is reserved at present.

Throughout the seven areas already examined the mode of distribution of the mineral in the matrix is generally the same, that is to say, it is a scattered distribution; the crystals or lumps or grains are dispersed at intervals through the rock like plums in a pudding, or porphyritic crystals in an igneous rock. The particulars of this distribution in the various cases under notice are of practical importance. (1) The richness of the rock varies within certain limits (which cannot be obtained without a prolonged practical test). (2) The presence or absence of a shell of a softer mineral, *e.g.*, calcite round the corundum, determines the ease or otherwise with which it can be extracted pure from the rock. For instance the Sittampundi rock is poorer than the Karutapallaiyam rock, but the former can be got out nearly pure whilst a heap of the latter is generally half felspar.

Mode of distribution of the mineral in its various matrices.

A scattered distribution.

Nowhere in the areas that I have seen does the mineral become massive and aggregated into layers or beds as in the well-known Rewah deposits of Pipra, described in 1872–1873 by Mallet (*Records G. S. of India*, vol. V., p. 20, and vol. VI., p. 43), where a bed of several yards thick (maximum thirty yards) is traceable for $\frac{1}{2}$ mile.

No beds of massive corundum as at Rewah.

As all corundum must be reduced to a granular coarse powder before it can be used by lapidaries, &c., it is open to

question whether a scattered distribution or a massive occurrence is the more easily manipulated form. Massive corundum would certainly present difficulties to the simple form of working adopted at present by the natives of Salem and Coimbatore.

It may be mentioned that the so-called "sand vein" of corundum at Culsagee and Laurel Creek, United States, which is loose and incoherent, and can be worked by the hydraulic process, is preferred to the more massive crystalline lumps, as it saves the labour of pulverizing (see *Mineral Resources of U. S.*, by T. M. Chatard, p. 714).

At Sittampundi, rubies have been found as detailed before in this report. Sapphires are also mentioned by Newbold as having been found in the valley of the Cauvery (*Journal Roy. Asiatic Soc.*, vol. VIII., p. 153). This is rather a wide field, and so far I have been unable to corroborate the statement.

Gem forms of corundum.

It may be mentioned, however, that the form and shape of the crystals in the Paparapatti and Karutapallaiyam areas and their mode of distribution very much resemble the like conditions under which the sapphires of Zanskar in Kashmir appear. In our area the colours differ by being of a dark greenish or reddish grey, whilst in Zanskar, they are of a bluish grey, which locally becomes a deep violet-blue (sapphire). The colouring of such minerals, depending as it does on accidental impurities in them, may easily vary. The finding of sapphires in the corundum areas of Salem and Coimbatore is therefore quite possible.

Corundum occurrences in these districts similar in appearance to that of the sapphires in Zanskar.

The mode of occurrence of the corundum in Salem and Coimbatore in rock masses which appear only at intervals above the alluvium, but which have a very extended distribution, shows that the area of productive rock is practially inexhaustible. As a petty article of commerce, therefore, so long as corundum is used in the arts, it will be worked in a desultory way. Whether it will ever rise to be an important item in the trade of the Presidency or not, depends on so many causes and conditions of demand, labour, opportunity, fashion, capital, boom, &c., that I can give no opinion thereon.

Inexhaustible supply of corundum.