

MINERAL SURVEY REPORTS JAMMU & KASHMIR GOVERNMENT.

ORE DEPOSITS

OF

LEAD, COPPER, ZINC, IRON
AND OTHER METALS

IN

JAMMU AND KASHMIR STATE

BY

C. S. MIDDLEMISS, C.I.E., F.R.S., F.G.S.,

Superintendent, Mineral Survey, His Highness' Government, Jammu and Kashmir.



BOMBAY:

PRINTED AT THE TIMES OF INDIA PRESS.

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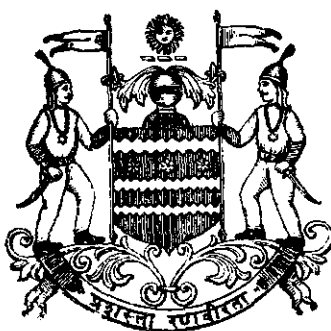
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P R E F A C E.

Excluding certain reports on Kashmir minerals published in the *Records of the Geological Survey of India* during the earlier years of the Mineral Survey of Kashmir, the present report on the ore deposits of some metallic minerals is the seventh of the present series, as issued by the Jammu and Kashmir Government.

Although the report appears under my name and responsibility, by far the greater part of the field work on which it is based, including the discovery of many new mineral occurrences, has been done by my colleagues, Messrs. Joti Parshad, Labhu Ram and Sohni Ram; whilst the chemical work quoted has been carried out, partly in the Prince of Wales College Laboratory, Jammu, and chiefly in the Industrial Laboratory, Srinagar.

This account will be followed shortly by others on the non-metallic minerals and the precious and semi-precious gemstones, etc. These, it is hoped, will appear as soon as they can be put through the press.

Subjoined is a list of published reports on Kashmir minerals that have so far appeared since the Mineral Survey started work in 1917 :—

- (1) Note on the Aquamarine mines of Daso on the Braldu R., Shigar Valley, Baltistan, by C. S. Middlemiss and Joti Parshad (published in *Records, Geological Survey of India*, Vol. XLIX, pt. 3, 1918, with plates 6 to 10).
- (2) Possible occurrence of Petroleum in Jammu Province: Preliminary note on the Nar-Budhan dome of Kotli tehsil in the Punch Valley, by C. S. Middlemiss (published in *Records, Geological Survey of India*, Vol. XLIX, pt. 4, 1919, with plates 13 to 16).
- (3) Lignitic Coalfields in the Karewa formation of the Kashmir Valley, by C. S. Middlemiss (published in *Records, Geological Survey of India*, Vol. LV, pt. 3, 1923, with plates 28-30).
- (4) Abrasives: Note on the Polishing material of Risin Spur Khunamuh near Srinagar, by C. S. Middlemiss (printed by order of the Kashmir Government, with plates 1 and 2).
- (5) The Graphite deposit of Braripura, Uri tehsil, Kashmir, by C. S. Middlemiss (printed by order of the Kashmir Government, with plates 1 to 5).

- (6) Ochre deposits of Nur Khwah, Rata Sar and Jhuggi in the Jhelum Valley, Uri tehsil, Kashmir, by C. S. Middlemiss (printed by order of the Kashmir Government, with plates 1 to 6).
- (7) The Gypsum deposit of the Lachhipura, Bagna, Islamabad, Limbar and Katha talas, Uri tehsil, Kashmir, by C. S. Middlemiss (printed by order of the Kashmir Government).
- (8) Bauxite deposits of Jammu province by C. S. Middlemiss (printed by order of the Kashmir Government, with plates 1-17).
- (9) A Resurvey of Jammu Coalfields : The Kalakot, Metka and Mohogala fields (with notes on the Chakar, Chinkah, and newly discovered Dhansal-Sawalkot fields) by C. S. Middlemiss (printed by order of the Kashmir Government with plates 1—25).

C. S. MIDDLEMISS.

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Ore deposits of **LEAD, COPPER, ZINC, IRON**
and other metals, in **JAMMU and KASH-**
MIR STATE, by **C. S. MIDDLEMISS, C.I.E.,**
F.R.S., F.G.S., *Superintendent, Mineral*
Survey, His Highness' Government,
Jammu and Kashmir.

INTRODUCTION.

The present report is intended more particularly to describe, and as far as possible delineate by means of detailed or sketch maps, the ore deposits of such of the useful metals in Jammu and Kashmir State as have recently come under examination by the Mineral Survey.

Whilst describing these as concisely and yet, I hope, as comprehensively as the particular subjects demand, my aim will be to include in this account only those investigations which have been carried out systematically by members of the Survey. No attempt will be made to include a number of scattered references to places and mineral occurrences taken from old books and office files, for which there is often only hearsay evidence, or evidence that is vague and indefinite. Such material is often a great help to the investigator in the field; but, until it has been verified and quantitatively restated, it is better omitted in a publication such as this.

Although this report deals with the ores of the principal metallic minerals, one important mineral, namely bauxite, the ore of aluminium, is omitted, since it has already been described in a previously published report of this series. (See Preface.)

On the whole the information able to be supplied about these ore deposits of Jammu and Kashmir is not very detailed or extensive. The chief reason for this is that, with the exception of a little alluvial gold-washing in the Indus river bed and its tributaries, and occasional spasmodic attempts to prospect for lead at one or two places, all primitive metal mining in this mountainous State, especially that of iron, copper and

lead, ceased long ago, though old pits and workings and the testimony of a few aged people demonstrate that the mining of these common metals was carried on within the memory of some still living.

There is consequently no present-day production to record of any importance. The ore deposits still lie almost untouched, awaiting the advent of economic conditions and enterprise that will enable them to prove their quality and the practicability or not of their being worked as modern industrial concerns.

The survey of the deposits has not everywhere yet advanced to the stage of large-scale delineation. Many ores of the metals, being in the form of lodes or veins, which are apt to take erratic courses underground and which often do not appear at the surface at all except in traces or fragments, cannot be described and mapped by surface survey work alone or with the help only of boring plant. Mineral lodes, as distinguished from bedded ores, can only be adequately known and described after they have been followed below the surface by expensive and protracted work such as trial pits, adits and tunnels. It is not a matter of surprise therefore that, during the short life the Mineral Survey has so far enjoyed, such work has hardly been begun yet in the case of mineral veins.

Thus restricted, I am hopeful that the present account of such survey work as has been done will be found accurate within the limits set. All localities are rigidly defined beyond the possibility of future mistakes. Quantities and sizes of ore-bodies are given whenever possible, together with analyses of them, and all are represented by specimens or samples preserved and registered in the collection of the Mineral Survey.

LEAD AND SILVER.

Deposits of lead-silver ore, in the form of galena, are known in Jammu and Kashmir, distributed sparsely in the older slate and schist formations, and in some abundance in the Great Limestone formation of the lower hills of Jammu Province.

In some abundance in the State. copper and iron, some of the lead-silver deposits of the State have been worked in a primitive way in ancient times and have even continued to be so worked spasmodically down to quite recent times—a form of industry however that cannot long survive unless reorganised on modern lines.

So far as the larger area of India itself is concerned, all other deposits of galena pale in significance before those of the **Bawdwin mines.** ancient Chinese-worked mines of Bawdwin in the Northern Shan States of Burma (worked originally for the sake of the silver, which the Chinese carried away leaving the lead behind in large accumulations). These deposits, which have now been extensively worked by the Burma Corporation (Ltd.) as a great metallurgical industry, since the year 1909, are believed to be the largest and richest silver-lead-zinc ore bodies in the world.

The Mineral Survey has superficially explored and described some of the galena occurrences in the State, but the **Partly surveyed only by the Mineral Survey.** veins and lenticles as a rule do not show at the surface, except in loose fragments; whilst ore-bodies in lodes or cavity infillings, unlike bedded deposits, must always be uncertain in their underground continuation. Hence, such deposits are difficult to detect, and, when found, they cannot be trusted further than they can be seen. Furthermore, detailed surveys of these ore-bearing areas have not yet been made on large-scale plans; so that there is obviously room for much intensive study of the ground, especially in the region of the Great Limestone, before we can say what the lead-silver resources of the State amount to. The information already obtained by casual discovery, and to some extent by more organised enquiry, is given below.

Buniyar (Hapatkhai N.)

This locality for galena is situated 2 or 3 miles south-east of Buniyar in lat. $34^{\circ}-6\frac{1}{2}'$, long. $74^{\circ}-12\frac{1}{2}'$. The **Situation.** Hapatkhai N. joins the Jhelum river $\frac{3}{4}$ mile above Rampur, which is only 5 miles along the Jhelum-Valley cartroad above the Mohura power-house.

Mr. Joti Parshad's exploration. Mr. Joti Parshad during the years 1912-1913, when he was Mining and Prospecting Officer of the State, was the first to begin a systematic exploration of these galena occurrences. They had previously attracted the attention of General Anderson's syndicate which had once applied for a prospecting license in that area, but apparently without any result. It is not known that any traces are to be found showing that the deposits were ever worked by primitive man in these parts.

The whole neighbourhood is a highly mineralised one. On the other side of the Jhelum there are extensive deposits of graphitic shale, of ochre, and enormous masses of gypsum (See printed reports on these subjects issued by the Mineral Survey). There is also ilmenite near Wari Khwah **A highly mineralised neighbourhood.**

and a certain amount of pyrrhotite and chalcopyrite associated with the lead ore which is the subject of this Section.

The galena occurs principally at various heights up to 2,000 feet above the stream on the right bank of the Hapat-khai nala and not far from the hamlet of Pran Kutrian and the Salnian forest. The hill slopes are very steep (about 40° and over), are deeply covered with forest of pine and birch and with a thick mantle of soil, rainwash and talus derived from the disintegration of the slate or phyllite rock, wherein are found with great difficulty the quartz veins containing the galena. A large boss of intrusive biotite granite lies a few miles to the south, and, in the other direction towards the north, there is a thick intrusive dyke of dolerite or gabbro showing much pyrrhotite and with a marginal concentration (magmatic segregation) of ilmenite as already mentioned near Wari Khwah.

After a short visit which the author paid to this locality in 1917, it was possible to appreciate the difficult task which Mr. Joti Parshad had set himself in endeavouring to prospect the veins and lenticles of galena which are so effectually hidden from sight by forest, grass and superficial accumulations.

As exposed in the bed of the side-stream north of Pran Kutrian, the country rock near the main galena locality is a dark chloritic argillaceous schist with occasional thin quartz veins an inch or so across and occasional, much foliated, dykes of Panjal Trap. Further north near Buniyar these argillaceous schists give way to quartz-schists, straightly foliated, the strike of which carries them round in the direction of Rampur, making the vertically bedded bold precipices so noticeable to the south and west of that place as one journeys along the Jhelum-Valley cartroad. Beyond this again, further north and north-east of Buniyar, these gradually give way to green schists (probably pressure-foliated Panjal Trap) and these to massive Panjal Trap much epidotised.

Joti Parshad had put down 10 pits, 2 trenches and 3 little tunnels within a few hundred yards of each other on the hill-side 1 mile due east of Pran Kutrian. By the end of the 1913 season he had come to the conclusion that the ore was present in nodular masses, thin strings and small patches, of finely granular crystalline galena with a few specks of chalcopyrite and malachite. Some of these nodules were at most 2 to 3 feet across but generally about 1 foot. He had collected from his workings ore weighing about 12 tons, leaving

about as much again in the mines. The drives he had made into the steep hill-side were only about 20 to 25 feet long, but they were sufficient to show that there was no true and continuous lode but that the veins probably were nodular and discontinuous among the contorted schist.

At this stage the prospecting work was discontinued, except that, by searching the hill slopes in the vicinity, a few other places were found where nodules and thin strings of ore were discovered. Some of these are indicated on the outline map (Pl. 3), but, as no large-scale survey had then or has since been attempted, it is impossible to give further explicit details as to these minor occurrences.

One other occurrence of galena is at $\frac{1}{2}$ mile N. of Limbar village (lat. $34^{\circ}-10\frac{1}{4}'$, long. $74^{\circ}-10\frac{1}{2}'$) and $2\frac{1}{2}$ miles N. by W. of Buniyar. It consists, so far as seen, of a few veinlets and lumps an inch or two across in vein quartz; but, from its position in line with those occurrences which are marked on the map (Pl. 3), it may well belong to the same set of veins as those of the Buniyar localities and so is given individual mention here. It is a little way outside the area shown in Plate 3 and has not been excavated or further explored by the Mineral Survey.

Chemical analyses were made of the mined galena by Mr. C. S. Fawcitt, F.C.S., Analytical Chemist, Bangalore.

Chemical analysis. One of these gave the following percentages:—

Lead	..	..	..	..	..	69.39
Silver (per ton of 2,000 lbs.)	..	..	..	..	..	42 oz. 7 dwts.

another gave:—

Lead	..	..	..	..	..	65.50
Copper	..	..	..	..	..	0.03
Zinc	..	..	..	..	..	0.93
Silver (per ton of 2,000 lbs.)	..	..	..	..	..	30 oz. 18 dwts.

Chemical analyses were also made by the above chemist of fragments of the vein containing galena with malachite, etc., with the following percentage results:—

Lead	..	..	..	..	..	30.45
Copper	..	..	..	..	..	1.80
Zinc	..	..	..	..	..	1.18
Silver (per ton of 2,000 lbs.)	..	..	..	..	..	13 oz. 17 dwts.
Gold	..	..	..	..	..	trace.

The pyrrhotite was analysed also by the above chemist. It gave no copper, nickel, cobalt and no gold or silver.*

* The specimen of pyrrhotite collected by the Mineral Survey from $\frac{1}{2}$ mile E. of Banali, Buniyar nala, was found to contain nickel by Labhu Ram and the Industrial Chemist, Srinagar, reported .06 per cent. nickel in it.

During the years that followed, some exploration of these deposits was done in a small way by a private firm without any appreciable results. **Applications for prospecting rights by private companies.** Prospecting rights were also asked for by another firm over the principal area explored by Joti Parshad, the intention being to hydraulic the hill-side in order to lay bare the veins of galena under the overburden of soil and rock debris. Although this method had the approval of the Mineral Survey as being perhaps the only one likely to be successful, Government sanction was not accorded to the application. Nothing further has been done since that time to prove the continued extension of the galena veins into the hill-side. On the evidence before me, supplemented by a later brief exploration by Mr. Labhu Ram, I think the proving of the veins by hydraulicking these steep slopes worth a definite trial.

Nigote.

The writer has not had any personal experience of this locality. **Locality.** The information given below is derived from manuscript reports submitted by Mr. Labhu Ram, Assistant Superintendent, Mineral Survey. Nigote is a sub-division of Riasi Tehsil, comprising the mountainous country between Sarmegan and the stream-bed south of Rahot Kot. It is shown on the map (Pl. 4), but without the name "Nigote" appearing, as lying immediately S. S. E. of the Chenab river. It is only 6 miles north-east of Riasi town, but the last four miles are over rugged hill ranges in the Great Limestone and includes several high passes.

The Great Limestone has a N. W.— S. E. strike and a north-east dip of 40°—55°. **Great Limestone and quartzite cap.** Near its junction with the Nummulitics it is covered by a certain thickness of quartzite-like rock the amount of which has not yet been determined. It seems uncertain whether this may represent a quartzitic phase of the Breccia or be a silicified portion of the Great Limestone. Galena was worked and obtained from this place from antiquity. All the old workings and tunnels are located on the northern dip-slope of the Khandwar ridge within a distance of half-a-mile from the border of the Nummulitic Series.

In the area between Kheri-Kot and Sersandu old workings are found in the "quartzite" capping the limestone. **Old workings.** Between Kheri Kot and the Anji river, to the south, the old workings have been made in the limestone, no quartzite cap being present there.

From the time of its original discovery (around which certain myths have gathered) till the reign of Maharaja Gulab Singh, the deposit remained the property of the people, who worked the original place, the so-called "old mine", to a good distance underground and probably obtained a large quantity of galena. In addition to the "old mine" the area was opened up at many other places by them, and the existence to-day of a great many old tunnels and drives bears testimony to the activity in mining displayed by the people at that period.

Mr. Labhu Ram was informed by the local authorities, including lambardars and old men, that, when the deposit began to be worked under official supervision in the reign of Maharaja Gulab Singh, all the mines except the "old mine" were closed, and that the work on the latter was resumed at a place underground called "draman", under an arrangement by which three-fourth of the outturn went to the State and the rest to the workmen.

In the year 1893, when the late Raja Sir Amar Singh visited the place, mining operations were stopped, partly because the great length of the workings made them not pay and partly because the latter had become dangerous.

At still later periods the mine was visited by Mr. J. Godwin, Engineer of the P. W. D., and in 1902 by the then State Engineer. In 1903 Mr. R. R. Simpson, then of the Geological Survey of India, inspected and reported on it.

In consequence of Lala Chuni Lal of Jammu having taken out a license to work the deposit in 1923, Mr. Labhu Ram was detailed to visit it and report on it for future reference.

He first visited the "old mine", which is situated $\frac{3}{4}$ mile west of Kheri Kot (a village of a few houses only), lat. $33^{\circ}-7'-12''$, long. $74^{\circ}-54'$, but he was no more successful than the State Engineer and Mr. Simpson in penetrating further into the mine than a short distance from the entrance. No first-hand observations therefore are available about this mine, except Mr. Simpson's statement that, after a careful examination of the walls of the tunnel, he found no trace of any tool markings—from which he concluded that the passage to the mine ran through a natural fissure.

Labhu Ram, however, collected some information about the mine from Phaggo, lambardar of Rahot Kot, who had been one of the workmen. Its total length was said to be $\frac{1}{4}$ mile, and that it took 4 to 5 hours to reach the end of the

mine and almost the same time to return. The course of the mine underground was said to be most irregular and in some places very narrow, at others very wide.

The amount of ore extracted and stacked in 1902, when the State Engineer paid his visit, was found to be about 60 tons, which Labhu Ram thinks can only represent three-fourth of what was obtained during the period of official control. No figures are available for the earlier period when the whole winnings went to the people.

Between the old mine and Sersandu, a distance of about 2 miles in a N. W. direction, some 5 or 6 main tunnels are found at varying distances apart, but most of these have collapsed and are almost hidden by vegetation.

In addition to them, there also exist a number of small pits, probably put with a view, to test the deposit at other places. Mr. Labhu Ram was informed that one or two of them still paid to work when the mining of the larger excavations had been given up.

Between Kheri Kot and Dinga Kot, in a S. E. direction he noticed some four or five old drives within a distance of $1\frac{1}{2}$ miles as the crow flies.

The one found $\frac{1}{2}$ mile W. of Dinga Kot forest had a N. E.—S. W. course and is an open drive. This is in the Great Limestone, and galena in patches in some cases 1 inch across are met with in it at a point some 16—17 feet from its entrance. No richer concentration in veins than these was noticeable.

Nearby there were other holes and openings probably intended for testing the deposit. The one 200—300 yards S. S. E. of the above, was put along the strike.

The general direction of the drives in the area is either S. W., *i.e.*, opposite to the direction of dip, or along the bedding, and therefore these may very well represent the general direction of the ore-bearing fissures or cavities in the area.

Mr. Labhu Ram also examined the small excavations made by Lala Chuni Lal. During the run of the first part of his license for 1923, the latter opened up the area between Kheri Kot and Sersandu at 6—7 places, but only discovered galena indications in two cases located $\frac{1}{4}$ mile N. N. W. of the Old Mine. He obtained some 25 seers of rock with galena occurring in dissemination in patches 1—2 inches across, and sometimes in veinlets 3—4 inches in length and $\frac{1}{8}$ th of inch across.

In the latter part of 1923, he (at Mr. Labhu Ram's suggestion) opened up a likely place about $\frac{1}{2}$ mile S. of Bakkal. There he struck galena in lumps, 2—3 feet below the surface, in some quantity, and next year in 1924 he entirely concentrated himself on working this locality and obtained some 100 maunds of galena in lumps in some cases weighing one maund or over. Of course this was started after Mr. Labhu Ram had left the place.

On being interviewed at Jammu, in January 1925, the licensee stated, that the excavation had progressed some 16 feet inside, the opening being 3 × 3 feet all along.

According to his statement, the galena does not run continuously, but was interrupted by lenticles and horses 3—4 feet in length, of barren rock at two places, within a distance of 16 feet or so, the remaining portion of the opening having a galena vein of from 1 inch to 12 inches in thickness, and that this was enveloped in "makol" clay and ochreous material.

From the above evidence, collected from Lala Chuni Lal and village authorities (including old men, Lambardars and Zaildar) and also from his own observations concerning the extent, size and number of the old tunnels and excavations, including the Old Mine, Mr. Labhu Ram infers that veins or rich disseminations of galena occur in this horizon of the Great Limestone at a moderate depth, varying from 4 to 20 feet below the surface; that they occupy fissures or cavities running either along the bedding or across it, in a direction at right angles to the dip, in the latter case, conforming, both in direction as well as in inclination, to the joints in the mother-rock; and that these veins or disseminations are irregular both in thickness and in the course followed by them, being interrupted here and there by lenticles or horses of barren rock.

Galena in this area is found invariably associated with either red or yellow ochreous material or "makol" clay or both, which form generally the outer portion.

Pieces of iron pyrites were also obtained from the Old Mine, the ochreous material probably being its decomposition product.

In one or two cases barite was also found associated with it.

At Sukhwal Gali galena is found associated with copper ores (see page 28).

Almost all the tunnels in the area are located near or in crags in the rock, where red or yellow stainings along with kaolin or makol are of common occurrence.

Position of old tunnels.

Since galena seldom or never shows itself at the surface, the following points were taken into consideration by the old workers for selecting the sites for putting drives or tunnels :—

1. The presence of yellow ochreous material at the surface.
2. The occurrence of “makol” or kaolin at the surface. As it was generally found that places where these conditions are fulfilled are the crags, it is owing to this that most of the old tunnels are found in or near them.

In addition to the above, evidences of galena are also noticeable at the following localities in the Great Limestone which form the eastern and western extensions of the Panoni—Bakkal galena-bearing zone, and therefore it may not be an exaggeration to say that the Great Limestone inlier of Trikta, Salal and Sangarmarg, towards the north near its junction with the Numulitics, is galena-bearing at intervals from Jangal Gali to Ikhini :—

1. **SUKHWAL GALI.**—Galena in dissemination associated with copper ores of Sukhwal Gali occurs in the Great Limestone and its associated chert. The matrix rock is very much decomposed, so much so that a little tapping with the hammer detaches galena from the rock. The deposit has not been examined in detail.

2. **JANGAL GALI.**—Mr. Godwin is said to have obtained galena in traces at a place 1 mile N. W. of Jangal Gali pass, on the western side of the Doodar nala.

On visiting the place, which is rather a difficult climb, Mr. Labhu Ram found three openings 10—12 feet in length in the quartzite that caps the Great Limestone, the thickness of which he could not ascertain on account of the difficult nature of the locality. He descended into some of these openings, and found no trace of galena. The length of 10—12 feet was rather small for test purposes, inasmuch as, if the deposit here is also similarly conditioned to that in Nigote area, it is necessary at least to pass through the quartzite portion of the openings, which has, as already stated, no connection with the origin of the deposit, excepting that it may have helped its precipitation by impounding the ore-bearing solutions.

3. **GOL NEAR IKHINI.**—Specimens of galena were obtained by Lala Joti Parshad from Gol, while he was at Chinkah. The exact description of the deposit is not available, but it is said that it also occurs in the decomposed Great Limestone.

The collection contained pieces sometimes an inch across and sometimes more.

Besides the above, other occurrences of galena are reported along that line, but none of them has been visited to confirm this.

As the result of a second short visit paid to Nigote area the next year (1925) Labhu Ram gave some more details of the excavations made by the licensee, Lala Chuni Lal, who had worked to some depth and distances of 20 or 30 feet underground at places $\frac{1}{2}$ mile S. of Bakkal and $\frac{1}{2}$ mile W. N. W. of Samat Khad. A number of lenticles of galena were found up to 9 inches across in a gangue of calcite, like that of the zinc blende veins and lenticles of Darabi (see page 35). These also seem to occur like the above in parts of the limestone that have been shattered and brecciated and that lie a short depth below the quartzitic covering rock.

Labhu Ram's second visit in 1925.

Some further observations were also made on other old mines in the neighbourhood. At Rainka Kot galena was found in calcite veins running in all directions in the limestone and associated with zinc blende and chalcopryrite (see page 40) and similar occurrences were noted at Ramala Dabar and in the old mines along the Rahot Kot stream. The calcite veins were a few inches to a few feet in length and $\frac{1}{4}$ to $\frac{1}{2}$ inch across, the zinc blende and galena being in about equal proportions in streaks 2 inches or over in length and a fraction of an inch across.

Further observations.

It was of course not possible to make any estimate of the amount of ore available in these old mines and new workings, because of the irregularity of the fissures in which the galena is present. Nothing but systematic trial over a good period of time and throughout a good area would enable any such estimate to be formed. Mr. Chuni Lal did not continue the work after 1925, and it is probable that transport difficulties over the mountains and from Riasi to rail-head at Jammu were the principal difficulties met with. It is manifestly impossible now-a-days to work metalliferous minerals in this primitive way, unless the amount of silver recovered is very great, or the metal is immediately required for some purely local market.

No estimate of quantity possible yet.

Other Minor Occurrences of Galena.

Galena, in small disseminated patches and spangles, is found in many other parts of the State. Some of these occurrences are noted below. They have become known by collections and brief notes made during other mineral investigations. Their value as ores is not known, because their connection with larger workable ore-bodies of galena is at present uncertain. They are put on record here simply to draw

Extent and value.

attention to the fact that galena is present there in some unknown amount, and in order that the subject may be further investigated when found advisable and convenient.

Ramsu neighbourhood (lat. 33°-20', long. 75°-12').—In September 1923 Mr. G. E. C. Wakefield, C.I.E., O.B.E., forwarded to the Mineral Survey specimens of galena from Dhanmasta, a village a few miles to the east of Ramsu. Later, Mr. Labhu Ram, whilst investigating the nickeliferous pyrrhotite of the locality (see page 50) found galena in certain rocks of the area, which comprise an enormous extent of slate, phyllite, and graphitic schist, with limestone lenticles arranged in two or three N. W.—S. E. lines extending for several miles along the stretch of country parallel to the river on both sides of Ramsu. (See page 51 for further details). The above are intruded by long bands of epidiorite, parallel to the above, and apparently at a later period by masses of gneissose granite and quartz veins.

The galena he found to be disseminated as follows:—

- (1) In the limestone lenticles along with pyrite and pyrrhotite.
- (2) In the quartz veins found in or near the great granite mass N. E. of Ramsu, and also in veins further away from it towards the south. The former follow the foliation planes of the granite and vary in thickness from 2 to 5 inches and are a few yards in length at the surface. They bear galena in lenticles 1 to 2 inches across. They were specially noted at a point $\frac{1}{4}$ mile S. W. of Dharni up the Pugal Gad, also near Makroli, 3 miles N. N. W. of Ramsu, and in veins with pyrrhotite N. W. of Gangro.
- (3) In the granite mass near Makroli as specks and eye-like lenticles.
- (4) In epidiorite bands.

The most important of these are the quartz veins and granite, where lenticles of galena are spaced at intervals of 1 to $1\frac{1}{2}$ inches, or sometimes less, so as to be practically continuous. In the other rocks it is only sparsely distributed in minute specks and very fine thin streaks.

A specimen of pure galena from Dharni yielded 0·1 per cent. silver which is equivalent to 29·35 ounces troy to the ton of lead, and is very much the same percentage as that yielded by the Buniyar galena.

From the apparent association of the galena-bearing quartz veins with the granite, Mr. Labhu Ram hazards the opinion that the former are genetically connected with the latter and represent the last phase of acid differentiation of the granitic magma.

Khaleni.—Mr. Labhu Ram has noted the occurrence of old galena workings at this place in the Chenab valley (lat. $33^{\circ}-8\frac{1}{4}'$, long. $75^{\circ}-31'$) and drawn attention to the fact that the Buniyar, Ramsu and Khaleni occurrences all lie in one N. W.—S. E. line, all are among an old slaty or schistose formation and in the first two cases at least are in proximity to granite intrusions. This N. W.—S. E. direction taken by the individual occurrences, and by them all taken together, is also the direction of the prevailing flexure axes (orogenic lines) of the Himalayan range. These observations are of obvious importance in searching out and discovering further occurrences of galena in the State.

Shumahal copper locality.—Galena in small spangles was found by Mr. Joti Parshad in quartz veins with copper minerals in the stream-bed $\frac{3}{4}$ mile N. W. of Shumahal (lat. $33^{\circ}-50'$, long. $75^{\circ}-17\frac{1}{2}'$). Other somewhat larger patches and small nodules were found by Mr. Sohani Ram in loose pieces of limestone on the hill-slopes east of Hapatnar village (lat. $33^{\circ}-50'$, long. $75^{\circ}-21'$) and in the Dudhpathar nala, 1 mile S. E. of Shumahal (lat. $33^{\circ}-49'$, long. $75^{\circ}-19\frac{1}{2}'$). These occurrences of galena are manifestly connected with the copper-bearing quartz veins of Shumahal and are probably distantly related also to those of Kangan in the Sindh valley (see p. 21) which lie due north-west, that is to say along the same line of Himalayan folding.

COPPER.

A number of copper occurrences are known in Jammu and Kashmir where they are distributed as lodes with a quartz gangue or as veins following planes of brecciation in limestone. In a few places these have been mined in ancient days, as is indicated by old pits and underground workings, just as has been the case in many other parts of India, where however none of these old copper-mining industries have as yet been revived successfully except very recently in the Singhbhum copper belt.

A certain number of copper ores in the State have been reported on by the Mineral Survey. Several of these, from the absence of old workings, appear to be new discoveries. As is the case with all other metalliferous minerals in India the working of them

Working them depends on establishing communications.

under modern conditions will depend on the opening up of the country by communication lines, on the co-ordination of related industries, and on the utilization of by-products.

They are described in the following pages in a certain amount of detail in order that the observations made on them in the field, the maps and sections recording the above, and the analytical work done on them may not be wasted and lost but preserved against the time when a revival of the metal industries on modern lines takes place, as it probably will at no distant date.

Shumahal.—Kashmir Valley.

The old workings for copper at the above locality have been known for long. They are mentioned by Vigne—
Locality. “Travels in Kashmir, etc.” (1846) and quoted from this source without further information in subsequent publications. The locality, as given in La Touche’s “Bibliography” (1918) is “Harpatnag” (lat. 33°-50’, long. 75°-23’-30”) which is obviously the village now known as Hapatnar, lying in the valley of the same name. Hapatnar is 1½ miles due east of Shumahal springs, and the latter is a few miles S. E. of Aish Makam (Eishmakam), on the Lidar river (Survey of India sheet 43 O/5).

The general geological structure of the locality and neighbourhood has been outlined in Lydekker’s work (*Mem. Geol. Surv. of India*, Vol. XXII, 1883) and more in detail by the present writer (*Rec. Geol. Surv. of India*, Vol. XXXVII, pt. 4, 1908-9 and Vol. XL, pt. 3, 1910). From the above it will be seen that the area round about Shumahal is composed of a very thick set of thin-bedded imperfectly cleaved phyllitic slates, chiefly argillaceous, sometimes sandy and micaceous and with occasional calcareous layers. This vast slate series is considered to be of Silurian, or older age, from the fact that it is overlain by a thin layer containing Silurian fossils at Guguldar, 2 miles N. E. of Shumahal. F. R. Cowper Reed (*Rec. Geol. Surv. of India*, Vol. XLII, pt. 1) has described these fossils as being of Llandovery or Ludlow age. The Shumahal rocks, then, may be regarded without much doubt as being Cambro-Silurian or older.

The locality of the copper mines was investigated in recent years by the Mineral Survey, Messrs. Sohani Ram, Joti Parshad and the author having taken part in this investigation at different times from 1920 to 1925.

Investigation recent-ly by the Mineral Survey.

The mine area is situated near the base of a steep little hill spur, 300 yards north-west of the *Ziarat* at the Shumahal Springs, and about the same distance north-east of Shumahal encamping ground, its height being from 150 to 200 feet above the latter. At the places where the old pits occur the sloping surface of the ground is broken up into rough crags owing to the impregnation of the country rock by harder quartz veins the pieces of which, scattered about, are everywhere stained. The surface has also been excavated in places, revealing old quarries and trenches in addition to the actual pits and underground workings.

In the plan accompanying this report (Pl. 5) the general relief of the surface is indicated by approximate contour lines, the outcrop of rough rock is shown by short strike lines, the surface excavations by "hachure" shading and the pits and underground passages by black squares continued as broken parallel lines. On this plan the common country rock, consisting of Silurian (or older) phyllitic slates, and the copper impregnated area, besides alluvium and surface scree and talus slopes, are also indicated. It will be seen that the last, near the middle of the plan, extends upwards and obscures a portion of the impregnated area.

The impregnation, or veining, of the country rock of slate with quartz containing the copper ore is of a very irregular character. It is not a single, double or triple vein traversing the slate rock, but a multiplicity of small veins and lenticular bodies, or stock-work, appearing and disappearing among the slate, and contorted with it. Whilst their general direction of elongation is parallel to the bedding and cleavage of the enclosing slate, their close assemblage and massing together in certain places give the general effect of a single vein mass 50—70 feet thick.

It would have been an impossible and unprofitable task to indicate these quartz veins even diagrammatically on the plan. The actual surface arrangement is not always very clear owing to disintegration into blocks and superficial movement; whilst it is improbable that any of the veins and lenticular layers keep constant in thickness and direction to any appreciable depth.

The one general truth that seems fairly established is that there is a quartz-copper ore impregnated layer, of the shape at the surface as shown on the plan, and which takes some course or other underground. When we enquire what that course below the surface is, we have two facts to go on and a possibly modifying influence. The facts are: (1) the general dip of the country rock, which is between 30° and 40°

N. N. E. as taken at the surface with the clinometer, and (2) the curve of the outcrop of the impregnation layer in relation to the surface configuration of the hill slopes. This latter gives much the same angle and direction, when plotted out sectionally, as that observed instrumentally at the surface. Hence we may consider that it is true for the main ore-body near the old mines that it is inclined to the horizontal at an angle of between 30° and 40° N. N. E. as shown in the sections (plates 6 & 7), or it may be somewhat steeper.

There are not wanting signs, however, that this parallel arrangement of the vein stuff with the bedding of the slates is fortuitous rather than necessary : a temporary companionship that need not continue far beyond what we can see. We observe such signs in some of the quarry faces, where nearly vertical ribs of quartz sometimes may be seen, and we also see indications furnished by the other quartz reefs that penetrate the country rock outside of the main mine area.

Whether temporary or not, their parallelism probably holds (at the actual locality of the mines) to depths down to ground-water level. If there be any gradual change of horizon of the assemblage of quartz reefs within the country rock it will probably be found to have taken place towards the vertical rather than towards the horizontal.

The old pits are marked on the plan A, B and C. Pit D is a shallow
 Old pits and under- hole put down a few feet only by Sohani Ram
 ground workings. in 1920.

Pit A is the only one of any importance. Its course is roughly shown in the plan and section. Primarily it is an incline working following generally the dip of the strata and shifting slightly laterally according to some circumstances with which we are not acquainted, but probably in order to follow the richer shoots of ore.

The workings include irregular widenings and lateral excavations in the upper parts, where no doubt the rich ore body or shoot took on an expanded character. Side workings that go a short distance and then stop may likewise have followed ramifications of the ore or may have been for trial purposes. Beyond roughly tracing the course of pit A, but little could be done to ascertain the character of the ore in the workings. The old miners probably removed all available material of sufficient richness, and since then the walls, roof and floor have become encrusted with the carbonates by percolating water. It would have been a long process cleaning all this off in order to see the nature of the richer ore, had any been left, and it was not considered feasible or advisable. A few samples were taken at random here and there but these are not of great interest.

The total depth from the surface to which this working goes is about 50 or 60 feet along the dip. From the section it may be seen that it penetrates to a level of about 6,540 feet (altitude).

Pit B starts a short distance below A and only goes for a short distance. It may have once joined with A and subsequently become blocked by rock falls. Pit C is a long narrow cleft possibly along a fault. It starts at a lower level (about 6,530 feet) and possibly was once connected with the quarry N. E. of it. Both of these are of small importance.

Besides the underground mining done by the old workers, it is clear that a considerable amount of excavation was also carried out at the surface itself. Although it is not possible, at this length of time, to say that all the holes, trenches and depressions were positively made by human agency, yet some seem without doubt to point to this conclusion.

The most noticeable of these is a long shallow trench to the west of pit B. This is about 100 feet long and is hachure shaded in the plan. It is partly filled with fallen rock and partly overgrown by shrubs. It has since been partly reopened.

The next shallow excavation appears to have been made in connection with pit A. Very probably the ore was found at the surface first and afterwards was followed underground by means of pit A.

The third appears to be a quarry excavated at a point N. E. of pit C and between it and the dry stream bed further east.

There can be no question that the primary ore was chalcopyrite disseminated in a quartz vein-stuff, and that this has been oxidised at the surface chiefly into malachite and azurite (the green and blue carbonates). No chalcocite or bornite, the grey and purple ore that are so characteristic of secondary enrichment, can be seen anywhere in the area, either at the surface outcrops or in the underground workings as far as they have gone. So that these minerals, if they exist, must lie at levels as yet unexposed. There is no surface cap or "gossan" of a definite ferruginous nature. This of course would hardly be expected on such steep slopes as are presented by this part of the Himalayan range and in a part of the country subject to heavy rainfall. Hence if such gossan once existed, it must have been entirely denuded away.

We may presume then, so far as the exposed parts of the vein at Shumahal go, that we are in the oxidation zone. In addition to the carbonates, in a few places there is a peculiar purple slaty variety of the country rock, which, besides

Opencast old excavations.

Primary and secondary ore minerals.

Zone of oxides.

containing films and veinlets of malachite, also shows veinlets of cuprite. It is true these are very small, but quite distinct, and pieces of this ore analysed as much as 2.1 per cent. copper. The purple matrix itself, apart from the cuprite and malachite, reacts for copper. It is not improbable I think that the old miners worked this variety of the ore, which may perhaps be regarded as a superficial enrichment in the oxidation zone, and there may still be veins of this left near the surface.

The primary chalcopyrite is very generally altered into a compact black or brown product, in which the unaltered particles of the shining brassy chalcopyrite can be seen to be embedded. This alteration product, however, reacts as strongly for copper as the chalcopyrite and is very probably black oxide or a mixture of cuprite and hematite or limonite. This product of change, which is markedly seen in the small pit put down by Sohani Ram above the springs, seems to be a further argument for regarding the portion of the vein so far accessible as being well within the limits of the oxidation zone.

The following specimens collected at the surface and from the pits Assays by Prof. B. K. Bose. and slightly selected from the richer fragments were analysed by Prof. B. K. Bose of the Prince of Wales College, Jammu, with the following results:—

Specimen.	Per cent. Cu.
Purple country rock impregnated by malachite and cuprite W. of pit B	2.112
Quartz veins W. of pit B	0.576
Quartz veins, Sohani Ram's pit above springs	1.92
Quartz veins W. of mine area	1.152
From pit A	1.536
From pit B	1.152
Average	1.408

It is not of course pretended that even this percentage would constitute a workable ore (though 1.5 ores are worked) but it does point to the possibility of better ore being found, possibly at lower levels, and especially so if we can hit upon a level of secondary enrichment anywhere in the lode.

It will be seen from the section that the depth, so far explored by the old miners, only extends a short distance downwards. Between it and the water level in the spring at the *ziarat* there is left a considerable space where the lode in its downward extension is still unknown.

In view of requests from the Kashmir Government to have the area prospected further, it was eventually decided to drill or tunnel into this portion of the hill. Certain arguments had been advanced by my Assistants against this action, on the ground that a zone of secondary enrichment was not likely to be found beneath the present surface. But, inasmuch as in this country we are without any actual recorded experience to guide us as to what happens in any similar case, it seemed better to explore down at least to the level of the springs and see what was, as a matter of fact, there. The tunnel idea had to be given up for the time being on the score of expense. Drilling consequently was undertaken. It failed, owing to certain difficulties explained below. It is advisable briefly to mention the results and difficulties met with for future guidance and avoidance.

The drilling work was done under the supervision of Mr. Joti Parshad, late Senior Assistant, Mineral Survey, at places selected by the writer.

Borehole 1: Calyx drill. Borehole 1 was made with a portable G. O. Calyx core drill. After 77 feet of slate had been passed through, 10 feet of broken quartz vein with malachite, and then a similar amount of ordinary vein quartz, were struck down to 94½ feet. Difficulties, in the way of caving and disappearance of the pump water, appeared, which were not overcome by cementing the hole and by using pipes borrowed from the Isler percussion drill.

Borehole 2. Borehole 2 was also made with the Calyx drill. There were alternations of slate and vein quartz for the first 25 feet, after which for 10 feet the drill penetrated into an old working, filled with loose pieces of quartz impregnated with malachite (probably an extension downwards of the quarry opening as marked on the map to the south). At 26 feet the pump water suddenly disappeared, just as in No. 1 boring. Cementing and piping were tried twice without

any good results. No further progress with these two boreholes was possible without piping the holes all the way, for which we had not the material.

Borehole 3 made with the Isler percussion drill, went down 80 feet in decomposed slate. At this point the hole had to be abandoned owing to jamming of the tools and breaking of the rods when the jacks were used to extricate them. This boring confirmed No. 1 in the view that the lode steepens more than was expected.

Borehole 4 was put down by the Calyx drill in an inclined direction at an angle of 40°, starting at a lower level in the hope that we might cut the ore body or lode at depth. After 115 feet had been easily bored in the slate, another 8 feet were done (with great difficulty owing to caving) in slate with some quartz stringers and traces of malachite. The tools then jammed and broke and the hole was abandoned.

It will be appreciated that the results of these borings were negative as regards the unknown depths below the old mine shafts. When the lode was struck at those levels the disappearance of the pump water and loss of tools and of the holes followed. It seems that it is impossible to use the Calyx drill on steep hill-sides among fissured rocks.

We are therefore still without the information sought. In the future it may be necessary to fall back on the tunnelling scheme to explore the depths in the vicinity of ground water level, where, if anywhere, we may expect to find some enrichment of the lode. In view of the failure of the drilling, there can be no certainty of this; but there is the probability that it may occur, which is strengthened by the fact that, though some sulphide still remains, the old workings, in the main, appear to be in the zone of oxidation.

It has been usual to presume that a lean ore of chalcopyrite at considerable depths precludes the possibility of any further enrichment at depth. That this, however, does not invariably happen has been shown recently by the record of the Mosaboni area of Singhbhum, where work carried out by John Taylor & Sons in 1920 proved that, beyond the impoverished zone, chalcopyrite began to make its appearance as small lenses of ore. At a vertical depth of 169 feet from the surface tunnels driven along the lode proved solid chalcopyrite in some places 2 feet wide, over

a considerable distance in length, giving values of from 10 to 25 per cent. of copper (Quinquennial Review of Mineral Production in India 1919 to 1923, *Rec. Geol. Surv. of India*, Vol. LVII, 1925, pp. 102, 103). The Singhbhum rocks are much more metamorphosed than those of Shumahal and probably belong to a deeper zone of original impregnation; but nevertheless, in view of our lack of knowledge concerning the behaviour of lodes in this part of Kashmir, I should recommend further sinking or tunnelling down to or a little below the level of the springs if it is desired to know for certain whether any richer ore is to be found there. This would not be a very expensive operation, and it would yield valuable information for or against its presence there, which again would be more profitable than theorising on imperfect data.

Besides the lode, or stock-work, at Shumahal as described above, there appear other small detached outcrops of it
Other near localities. veering towards the north in the nala $\frac{3}{4}$ mile N. W. of Shumahal and, in the thick pine forest $1\frac{1}{2}$ miles N. W. of the springs, Mr. Joti Parshad found thin irregular lenses of chalcopyrite with strings of malachite and azurite in quartz veins among a grey coloured limestone which appeared to be fairly rich in copper content. In Dudhapathar Nar, S. E. by S. of Shumahal and in the next stream to the N. E. just above the fields, loose blocks of vein quartz with copper ore were found by the author. If these two localities and Shumahal be connected up they give a general direction for the lode of N. W.—S. E. through a distance of about 3 miles.

A few miles further to the north-west, the ancient slate series, in which these copper-bearing quartz veins occur, disappears at the surface as a pitching anticline beneath the younger formations. Shumahal lies centrally along the axis of this pitching anticline. The next appearance in a north-westerly direction of these ancient slates is in the Sindh Valley near Kangan, where it is interesting to note that another copper-bearing quartz lode occurs (described elsewhere in this report see p. 30). There may very probably be some orogenetic connection between these two occurrences, a supposition that is strengthened by the direction being that of the general axis of folding of the Himalayan ranges here.

The quartz gangue and the lode-like aspect of the Shumahal copper deposits incline one to regard them as having been
Origin. formed by ascensional solutions in a moderately deep zone. Although in explanation of this there are no plutonic igneous rocks exposed among the phyllitic slates of Shumahal or its neighbourhood to the south-east, intrusions of granite do occur quite near to the Kangan occurrence. (See p. 30).

Rad nala S. of Panhasa.

This locality is on the left bank of the Rad nala, a short distance before it joins the Chenab river and half a mile west of the point marked 1516 on the Survey of India, Sheet 43 K/16. It is in lat. $33^{\circ}-10'-22''$, long. $74^{\circ}-45'-20''$. The villages of Doga and Panhasa lie respectively $\frac{1}{2}$ and 1 mile due north of it. Its altitude is 2,000 feet and its vertical height above the Rad nala is 250 feet.

The deposit is of a similar kind to that at Shumahal, although in this case it lies as a small lode along the bedding of the Great Limestone. It is a quartz vein dotted, spotted and sometimes veined with copper minerals. At the surface these are mostly the green carbonate, but within there is sometimes a little chalcopyrite surrounded and veined as at other places by the compact brown and jet black shining oxides, which appear to be mixtures of tenorite (melaconite) and oxide of iron, in the case of the former, and pure tenorite in the case of the latter.

This quartz lode differs from those at Shumahal, however, by some of the copper mineral being perhaps bornite in the form of irregular patches ramifying among the quartz and sometimes as continuous veinlets. The characteristic, finely granular or scaly appearance of this purple and iridescent ore, and a rough qualitative test, seemed to point to bornite. A concentrate of this, picked out from the broken up rock, however yielded the following part analysis done by the Industrial Chemist, Srinagar:—

Copper 42.11, iron 8.44, sulphur 5.32 and silica (presumably an impurity) 11.32. The small percentage of sulphur here shown indicates in any case a small total amount of sulphides present.

The lode here is only 2 feet thick, and, so far as explored by pits along its course, only 50 feet long. Except for the fragments lying on the talus slope, the vein was not visible until excavated along the strike at the top of the talus slope and at the base of a nearly vertical crag of the Great Limestone which dips at 20° northward. The bottom of the lode is marked by a layer of soft chocolate-brown earthy material. This only gave a faint reaction for copper, and is doubtless mostly iron oxide. Pieces of the ore collected from this lode were analysed in the Industrial Laboratory, Srinagar, and gave 5.13 per cent. copper.

The lode was discovered by Mr. Sohani Ram in 1923 when surveying the bauxite and was visited by the author in 1924, with the idea of using the newly imported G. O. Calyx drill to bore into it. The steep limestone crags above rendered this, however, impossible and the small size of the vein, as so far made visible, was also against this idea.

The Rad nala at this place runs east along an anticlinal fold in the Great Limestone ; so that the copper lode here is a strike lode and had found its way into a crevice along the bedding and near the axis of the fold. Both the copper bed of Gainta and the zinc blende of Darabi are associated with brecciation and a limestone gangue. In the case of the Rad nala there is no brecciation, the gangue is vein-quartz instead of calcite.

Although the vein is only 2 feet thick at the outcrop and 50 feet long, the promising yield of 5.13 per cent. copper shown by the analysis made of the few specimens gathered, suggests that further exploration and excavation in the neighbourhood, and some following of the vein underground would be desirable. As the map (Pl. 8) shows, the outcrop is 250 feet above the Rad nala, so that there is plenty of room here as at Shumahal for more enrichment in the secondary copper minerals to have taken place between that level and the level of the river.

Gainta.—Riasi District.

The copper occurrence at Gainta may be taken as a typical local instance of a deposit which has an extended, though intermittent, outcrop throughout a distance of 16 miles, from near Jangal Gali (on the south-east) to Sersandu, near the Chenab R. (on the north-west). Its devious course, following generally parallel to that of the outcrop of the younger formations above, can be understood from the map (Pl. 4) where also it is seen to form a portion of the Great Limestone formation, a feature which will be referred to again later.

We owe the discovery of this copper deposit to Mr. Labhu Ram who has laboriously traced its course, firstly on the 4-times enlarged portions of the Survey of India sheets 43 K/16 and 43 O/4 reproduced in Pl. 4 and afterwards, for the particular neighbourhood of Gainta, on a specially constructed large-scale plan. Pl. 9. There are no old mines associated with this deposit to indicate that it was ever worked in bygone times. In the remarks which follow I draw almost entirely on the descriptions furnished by Labhu Ram in his reports.

The village of Gainta lies $7\frac{1}{2}$ miles E. of Riasi, up the Anji river, in
Locality. latitude $33^{\circ}-5'$ and longitude $74^{\circ}-58'$.

It is a village of several huts and the water supply for the main vil-
 lage comes from a spring or two, but its eastern portion lies on the bank
 of the Lajor Khad whence it gets its water supply and where there is a
 good site for a camp. The Anji Khad flows 700—800 feet below the
 village on its north and east sides.

The village lies at an altitude of 4,000 ft., and therefore all mining and
 survey work can be carried on for the most part of the year.

Besides the route *viâ* Riasi, Gainta is also approached from Tikri
 (a place on the Banihal cartroad, some 30 miles from Jammu), the latter
 route involving a good climb up to Sukhwal Gali (7,000 ft. above sea
 level) and down again to Gainta (4,000 ft.).

The ore-bearing horizon occurs in the Great Limestone, some 2,400 ft.
 below the Nummulitic series (see Section, Pl.
The ore-bearing horizon. 10) and consists of limestone and chert beds,
 which are characterised by yellow and red
 weathering, and are thinly bedded. It appears to belong to the category
 of copper deposits replacing limestone, in a tabular manner along the
 bedding, and especially along lines of fracture and brecciation.

The following is a vertical section through the ore horizon at Gainta
 in natural order :—

Above:—Chert and limestone beds with no trace of copper ore,
 changing to hæmatite rock at places.

- | | | |
|--------------|---|--|
| Ore-bearing. | } | <ol style="list-style-type: none"> 4. Yellow limestone, about 2 ft. thick, with traces of copper. 3. Red and yellow chert rock, about 4 ft. thick with traces of copper. 2. Yellow decomposed and partly silicified limestone, about $4\frac{1}{2}$ ft. thick, containing good impregnations of copper ore. 1. Massive blue-grey limestone with chert nodules, copper bearing, 1 ft. thick. |
|--------------|---|--|

Below :—Massive Great Limestone of great thickness.

The beds 1—4 contain copper ore, of which 1 and 2 constitute a good ore.

The copper-bearing beds have a low angle of dip as illustrated in the section (Pl. 10). The dip is towards E.S.E. with local irregularities.

The copper minerals occur impregnating the thinly interbedded limestone and chert beds, the impregnations being in the shape of streaks, veins, lenses and grains or patches traversing the partly silicified limestone in all directions. A diagrammatic drawing of a typical fragment of the ore bed is shown (Pl. 10a) where the streaks and lenses of chalcopyrite are seen surrounded by the black oxide. The latter also, as disseminated specks and patches together with malachite and azurite, may be seen impregnating the silicified limestone breccia all round.

In the case of lean ore, these veins streaks, or patches are wider apart and are very small, while in the case of rich ore, the veins streaks or patches are closer together, the veins in a few cases being $2\frac{1}{2}$ inches in length, $\frac{1}{4}$ — $\frac{1}{3}$ of an inch thick and over an inch wide.

The rich ore invariably occurs in brecciated portions of the silicified limestone bed, and represents incomplete replacement of the rock by the ore minerals, which are thereby quite irregular, except in so far as they, as a whole, appear to be confined to one particular bed of the limestone formation.

The main copper-bearing mineral in the ore is chalcopyrite. It occurs massive. This, on alteration, gives rise to a dull but sometimes jet black mineral, which gives reactions both for copper and iron, and hence may be a mixture of melaconite and some iron oxide, the proportion of copper and iron in it being about the same as in chalcopyrite.

The alteration of chalcopyrite to this mineral can be best studied under the microscope in thin sections where it is found that alteration starts along certain cracks in the chalcopyrite making a continuous aureole round it and extending into its mass as a number of closely ramifying veins. The dull black mineral, on further weathering alters to malachite, and the iron content either changes to limonite or to hæmatite, which last two minerals, being stable, are not affected by atmospheric waters, while malachite is leached out.

The ultimate result of weathering of chalcopyrite is either the limonite or hæmatite or both, which are generally found in the copper bearing horizon at places where the atmospheric weathering is active.

The chalcopyrite, the main ore in the deposit, gives reaction for iron, copper and sulphur. The variable intensity of its yellow colour, as noticeable in the hand specimens as well as in thin sections might be due to the presence of copper and iron in different proportions in it, the intensity of colour varying inversely with the amount of iron pyrite mixed with it.

An average sample of the ore bed gave the following percentages of copper, iron and sulphur, on being analysed in the Industrial Laboratory, Srinagar :—

Copper	..	..	..	5·8	per cent.
Iron	..	..	..	10·0	per cent.
Sulphur	..	..	..	3·0	per cent.

Some digging was done during Mr. Labhu Ram's two visits in 1925 and 1926 and a number of pits were opened as shown on the large-scale plan, Pl. 9. From pit 1 some large blocks of the brecciated and impregnated limestone were obtained, some of which are illustrated in the photograph (see Pl. 1). They were analysed by the Industrial Chemist, Srinagar, and gave 5·6 to 5·8 per cent. copper. On breaking up the blocks and hand-picking them, this was increased to nearly 20 per cent. Later a ton of this ore was extracted and brought to Srinagar for experiment*. Grab samples, taken unseen from all the 32 bags containing this ton, were made and the whole analysed at the Industrial Laboratory; when a much lower estimation of copper was obtained namely 2·7 per cent. for this ton of ore. This was not surprising since the pieces first analysed were of better looking ore.

During this second visit to Gainta in 1926 Mr. Sohani Ram was also associated in the excavation work when pits 1 to 9 were put down. As a consequence of the more detailed examination then made possible, it became clear that the richer brecciated portions of the limestone (where alone the copper ore was abundantly deposited) were not immediately continued downwards along the same bed, after some few feet had been excavated. At the present moment the excavations actually made leave it uncertain as to what direction these richer brecciated shoots of the ore take, or, if they are isolated patches, where they are likely to begin again.

Mr. Labhu Ram's conclusions, expressed in a communication dated 26th Feb. 1926, were that "copper in traces and some enrichment is found at the soft and decomposed portions of the outcrop and is distributed as minute particles, hair-like stringers and also as veinlets, streaks and patches, in certain cases a few inches across." He also considered that his observations prove "the copper-bearing nature of horizons 1, 2, 3 and 4 of the general section, 11 to 12 feet thick; though the nature of the deposit can hardly be ascertained from these data, to prove which more extensive development work is necessary."

* This was intended to be experimented with by Mr. L. Zutshi, sometime Mining Engineer to His Highness' Government, but this has not so far been done.

Mr. Sohani Ram made some careful plans and sections of the pits Mr. Sohani Ram's opened. Only in the case of pits 1, 2, and 3, 8 and conclusions. 9 did he consider that some copper ore or traces of it were noticeable. He concluded as follows : " In this area we have some evidence of copper ores, consisting of 2 or 3 ore patches and a few malachite and chalcopyrite strings, streaks and films, scattered here and there in the rock. A couple of these patches have certainly yielded very rich ore pieces and in one case over a ton of fairly good ore, but these patches—unless we can prove that they indicate hidden possibilities—are, or rather were, very few in number and apparently very limited in extent."

Since the above work was done by Mineral Survey officers in 1926, Mr. Zutshi's visit to the only other officer to examine it has been Mr. Gainta. L. Zutshi, Mining Engineer to the Government, during the early part of 1928. He set off alone to Gainta without fully consulting the latest work done there by the Mineral Survey. He found (as stated in his report) no ore *in situ*, except one small piece in No. 7 pit, and the 30 samples of clean rock taken by him, on analysis, yielded no trace of copper by tests sensitive enough to have detected one-thousandth of a gram. This negative finding, by one inexperienced in the local conditions, does not seriously disturb my opinion about the deposit. Negative evidence is never of much value, especially when, as in this case, it is balanced against positive statements of experienced field geologists, backed by the collection of a ton of ore analysing 2.7 per cent. copper.

In addition to the above, and the earlier analyses done on better-quality pieces of the ore which gave 5.7 per cent. Further analyses of Gainta ore. copper, the following samples were analysed by the Industrial Chemist, Srinagar. They represent collections made by the Mineral Survey during the 1926 operations :—

				Percentage of copper.			
Copper ore, Gainta, pit	1	..	..	..	..	..	2.25
" " " "	2	..	..	..	..	..	0.91
" " " "	3	..	..	..	..	..	0.60
" " " "	4	..	..	..	..	..	2.61
" " " "	8	..	..	..	..	..	1.35
" " " "	9	..	..	..	..	..	7.98
				Average	..	..	2.61

The average percentage above is very near in value to that obtained from the ton sampled, namely 2.7.

I think it is clear from the whole of the evidence that there is in the **Conclusion : Gainta Ore.** Gainta locality ore of the above quality, distributed along fracture lines in a particular bed or beds in the Great Limestone series. There must be other parts of the same beds that are barren. There are probably others here and there, that have yet to be exposed by more detailed working, which will show a quality approaching a 5 or 6 per cent. ore and be capable of being broken up and hand-sorted to something under a 20 per cent. ore. The problem for the future is to discover how these fracture lodes run and to lay them bare in their course through the copper bed.

It is necessary briefly to mention the evidence there is for the extension of the Gainta copper bed along the line of **Other localities along the outcrop : Sukhwal Gali.** Sukhwal outcrop, as shown on the map (Pl. 4). Starting at the south-east end of this line, the first place is marked by an exposure on the Katra-Sukhwal Gali footpath, $\frac{1}{4}$ mile S.S.E. of Sukhwal Gali village (or rather shop). Its height is 6,500 feet, lat. $33^{\circ}-2'$, long. $75^{\circ}-0'-28''$. Labhu Ram twice visited this place and collected largely from it after blasting the rock. He was much struck by the likeness of the copper bed there to that at Gainta, 6 miles away along the outcrop, in the nature of the section, its thickness and in the distribution and richness of the copper in it. The following is the section of the Sukhwal Gali exposure :—

North.

Above :—Thinly bedded limestone.

$4\frac{1}{2}$ ft. thick.	{	A.—Limestone and chert with copper ore and galena in specks—3 feet thick.
		B—F.—Chert layers with malachite at the base, and two layers of yellow-weathering limestone, a few inches thick. Total thickness $1\frac{1}{2}$ feet.

Below :—Limestone with chert, followed by massive blue-grey limestone.

South.

The bed exposed is 60 feet long, but it appears to continue for four-times that distance towards the west, but without showing any more ore in that part. The ore is primarily chalcopyrite, disseminated in the brecciated matrix in small specks, veinlets and lenses, the latter being 3 to 4 inches long and $\frac{1}{2}$ inch thick. There is also the black oxide alteration surrounding and penetrating the chalcopyrite and some malachite and

Size of the exposure : nature of the ore.

azurite. Galena also is associated with it, in a matrix of decomposed rock in bed A. Fragments weighing about 2 lbs. were collected there after some excavation had been done. The pieces of A bed with chalcopyrite, which were collected, gave 1.54 per cent. copper on analysis at the Industrial Laboratory, Srinagar.

The area between Sukhwal Gali and Gainta was not explored in detail, but the copper bed was met with at a few places and collected from without excavation.

Area between Sukhwal Gali and Gainta.

These are:—

(1) 200 yards north of Triкта peak (8,876 feet); (2) $1\frac{1}{4}$ miles south of Rimindi and (3) $\frac{3}{4}$ mile S.S.W. of Panchari Gali. At (1) and (3) the ore is similar to that found at Gainta and Sukhwal Gali. That at (1) was inferred from loose pieces in the stream beds to north-east of the inferred locality. (Similar loose blocks were found on the other side of the watershed by the author in the stream-bed near Purana Daruhr). At locality (2) only the top iron ore was sighted from afar.

In the area between Gainta and the Chenab the following points were visited:—(1) 1 mile N.E. of Lower Darabi, (2) $1\frac{1}{2}$ miles S.S.E. of Rahot Kot, (3) Chinala Kot, (4) $\frac{1}{4}$ mile south of Khandwar point (6,563 feet), (5) 300—400 yards west of Ramala Dabar, and (6) between Sersandu and Sarmegan. At localities (1), (5) and (6) only the top red iron ore was found, the copper-bearing horizon either not being exposed or having been overlooked, as its copper-bearing nature was not known at the time of the visit. At localities (3) and (4) the copper-bearing horizon was met with, but instead of chalcopyrite or malachite, there were only visible streaks and patches of red iron ore representing most probably the final alteration product of chalcopyrite. Only at locality (2) real traces of copper ore in the form of malachite were found.

Mr. Labhu Ram believes that the above occurrences constitute a definite bed in the Great Limestone running parallel to the overlying formations in a general way and so representing a definite horizon. It may even extend further north-west into other partly explored regions such as those embracing Matah, where a similar iron ore bed is known, and also the Rad nala (see p. 22).

It is not necessary to suppose that the ore is continuous and regular throughout the length of outcrop which has been identified and mapped. More probably it has been concentrated into ore shoots along brecciated portions of the bed. The problem appears to be to follow and trace out these richer portions, especially in areas such as near Gainta, where a beginning of more detailed work has already been done. The great

A definite bed: possible further extension.

Not continuous but probably concentrated locally into shoots.

length of outcrop should indicate a corresponding extension to the dip. Here too as at Shumahal (see p. 17) we seem to be in an oxidation zone, so that, at some depth below the present surface, we may not only find more shoots and patches of ore, but possibly a greater enrichment by concentration in brecciated parts of the bed.

Kangan area.—Sindh Valley.

In the summer of 1925 some small pebbles of chalcopyrite were found by a Biscoe schoolboy in the boulder-strewn bed of the Sindh river at Nunar village, 3 miles north of Gandarbal. Although about a pound weight was first obtained, further search at the spot by Mr. Joti Parshad in the boy's company, and later by digging in the river-bed, revealed no more pieces. On analysis by the Industrial Chemist, Srinagar, the pieces yielded 34·44 per cent. copper, and so were pure chalcopyrite. They were not much rounded, and could not have travelled far, so exploration during this and the following year was made by the above officer in the surrounding parts of the valley.

Eventually, in the neighbourhood of Kangan (See Pl. 11) a few places were located where similar copper ores in a quartz gangue were found, in some cases *in situ*, and in others approximately so. The principal of these is a quartz lode, a few feet wide, striking about north and south on the hill spur west of Najawan, and descending to the canal and river at the point where the hill-spur is washed by the river, $\frac{1}{2}$ mile below where it is joined by the Wangat stream (lat. $34^{\circ}16'25''$, long. $74^{\circ}52'5''$). Other places where copper ore with vein quartz were found and collected from, are $3\frac{1}{4}$ miles N. E. by E. of Kangan, high up on the western slopes of Karkut trigonometrical peak (12,346 ft.), and other places at the foot of the hills due north of Najawan across the Sindh Valley. These occurrences are not marked by any old workings and are all in the ancient slate rocks, of presumed Cambro-Silurian age, which occupy large areas of the surrounding parts. Among the slates occur several muscovite-biotite granite intrusions, the one on the left bank of the river being 3 to 5 miles wide, and, in its north-western extremity, reaching to within a mile or two of the Najawan lode. The hill-sides here are steep and forest-covered and difficult to explore. The investigation was not completed before Mr. Joti Parshad was detailed for other work. The following percentages of copper were found by the Industrial Chemist:—

Najawan lode	1·33
$\frac{3}{4}$ mile N. E. by E. of Kangan ..	0·484
Loose block, Poshkar nala	1·07

All this neighbourhood of the granite intrusions is well worthy of further study.

A few other places where copper ores are said to be found in the Sindh Valley are: Ganjwan nala, 5—6 miles S. W. of Gund, at Hangar and Tram Karam (probably Tram Kazam of the Survey of India map, as marked south of Thajiwas (Sonamarg) in sheet 43 N/7). The above information is extracted from notes made by the late Sir Amar Singh, K.C.S.I., at that time Commander-in-Chief in Kashmir. These places have not yet been visited by the Mineral Survey.

Other reported occurrences.

Kishtwar Area.

Dul Occurrence.

In the summer of 1927, Labhu Ram discovered this occurrence in the "Muth" quartzite formation, at a place 1½ miles E. by S. of Dul village, lat. 33°-22', long. 75°-47', consisting of several huts, in the Chenab valley. The quartzite forms a ridge, presenting steep scarps towards the W. and moderately gentle slopes towards the E. between the Amne N. and the Nagire N. (Survey of India, Sheet 43 O/15).

Locality.

The locality lies at an altitude of 6,000 feet.

The copper ore occurs impregnating the Muth quartzite, the impregnations being in the shape of streaks, veins, lenses, and grains and patches traversing the rock in all directions, most of them being along the bedding planes.

Mode of occurrence and distribution of the copper minerals.

In the case of lean ore, these veins, streaks, or patches are wider apart and are very small; while in the case of rich ore, they are closer together, and in certain cases being ¼ to ½ of an inch thick.

The main copper-bearing mineral in the ore is chalcopyrite. This on alteration, gives rise to a dull but sometimes jet black mineral, and ultimately to copper sulphate.

The presence of copper ore was noticed at three places within an outcrop length of ½ mile and width of 200 yards. The marked feature of these places is the presence of copper sulphate stains and incrustations which attract the eye from a good distance.

Sumjam Occurrence.

In the summer of 1927, while exploring the Sapphire Mines neighbourhood, Labhu Ram, located this occurrence of copper-ore in the hornblende biotite gneiss band in the Cambro-Silurian rocks of the area 300—350 yards N.N.E. of Sumjam, lat. $33^{\circ}25\frac{1}{2}'$, long. $76^{\circ}25'$, a village of one or two huts at an altitude of 10,200 feet.

In addition to the above band, traces of copper ore are also noticeable in other such bands of the area as well as in the granite veins.

The main copper-bearing mineral in the ore, seems to be chalcopyrite which gives rise to malachite on alteration.

Mode of occurrence and distribution of the copper minerals.

The copper ore is found disseminated in the rock, the disseminations being in the shape of streaks, veins, grains and patches, running in the direction of the foliation planes or occasionally across them.

The aforementioned occurrences of Dul and Sumjam have not been gone into in any detail but have only been collected from and briefly visited. Therefore their value as ores is not known. They are put on record here simply to draw attention with a view to further investigate them.

ZINC

Lower Darabi.—Anji Valley.

The hamlet of 2 or 3 houses, constituting Lower Darabi, is not marked on the 1 inch to 1 mile Survey of India map, sheet 43 K/16. It is situated in lat. $33^{\circ}5'$, long. $74^{\circ}55'-6''$, in the Anji stream bed, about a mile due north of the upper village of that name which is so marked on the map.

It lies in the very heart of the rugged Great Limestone country, and is approached from Riasi by the deeply eroded defile of the Anji river. This gorge is so shut-in by precipitous ridge-spurs that the path keeps to the river bed for most of the way—a route to be avoided when the stream is swollen after heavy rain. The confined nature of the ravine at Lower Darabi may be gauged by the fact that, on the 19th December 1925, my camp in the valley bottom only enjoyed fifteen minutes sun, which rose behind the hills at 10-50 and set at 11-5.

The place where the zincblende (sphalerite) occurs is indicated on the Detailed map and general map (Pl. 4) and more in detail on the sketch. specially constructed map (Pl. 12), reproduced on a scale of 1 inch to 400 feet. A camera lucida sketch (Pl. 14) is added to show the style of rugged limestone country prevailing there. The steep dip-slopes of the Great Limestone may be seen in that sketch inclined at angles of about 50° N. E. It is on these, and especially on the long slopes dotted with *Chir* pine, that the scattered outcrops of the veins of zinc ore occur, though not prominently enough to be able to be marked on the drawing.

The discovery of this occurrence of zinc blende was made by Assistant Superintendent, Labhu Ram, early in 1925. He first came across large boulders of ore measuring 200 cubic feet in the Anji stream bed, south of the village, and from these he tracked the deposit to its home on the hill slopes above. Local rumours to the effect that Mr. J. Godwin, of the P.W.D., had been shown specimens of it many years ago are current, but neither he nor any other officers who succeeded him have left any available record behind concerning it.

There are naturally no signs that any of the early miners, who so assiduously burrowed the hill sides elsewhere for galena, made any use of this other ore, the metallurgy of which was beyond the skill of those primitive workers. At the present day it is the principal ore of the metal zinc.

The zinc blende, or sphalerite, of this locality, as found *in situ* on the hill and in huge blocks and smaller lumps in the Darabi Khad and near its junction with the Anji R., is typically a very fresh-looking, massive, coarsely holocrystalline aggregate, usually of a pale to dark brownish or yellowish grey colour, translucent and with a resinous shining lustre, never black. On the freshly broken surfaces the cleavages are prominent and in the larger fragments they reflect the light in contiguous patches, each of from one inch to several inches across, with extraordinary brilliance, as the specimens are turned about in the hand. The whole of the ore is of this coarsely crystalline texture, whether constituting large masses forming the main veins and disconnected irregular lenses, or whether in smaller disseminated patches, of the size of nuts, distributed at the margins of the veins. There are no microcrystalline or compact varieties of the schalenblende type built up in concentric layers. Small specks and patches of a lemon yellow colour appear very sparingly among the sphalerite, suggesting the presence of a small amount of cadmium sulphide. With this exception the sphalerite is free from all other admixed ores.

The larger pieces of this uniformly pure and coarsely crystalline, splendid ore gave a specific gravity of 4.07 and the following percentage composition when analysed in the Industrial laboratory, Srinagar:—

Chemical composition.

Insoluble residue	..	..	..	0.13
Copper	..	..	..	0.064
Cadmium	..	..	..	0.174
Iron	..	..	..	0.87
Zinc	..	..	..	67.52
Sulphur	..	..	..	31.21
				99.968

The presence of indium, gallium and other rare metals was not determined by the Industrial Chemist, as the laboratory is without a spectroscope and the instrument at the Sri Pratap College, Srinagar, has not a sufficiently high resolving power.

The analysis speaks for itself, and, in particular, indicates an ore remarkably free from iron impurity.

The Great Limestone formation, among which the veins of zinc blende appear, is exposed across its full width in the river section from Riasi to Darabi and thence on to Gainta. It begins with its faulted junction $\frac{1}{2}$ to 1 mile east of Anji village and continues with a very steep dip of 70° to 80° E. by N. for some way, afterwards lowering steadily to 50° in the vicinity of Darabi, and still further to about 15° near Gainta, and finally steepening again before passing under the overlying formations. Thus the section exposed is apparently the eastern or north-eastern half of the Riasi dome-shaped anticline—the other half of which has been destroyed by the fault. For further details concerning the Great Limestone, please see the Section of this report describing the copper-bed of Gainta and the separately published reports on Coal and Bauxite.

The actual hill slope of limestone where the veins of blende occur is mainly a dip-slope. Such a slope, especially in steep country (though not too steep for soil and vegetation to flourish), is a difficult one on which to

Ore veins difficult to study.

unravel any particular geological structure. The isolated outcrops of the ore, as found in traversing it (with due regard to one's foothold) and which are represented as closely as possible on the large-scale map (Pl. 12) are not easy to fit together into a true representation of the lengths, sizes and disposition of the veins. Probably very many of the ore masses have slipped down from their original positions and in many cases, no doubt, that which is left now is only a fragmentary relic remaining over after erosion and disintegration by weathering and frost which have worked their will on it.

The veins do not attract attention by any prominent external features. There is no gossan, and differential weathering is not noticeable. The fresh-looking pale tints of the sphalerite, which is remarkably free from iron impurities, are not very different in appearance from the grey colour of the limestone, until actual breaking of the rock discloses the brilliant cleavage planes of the former. The weathered crust an inch or two thick, is all that is required to hide the veins in the great slabs of limestone. Neither here, nor elsewhere, (generally speaking) in this Himalayan region of rapid elevation and erosion, has there been produced, or at least retained, any definite superficial alteration zone of the veins. There is also in this case no oxidation zone marked by the carbonate and silicate, the thin weathered crust being immediately succeeded by the perfectly fresh sphalerite.

It appears, from the detailed work done by Mr. Labhu Ram and from a brief inspection of the more accessible portions of the area by myself, that the ore material, as described in previous paragraphs, generally lies surrounded by a gangue of calcite and also to a certain extent is invaded by other veins of calcite in the form of blunt drusy interruptions. These latter, when broken across, show rounded contours with a crusted structure, marked out by successive rows of minute specks of pyrites and by other slight changes of tint in the compact calcite. Against the boundary of these geode-like calcite invasions the cleavage planes of the large sphalerite crystals impinge sharply. The calcite of this inner compact material, and the coarser crystal forms which it assumes sometimes in the outer parts of the gangue, represent an unusually dense and hard variety of the carbonate which is probably somewhat dolomitic. The hardness is about 4, the density 2.8 to 2.9 and the solubility with cold acid somewhat less than with ordinary pure calcite.

This general structure of the veins of blende will be understood from the photograph of the large lump of ore reproduced in Plate 2.

Shown in photograph reproduction.

The ore lies in some cases in zones of local brecciation and shattering, filling spaces of brecciation or solution cavities (bb of the sections P1. 13) or along the stratification in crevices or joints which appear to have been enlarged by solution (aa of the section). In the shattered zone near Barun Wali Dabri, Thub Wali Dabri and Jaggo Wali Dabri (local names of different places marked on the map), the ore has a tendency to follow certain lines in the plane of stratification, which could be followed to a distance of over 500 feet, and consist in most cases of lenticles of exceptionally rich zinc blende of various sizes.

The ore occurs in zones of brecciation and in joints.

In the shattered zone of Cheeran Wali Phat, a large number of ore lenticles or irregular pieces are found scattered over an area of 750×400 or $300,000$ square feet, occupying the steeply inclined surface of the country which more or less conforms with the dip. These ore patches appear to constitute either remnants of a thin layer that has been ruptured or dissected by denudation, or a series of closely approximating lenticles.

Along stratification planes.

In the compact unshattered portions of the limestone, calcite veins, bearing zinc blende, are found coursing through it in all directions.

Irregular veins.

The ore lenticles vary in dimensions from a few cubic feet to as much as 576 cubic feet or 64 tons, the average being 60 cubic feet. The veins vary in length from a few inches to as much as 150 feet, and in width from a few inches to 10 feet (vein C of the map.) The patch of ore (D of map) over 100 feet in length is found exposed in the Cheeran Wali Phat, and it is likely that it may have a good thickness and width, but these were not able to be determined.

Size of lenticles and veins.

To get an idea of the yield in ore and calcite gangue from these partially exposed veins, the outcrop was blasted and broken with sledges into lumps of a size convenient to be carried down to camp. A rather large cooly load is illustrated in Plate 2. These were then further reduced by hand hammers to pieces, the size of road metal. It was then quite simple to sort out two grades, one consisting of pieces of pure sphalerite and another, of about the same quantity which was half sphalerite and half calcite gangue. To further separate the latter into its constituents it was necessary to crush it and wash the result. So far, then, as regards any ore-dressing and separation methods that would be necessary in treating this Darabi ore, they would be of the simplest. The above result also indicates roughly the scale of crystallization and the proportion of gangue that must be mined along with the sphalerite.

Ore and gangue.

As already stated the veins always carry some calcite of a particularly dense and hard variety. Occasionally calcite alone, as seen at the exposed surface, fills the vein.

Calcite veins. The biggest of these purely calcite veins that have so far been located in the area is situated about 300 yards south of Lower Darabi and is marked E on the map. It is some 800 feet in length and has a width of 5—6 feet in places, whilst at others it pinches out to a few inches. Unfortunately at the surface this vein did not yield any traces of zinc blende or other ores, but towards the south close by there are found a number of fragments and big blocks in the stream bed that appear to have dropped from it, which contain traces of chalcopryrite. It is possible that this calcite vein might turn out to be ore-bearing away from its outcrop. Another similar vein marked F, 20 feet in length and 12 feet wide, is found 540 yards south by east of Lower Darabi.

Several other assemblages of calcite veins are to be seen marked on the map in the Anji river bed half a mile below Lower Darabi, and at some intermediate places.

It would appear from the above descriptive part (most of which has been taken from Mr. Labhu Ram's original report containing the map and sections made by him) that the veins' of zinc blende may be reconstructed as in part consisting of gash veins, originally formed parallel to and across the steeply inclined bedding planes, owing to orogenetic forces of compression, and which were subsequently enlarged by the action of underground water. For the remainder we must postulate that the shattered and brecciated layer (*b* of the sections) has been directly occupied in the irregular intervening spaces by the zinc blende and calcite gangue.

Veins of zinc blende originally gash veins due to compression and shattering. Besides putting down a few pits near C vein and breaking away projecting crags in the upper part of D vein, no real proving of the area to the deep has yet been undertaken. Owing to the sporadic occurrence of the lenticles and veins, drilling downwards would be more likely to miss striking a vein than to succeed in doing so. The same remark would apply to any attempt to sink shafts into the layers of limestone below. Mr. Labhu Ram has expressed the opinion, gathered from his many cross traverses of the area made over most difficult ground, that the ore-bearing zone in the limestone as shown on the map of Lower Darabi, is between 380 and 400 feet thick. The particular field indications on which this estimate is framed are not given and there may be a certain amount of doubt attaching to this rather sanguine estimate. In any case we do not know anything by observation as to the extension of the ore-impregnated zone to the deep, below the present level of the Darabi Khad,

Thickness and extension of ore impregnated beds uncertain.

A certain amount of further information, based on detailed exploration of the bed of this side-stream, might be forthcoming at some future time, but I do not think that much advance will be made in this direction without actual mining. It is of course impossible, with such sporadic vein-ore, to make any estimate of the amount of ore available in the area. One could easily collect a few hundred tons, possibly a few thousand tons, from the scattered outcrops known, but, to predicate more would be to assume a bed-like continuity of the vein-impregnated area, which we can hardly do without more evidence.

The way in which the ore was formed and its ultimate origin are not very clear. Its invariable occurrence in the Darabi locality as very pure, coarsely crystalline, sphalerite, and the complete absence of schalenblende, or any tendency in the ore to a banded or crusted structure, certainly point to the conclusion that the deposit is a lode, or cavity infilling, rather than a metasomatic replacement, and probably that it was precipitated under high temperature and pressure conditions. But from what source the mineral solutions proceeded is obscure.

There are no plutonic igneous intrusive rocks known anywhere as penetrating through the enormous thickness and deeply eroded exposures of the Great Limestone; which again, with its layers of chert, has suffered no metamorphic recrystallisation. The only igneous rocks known as penetrating the limestone, throughout the whole course of its exposure in the great Riasi elliptical dome, are a few thin basic dykes of a gabbro or dolerite, found sparingly in the Barakh glen to the south of Sangarmarg, and N. of Pauni which are distant some 20 and 15 miles respectively from Lower Darabi. Hence their origin as primary ores in the deep vein zone or from plutonic intrusives is at least dubious.

From what has been said in other published mineral reports, the Great Limestone is suspected of being of very great age, since it contains no trace of any recognisable fossil remains throughout its whole thickness. We do not know of course what the subsequent history of this massive limestone formation has been, between the time it was deposited and the covering of it with the Breccia, Bauxite, Coal Measures, and the many thousands of feet of the Murree Series, the first of which cannot very well have been older than Gault or Cenomanian. We may presume that the gash veins, and the irregular channels of the shatter zone in the limestone where the masses of sphalerite appear, have allowed the injection therein of solutions from which the zinc ore was precipitated and that this injection may have

operated even for very long periods of time ; but, so far as the evidence at present goes, we cannot be sure that these solutions came ascensionally from plutonic depths and not otherwise by means of ordinary circulating ground water.

The mere absence of clean-cut straight fissure veins, traversing approximately vertically, has little weight in the argument, since such ideal lodes could hardly have formed in this part of the Himalayan area, and, as a matter of fact, they are quite unknown there.

We are then without any certain guide as to what happens or is likely to happen to this assemblage of irregular veins and lenticles of zinc ore at Lower Darabi when followed downwards ; that is to say whether they will feather out and disappear or continue, and perhaps thicken, and so form a considerable ore body to the deep. Nothing but extensive development of the area by exploration or by mining the deposit will be able to decide this question.

To explore them much further without working the deposits is hardly possible, and to work the ore profitably on a rather small scale for the extraction of the metal (notwithstanding the purity of the ore and the relative ease with which large masses of the vein material with its calcite gangue can be broken up and hand-sorted) would involve metallurgical operations novel to India. Should, however, the smelting of zinc blende eventually be started in some part of India (chiefly in order to treat the large quantity of zinc concentrates from the Bawdwin lead-zinc mines of Burma), it might be possible to experiment with consignments of our remarkably pure Darabi ore with some success. In that case an opportunity would be afforded to test the behaviour of the veins to the deep and so learn something further of their extension underground. The above problematical proceedings in any case are again obviously dependent on transport facilities being provided from the mines to Riasi and from there to the existing railway systems.

Other Localities.

Besides the Lower Darabi outcrops, other occurrences of zinc blende have been noted by Labhu Ram in the near vicinity and further afield. These are mostly small veinlets, but, from the appearance and habit of the mineral and its constant association with calcite as a gangue, they suggest a common origin with the Darabi veins. These smaller veins are less coarsely crystalline, as would be expected, and, in some cases,

especially in the higher horizons of the Great Limestone, where the ores of lead and copper are found, there are also found veins with galena in close proximity with the sphalerite. In examining the collections made from these places, I do not find that these two ores really mingle together : the veins of blende and calcite are generally, if not always, a replica on a small scale of the Darabi ore, that is to say the sphalerite is the only sulphide present, except for the lines of minute pyrites crystals in the drusy calcite veins which penetrate the blende. I have not seen any veins with sphalerite and galena forming an intimate mixture, such as is common in the Bawdwin ore bodies.

The following localities have been collected from :— (1) $2\frac{1}{2}$ miles E. by N. of Anji village, a lean ore with much calcite, also $\frac{1}{2}$ mile east of the above. (2) 1 mile north-east of Lower Darabi up stream : here there are two veins 100 to 150 feet apart, 10 to 15 feet long with many ramifications, and 3 to 4 feet wide. (3) $\frac{1}{4}$ mile N.N.E. of Lower Darabi (this is the locality where Godwin is said to have obtained specimens). (4) $\frac{1}{2}$ mile west of Lower Darabi, a spotted occurrence of sphalerite in calcite. (5) 1 mile N.N.E. of Triкта peak (see general map Pl. 4), in the stream bed many blocks and pieces of calcite with, in one case, sphalerite associated with galena. (6) Many places south, W.S.W. and S.S.W. of Rahot Kot. These are in the neighbourhood of the old galena mines and are generally small veinlets brecciating the limestone, the calcite and sphalerite very similar in a small way to those of Lower Darabi. At one place $\frac{3}{4}$ mile S.S.W. of Rahot Kot there is galena side by side with the sphalerite. (7) $\frac{1}{4}$ mile N. of Khandwar point, 6,563 feet. (8) Ramala Dabar, $1\frac{1}{4}$ mile N.N.E. of Khandwar point.

It is clear from the above related occurrences that zinc blende is a common and wide-spread mineral in the Great Limestone. In view of the difficulty of detecting sphalerite in limestone for reasons already given, and in view of the fact that it has never been mined or excavated by the early workers, I should suppose that there are many more unrecorded and undiscovered spots where this ore lies hidden. The Darabi occurrence on a dip-slope was the most favourable for exposing the ruptured veins over a large surface. In all other exposures it may well be that the absence of abundant blocks and float has not made evident the presence of the veins, which nevertheless may still be there in a certain discontinuous abundance. The whole of the area depicted in the general map (Pl. 4), as well as further away to the west and south-west, is worth the attention of the prospector, whether he be searching for lead, copper or zinc. The full content of this ancient limestone formation in ores of the baser metals remains yet to be discovered by intensive work.

Probability of many more undiscovered occurrences.

For similar reasons to those referred to before, the record of zinc minerals in other parts of India is a very brief one, except in those cases where it has been found in connection with other worked deposits, such as the famous Bawdwin mine of Burma, where it is intimately associated with galena, the two being mined together and the galena concentrated, and such as the antimony ores of Shigri in Lahoul and the copper ores of Sikkim.

IRON.

Ores of iron in this part of the Himalaya, as in most parts of India, were worked in primitive fashion from antiquity up to the time when the advent of cheap imported iron gradually, but completely, superseded them.

Primitive working superseded.

In a few conveniently situated parts of India during the last 20 years, however, this industrial revolution has been succeeded by the importation of European plant and processes for the local manufacture of pig-iron and steel from the very large and rich indigenous ores of India. At the present moment the Tata Iron and Steel Company and the Indian Iron and Steel Company are raising enormous quantities of ore and successfully smelting it for consumption in the land of its origin.

European methods established.

The introduction of western methods of metallurgy and manufacture stimulated the discovery of richer and better ores at a number of places, such as those of Singhbhum and Mayurbhanj. In the future it is only ores containing about 60 per cent. iron and over that will claim any attention from a modern iron-master. This is in sharp contrast to the very poor ferruginous laterites and sandstones and odd pieces of friable quartz-iron-ore schist that the primitive smelters of iron all over India were in the habit of using, either from reasons of necessity or convenience.

60 per cent. ores now only used.

A brief notice only, then, will be given in this report of a few of the iron-ores of Jammu and Kashmir, including some that have been smelted in the past and one new discovery that stands out very conspicuously by its richness and size; because, from what has been remarked in the preceding paragraph, it is only rich and extensive deposits that are likely to have any value in the future, when the successful manufacture of iron and steel has perhaps spread to this part of India.

Ores in the State.

From a mineralogical point of view, ores of iron are wide-spread throughout different parts of the State. It suffices to refer to one or two types such as the **Magnetite of Gangani.** magmatic segregations of magnetite in the granitic and dioritic intrusive masses of Gangani on the Suru river (lat. $34^{\circ}-8\frac{1}{2}'$, long. $76^{\circ}-8\frac{1}{2}'$) and which are probably also to be found in many other parts of the surrounding mountains. These, by their distance from any coalfield and their inaccessibility, are unlikely ever to have any commercial value.

There are also the more favourably situated layers and nodules of siderite, hematite and limonite, interstratified with the Coal Measures and Nummulitic formation of Jammu Province, and which have been described in the published report on the "Resurvey of Jammu Coalfields." These, though aggregating a fair total thickness, (except for the poorer quality clay ironstone bands at the base of the Nummulitics which amount to a few feet) only occur as layers of closely set nodules and flattened cakes an inch or two in thickness individually, but often distributed at a number of horizons in the Coal Measures. Such ores might well have been worked by the ancient iron-smelters, and might even be worked at the present day in connection with the associated coal seams. As a matter of fact they seem to have been completely neglected in favour of those next to be described under a special heading.

Iron-ores of the Bauxite Series and Breccia.

These ores appear to have originated along with the bauxite in the form of the green silicate of iron and aluminium, and to have first settled down and been deposited at the base of the Bauxite Series or to have been leached out of that series and redeposited in hollows worn out of the surface of the Breccia and subsequently folded into synclinal troughs and partly altered into the oxide at the surface. Good examples of these are seen in the northern part of C area Chakar and especially in D area where they are well exposed to view (see published report on Bauxite Deposits of Jammu Province). The iron content of many of these (chiefly in the ferrous condition) has been estimated by Mr. Wadia as frequently ranging from 16 to 55 per cent.

Probably a similar green ferrous silicate was the protore also of the iron-ores, (since formed from them) which are known to underlie the coal formation in the eastern parts of the Riasi ellipse, the working of which ores was applied for by the Erroll Syndicate just previous to the war, but was never sanctioned. R. R. Simpson in his **Iron-ore of Ladda slope.**

memoir on the Jammu Coalfields (*Mem. Geol. Surv. of India*, Vol. XXXII, pt. 4, 1904) refers to them in his descriptions of the coal sections, and it seems likely that extensive and thick beds of averagely good iron-ore are to be found at the above horizon, in the neighbourhood of Jangal Gali and other places along the Ladda slope. These ores have not as yet come under re-examination by the Mineral Survey.

The so-called Pauni or Barakh Iron-ore.

One of the most extraordinary sights met with in the bauxite areas west of the Chenab R., and especially in the Breccia. Chakar, Salal and Sangarmarg localities, is the number of old, overgrown, now partly filled-in, vertical shafts made in the Breccia in bygone times, but still remembered by the older inhabitants of the places. I have referred to these p. 4 of the Bauxite report.

These pits, which are 15 to 30 feet deep and 3 to 4 feet wide, are so crowded together on very many of the hill-spurs of Breccia that it is necessary to walk warily for fear of dropping unexpectedly into them. They are pierced into the extremely hard siliceous breccia, often only a few yards apart from one another, and all for the sake (so the inhabitants uniformly asseverate) of recovering what appear to have been trifling quantities of iron-ore from them.

I had several of these pits reopened and cleaned of their fallen debris and was only able to find very small nodules and pockets of hematite in the walls or bottoms of them. I also drilled with the G. O. Calyx drill into the Breccia at a spot surrounded by these pits, but did not succeed in striking iron-ore in any quantity. With some difficulty one of the most ancient men of the neighbourhood was brought into my camp at Chakar to tell us about the holes and the supposed ore won from them. We showed him fragments of pure specular hematite from the stream-beds, derived originally from the base of the Bauxite Series, we also showed him some of the abundant cakes of siderite, hematite and layers of limonite, which can be dug up everywhere without trouble from the Coal Measures and Nummulitics ; but these were waved aside by our visitor as not being anything like what the pits yielded. At last, by groping about the opening of the pits, he was able to identify some few tiny pieces of rotten earthy hematite, which he called "batti" as the particular ore for the winning of which the pits were made by the old workers.

Abundant slag heaps are scattered about the surrounding slopes, showing that smelting of iron-ore had been carried on there. Many of these slag pieces are still very rich in iron, developed as long blade-like crystals of iron silicate, richer I should say judging by the specific gravity, than most of the original ore smelted.

It seems that the iron, said to have been smelted at Chakar and other places from the ore collected from the **Worked under State control** mysterious barren-looking holes in the Breccia, was worked under the direct control of the State, and the workers got only one-eighth part of the total outturn for themselves as remuneration for their labours which were given free. In addition to this they had, as a concession, freedom from paying revenue for their cultivated lands.

The iron obtained was taken to Pauni or Barakh and sold there, **"Pauni or Barakh" ore.** and it appears that for some purposes it acquired a reputation and became known as "Pauni or Barakh iron." It has been stated that the suspension bridge spanning the Chenab R. at Ramban on the Banihal road was built of this Pauni iron.

That this sparse ore material, found deep down among the Breccia, **Stages of alteration of green silicate.** has been derived by oxidation and leaching of the silicate protore of the base of the Bauxite Series above, seems the only reasonable explanation, and it is certainly borne out by the large collections which were made by us on the spot of specimens showing all the intermediate stages between the green silicate and its various hematitic and limonitic derivatives.

I have been indebted to my Assistants, Messrs. Joti Parshad, Labhu Ram and Sohani Ram, for much assistance and **An unsolved question.** suggestions in endeavouring to unravel the puzzle of the contents and meaning of the vertical shafts in the Breccia. There still remains however the fundamental question, why these old iron workers took such great trouble to riddle the countryside with innumerable pits in the hard and resistant Breccia, when any amount of equally useful iron-ore, and often much purer specular hematite, were lying completely untouched all round them, and easily obtainable from the soft shales or Bauxite Series of the overlying formations.

It is just possible that the "batti" ore, which they took such pains to obtain, was a self-fluxing ore, or that the iron produced from it had some qualities which were **A suggestion.** specially desired and not obtainable otherwise.

Iron-ore of Matah.

The iron ore of this locality occurs in a well-defined bed, 7 feet thick interstratified with the Great Limestone of the Riassi dome, on the right bank of the Chenab R., and coming between massive grey limestone below, in which chert layers are scarce, and thinner bedded limestone above, in which chert layers are more numerous. From Mr. Labhu Ram's sections it appears to be dipping about due north at 20° in the direction of Matah village. Its outcrop is readily seen by its red colour, which stands out vividly along the top of the lofty 6,000 feet ridge, marked Dargari Dhar on the 1 inch to 1 mile, Survey of India Sheet, No. 43 K/12, (lat. 33°—8', long. 74°—44').

Numerous old pits lie crowded together in the thick forest on the top of the ridge, as well as on the gentle northward slopes; and iron, said to have been smelted from the ore obtained from them, was shown to Labhu Ram at Thakaraktot. This iron, as well as the Pauni iron from further west, was also said to have been used in the construction of the suspension bridge at Ramban. Slag, too, is found all over the area, proving that smelting of the ore was carried on side by side with the extraction of it from the pits.

Labhu Ram has described the bed as a sometimes red, and sometimes yellow, ferruginous chert. Samples in the Mineral Survey collection, however, seem to be more of a fine-grained ferruginous shaly sandstone, in which concentration of the hematite has varied a good deal, but was never probably very rich.

Elsewhere (p. 29) it has been suggested that this bed is a westward continuation of the ferruginous horizon of the Gainta copper bed.

Hematite of Khandli.

This very rich and thick deposit is situated 11 miles N. E. by E. of the town of Rajouri (Rajaori), a little W.N.W. of Gagrot village at the foot of a steep slope leading up to Khandli Devi, in lat. 33°—25½', long. 74°—27½' (see sketch map Pl. 15). The large village of Piri lies below it in the valley towards the south-west. The deposit was discovered by Assistant Superintendent Sohani Ram in 1925, and further explored by him in the following year. It does not appear from the latter's account that the ore has been locally worked for making iron.

The geological relations of the ore appear to be quite different from those described in the Chakar and other areas in Riassi district. The most important of these is that the ore has nothing to do with the younger Tertiary rocks, or the older formations exposed in inliers among the Murree Series ; but occurs to the north of the Tertiary boundary among the older and different series of formations that build the main mass of the Pir Panjal range.

A section through the hill shows a great thickness of Panjal Trap Formations representing the bulk of the ridge up to and beyond its summit, with Agglomeratic Slate below. The latter in turn is underlaid by a massive limestone followed by quartzite and then by a great slate series.

It is at the base of the quartzite scarp, and lying upon the slate series, that the hematite is found. If analogy with the Kashmir Valley sections is permissible one would be inclined to regard the massive limestone and the quartzite below it as representing respectively the *Syringothyris* limestone and Muth quartzite of those more typically northern sections (See "Revision of the Silurian—Trias Sequence in Kashmir" by C. S. Middlemiss, *Rec. Geol. Surv. of India*, Vol. XL, pt. 3. 1910). The above correlation has not however so far been substantiated by fossil evidence. The geological structure, as outlined above, will be seen to be different in important details from that mapped by Lydekker (*Mem. Geol. Surv. of India*, Vol. XXII, 1883) who depicted the Panjal Trap as coming in direct contact with the Murree beds at this place. An abridged form of Sohani Ram's report is as follows :—

The general strike of the hematite bed or beds is W.N.W.—E.S.E. and the dip about 25°—30° N.N.E. The outcrop has been traced for a distance of more than $\frac{1}{2}$ mile (See Pl. 15).

Owing to partial covering by superficial material in the stream beds running N. E.—S.W. the outcrop has been split up into three parts, which may be called the western, central and eastern parts. In the Outline map the small scale has necessitated showing it as a continuous line.

So far the hematite has been found to occur in 2 beds lying some 5 feet vertically apart. The upper bed is 2—3 feet thick and carries the metallic looking specular variety of ore in irregular bands interlayered with a hard compact ferruginous cherty rock.

It is, however, the lower bed which forms the main ore-bearing horizon of the section. The craggy outcrop of this bed as far as seen exposed, is variable in thickness at different places. In the

western outcrop the thickness exposed is 5—6 feet while in the central locality it increases from 11 feet in the western part to as much as 16 feet or even to 20 feet in the eastermost corner of the exposure. As the exposed craggy upper part of the outcrop is all through followed immediately downwards by sloping ground covered with debris, soil and grass, the above noted variability in thickness of the lower bed, may, for the most part, be due to the partial covering of the outcrop by superficial material ; and it is quite possible that the actual thickness of the ore-bearing horizon may exceed the maximum so far found exposed.

As is natural to expect in the case of such deposits, the bed is of composite character comprising hematitic ores showing various grades of concentration. These ores occur in the form of sheets, bands, bedded masses and layers all irregularly distributed in relation to one another.

On the basis of physical characters all the various samples collected may roughly be classified into the following four types :—

- (1) Purplish coloured specular variety : It is a soft foliated or platy textured hematite. It has a shining metallic lustre and crystalline structure. Its specific gravity varies from 3.9 to as high as 4.87. This constitutes a very pure and rich ore. One of the samples having a specific gravity equal to 4.7 gave 60 per cent. Fe. Other samples of this variety of ore, though not yet analysed are expected to have a somewhat similar composition—of course, naturally with slight variations.
- (2) Dark-brown to bluish coloured, hard crystalline to massive, granular ore : It has a specific gravity of 4.0 and here and there shows a vesicular texture and has a sub-metallic to dull lustre. No chemical analysis of the ore has yet been made, but from its other physical characters it seems that it might turn out to be the next best ore to the one above.
- (3) Dark grey, micaceous ore. It has a sub-metallic to metallic lustre and like the type No. (1) a more or less foliated texture. The chief distinguishing feature, however, about this variety of ore is that each lamina is characterised more or less by a sort of granular, uneven surface due to the presence of minute chert grains. It has a specific gravity ranging from 3.5 up to 3.89. The sample having specific gravity 3.79 yielded on analysis a little under 50 per cent. Fe.
- (4) Dark-brown, hard, compact, dull looking (non-metallic) ore : This has a specific gravity varying from 3.15 to 3.4. This seems to be a rather impure lean ore.

The ores of the various types described above exhibit a variety of form: Sometimes they, and particularly the richer varieties, constitute bands, sheets and bedded masses of quite large size and sometimes they are found occurring all quite irregularly intermingled in the form of small lenticles and thin layers.

As regards the quality and quantity of the ore it is true that our present survey of the deposit is quite incomplete, and in fact no work has as yet been done by way of opening up the outcrop at various points and examining the section in detail, which is necessary to determine in more definite terms the relative proportion of different quality stuff, and also to know the exact vertical extent of the ore-bearing horizon by investigating the section to some depth below the exposed surface outcrop. These are, however, matters of detail and can be settled whenever the necessity for them arises. But, from what it has been possible to see so far of the deposit and what has been given in the foregoing account, it would appear that there exists rich ore and that in large workable amount.

The approximate tonnage of the ore reckoned on a block $\frac{1}{2}$ mile \times $\frac{1}{4}$ mile \times 13 feet thickness, and with an average specific gravity of 4, comes to about 5 million tons.

There can be no doubt that for modern large-scale operations, such rich and enormous iron-ore resources as have been described above, are just what will be wanted, when, in conjunction with the fuel of the Kalakot coalfield, these minerals are given an outlet to the plains by the establishment of the necessary and obvious rail, road, or other facilities for transporting them.

**Large-scale operations
Transport facilities.**

TITANIUM.

Ilmenite of Wari Khwah.

This locality is in lat. $34^{\circ}-9\frac{1}{2}'$, long. $74^{\circ}-12'$, at the southern tip of the hill-spur west of Bambyar nala and immediately N. W. of the village of Wari Khwah, in the Jhelum Valley a few miles above Rampur. It is marked on the sketch-map (Pl. 3) illustrating the galena of Buniyar. Ilmenite is an ore of iron and titanium, but iron is not commercially extracted from it and the titanium may be used either as a metal in ferro-alloys or as the oxide for entirely different purposes such as "titanium white" for paints and enamels.

Locality.

The ilmenite of Wari Khwah occurs in the form of small rounded grains, the size of shot, closely aggregated together as a magmatic segregation round the borders of a gabbro dyke. This gabbro dyke (which, on the opposite side of the Jhelum, becomes much thicker and contains pyrrhotite) was traced due north for $\frac{1}{4}$ miles up the steep little spur from the fields below. Numerous pieces of the richly segregated ilmenite can be found easily at intervals up the spur. The parent gabbro itself was seen *in situ*, but the ilmenite-bearing portion was only found in loose-lying pieces. The latter is doubtless *in situ* below, and could be dug out if necessary. The original specimen of the ilmenite rock in the Mineral Survey collections was gathered by Mr. Joti Parshad, when he was Mining and Prospecting Officer. The author visited the place in 1918 and gathered more specimens without being able to see more of it than is recorded above. The ilmenite rock has a specific gravity of 3.62.

Other Titanium Ores.

Titania (TiO_2), as usually shown in analyses of bauxite, is present in all the bauxites and highly aluminous varieties of the Bauxite Series of Jammu Province (See Mineral Survey Reports, Bauxite Deposits of Jammu Province). In by far the greater number of cases the percentage of TiO_2 is between 3 and 4. It very seldom drops as low as 2 per cent. or rises above 4 per cent. In places where this does occur the mineral could doubtless be recovered as a by-product from the ferruginous slime waste in the Bayer process, when the bauxite comes to be worked.

The Jammu bauxites that are particularly rich in this component are those from the lower parts of the deposit in Chakar area C.a. and C.d. pits (see Pl. 7 of Bauxite report), where the TiO_2 percentage ranges from 5 to over 16. Dr. Fox (*Bauxite*, London, Crosby Lockwood & Son, p. 173) considers that titaniferous bauxite, in which the alumina is upward of 55 per cent. and the total impurities, excluding combined water, does not exceed 25 per cent. the titania above 7 per cent. with silica less than 5 per cent. and ferric oxide not exceeding 10 per cent., may have a great future before it for recovery of the titania.

The following analyses by J. and H. S. Pattinson of Newcastle-on-Tyne of certain Jammu bauxites are significant from this point of view :—

Analyses.

Chakar Field.

	C.a. pit. 2nd foot.	C.a. pit. 3rd foot.	C.d. pit. 2nd foot.	C.d. pit. 3rd foot.
SiO ₂ ..	9.40	6.70	4.53	4.93
Al ₂ O ₃ ..	67.71	58.03	71.40	71.74
Fe ₂ O ₃ ..	1.29	5.14	0.81	1.10
TiO ₂ ..	7.31	16.51	8.81	7.58
H ₂ O ..	14.00	13.10	14.25	14.60

NICKEL.

Nickel Deposit of Ramsu.

Mr. Labhu Ram discovered nickeliferous pyrrhotite in the Ramsu area in 1925. Ramsu is a small village in lat. **Discovery: Locality.** 33°—20¼', long. 75°—12', and lying on the south side of the Pir Panjal range in the valley of the Bichlari river about half-way between Jammu and Srinagar on the Banihal cart-road. Its elevation is 3,880 feet.

Although the percentages, so far recorded in the analyses, are not very high, only reaching 1.6 per cent. in one instance, it will be well to describe the geology and structure of the immediate surroundings in a little detail in order to provide a basis for further investigation and perhaps the discovery of richer material.

The length of the area so far examined is 4 miles and its breadth ¼ mile ; but the mineralised portions probably extend far beyond in north-west and south-east directions.

Size and area.

The prevailing geological formation of the area is a very old slate complex, considerably metamorphosed in places. By analogy with the structure of neighbouring areas, which the present writer worked out near Banihal in 1922, its age is probably Cambro-Silurian or older. This rock complex, as will be seen by the map (Pl. 16), is a parallel arrangement in bands, striking N.W.—S.E. and dipping N. E. 65° , of phyllite, graphitic schist, limestone lenticles and alternating layers of a dark basic epidiorite. Two large masses of well-banded gneissose granite are intrusive through these in roughly parallel masses, but which, in the northern part of the area, are represented on Labhu Ram's map as cutting across the outcrops of the bands of schist and epidiorite. In addition, very numerous narrow veins or lenses of quartz are also aligned in a similar N.W.—S.E. direction and appear as veining the phyllite and gneissose granite.

The ore occurs as disseminations and as small veins or veinlets ranging in length from a few inches to a few feet and in breadth a fraction of an inch; and also as thin layers along, as well as across, the stratification or foliation planes, in the following ways:—

- (1) In the limestone lenticles, impregnating the calcite veins and traversing them in all directions.
- (2) In the graphitic schist bands and phyllite, forming thin layers, with and across, the divisional planes and also impregnating the quartz veins in them and sometimes completely replacing them.
- (3) In the granite and epidiorite intrusions, as sparse disseminations.

Labhu Ram is of opinion that, besides the nickeliferous pyrrhotite which constitutes patches, streaks and sometimes veins 5 feet in length and 3—4 inches across, the ore includes pentlandite (a sulphide of iron and nickel containing 22 per cent. of the latter). This opinion is based partly on analogy with what is accepted as regards other ores of nickel, such as those of Sudbury Ont. and partly because of certain apparent inconsistencies in the chemical analyses made on the ore and its magnetically separated contents, as see below.

The following analyses were made by the Industrial Chemist at the
Analyses. Industrial Laboratory, Srinagar :—

Locality.	Nickel per cent. in the rock.	Nickel per cent. in pyrrhotite magnetically concentrated.
Ramsu	0.35	} 0.04 (1) 0.50 (2)
Slope N. of Ramsu (in limestone.)	0.40	....
E. of Rest-House Ramsu (in limestone lenticle.)	0.40	....
$\frac{1}{3}$ mile W. by N. of Rest-House Ramsu (in limestone).	1.628	....
Stream-bed W. of Rest-House Ramsu (in graphitic schist).	....	Nickel per cent. in brassy concentrate. 0.30
$\frac{1}{4}$ mile N. of Gangro		Nickel per cent. in clean pyrrhotite. 0.5

Of these analyses, if we consider first those done on the magnetically separated pyrrhotite (shown in the 3rd column above), which average 0.33 per cent. nickel, we see that they agree very well with the percentages generally found in clean pyrrhotite from the fahlbands of many parts of northern Europe and Canada (a complex type of banded structure in rocks of mixed origin very similar to those described by Labhu Ram at Ramsu). On the other hand if we consider the analyses done on the pieces of rock supplied (column 2 above), we find the average nickel percentage to run higher, being nearly 0.80 (in one case reaching 1.628).

In drawing attention to this Labhu Ram has suggested that the Pentlandite microscopically intergrown with pyrrhotite. explanation may be found in the presence of pentlandite, intimately mixed or microscopically intergrown with the pyrrhotite, but which, being non-magnetic, is left behind when the magnetically separated crushed pyrrhotite is extracted. This of course is on the analogy of a similar explanation, now pretty generally accepted, as applicable to the Sudbury ores.

The latest account of the celebrated Frood ore-body of Sudbury (see "Mining Journal" for April 13th 1929 and "Mining Magazine" for May 1929) shows the percentage of nickel to vary from 1.7 to 3.0 with depths from 1,000 feet to over 3,000 feet, and that much of the nickel is present as pentlandite.

Perhaps the analyses are too few and the field evidence too scanty in our Ramsu area, to base much in the way of theoretical speculation on them as regards origins; but they do seem to suggest the advisability of further detailed work on the deposit in the near future in the hope that richer workable ores will be found.

Nickel Occurrence of Sapphire Mines Area, Padar, Kishtwar.

This nickeliferous pyrrhotite occurrence was discovered in the summer of 1927, by Labhu Ram when exploring the Sumjam Sapphire Mines area and its neighbourhood.

Although the percentage, so far recorded in the analyses is not very high, only reaching 0.305 per cent., it will be well to describe the geology and structure of the area in a little detail in order to provide a basis for further investigation and perhaps the discovery of richer material.

The prevailing geological formation of the area is a very old metamorphosed complex. By analogy with the structure of neighbouring areas, its age is probably Cambro-Silurian or older. This rock complex is a parallel arrangement in bands of marble with lenticular masses of actinolite-tremolite schist, biotite graphite gneiss and hornblende biotite gneiss occasionally garnetiferous, intruded into by granite and pegmatite veins. Nickel ore is found disseminated in almost all these rocks.

The ore occurs as disseminations and as small veins or veinlets, a few inches in length, and also forming thin layers along the planes of stratification or foliation ranging in thickness from a fraction of an inch to half an inch or more in the following rocks of the area :—

- (1) In the marble bands.
- (2) In the hornblende biotite gneiss bands.
- (3) In the granite and pegmatite veins.

The above pyrrhotite-bearing rocks constitute several continuous parallel bands in the area, and are found interbedded with one another, the marble or the crystalline limestone yielding so far the rich ore, and being 10 feet.—100 feet in thickness.

The length of the area so far examined is 4 miles spreading over a distance of 16 miles from Sumjam to Mosh down the Bhut Na river (Survey of India Sheets 52 C/7 and 52 C/3), but the mineralised portions probably extend further afield in eastern and western directions.

In the age of the containing rocks, in the mode of occurrence and distribution of pyrrhotite, in the associated minerals, and as regards the ore-bearing minerals and to a certain extent in the nickel percentage, the Padar occurrence resembles the Ramsu occurrence and most probably represents a repetition of the latter towards the north, into the Padar area. As in the case of our Ramsu area, the advisability of further detailed work on this occurrence in the near future, in the hope that richer workable ores will be found, is suggested.

Riasi Occurrence.

The presence of nickel in traces sometimes 0.103 per cent. was noticed by Labhu Ram in the copper bed of Gainta and tracked home as far as Jangal Gali. This is another instance of a nickel deposit which has an extended outcrop. Here the ore exists as nickeliferous pyrrhotite as well as in the silicate form (garnierite?). The occurrence has not been gone into in any detail, but has only been briefly visited and collected from the surface and as such its value as an ore is not known. It is put on record here simply to draw attention with a view to further investigation of it.

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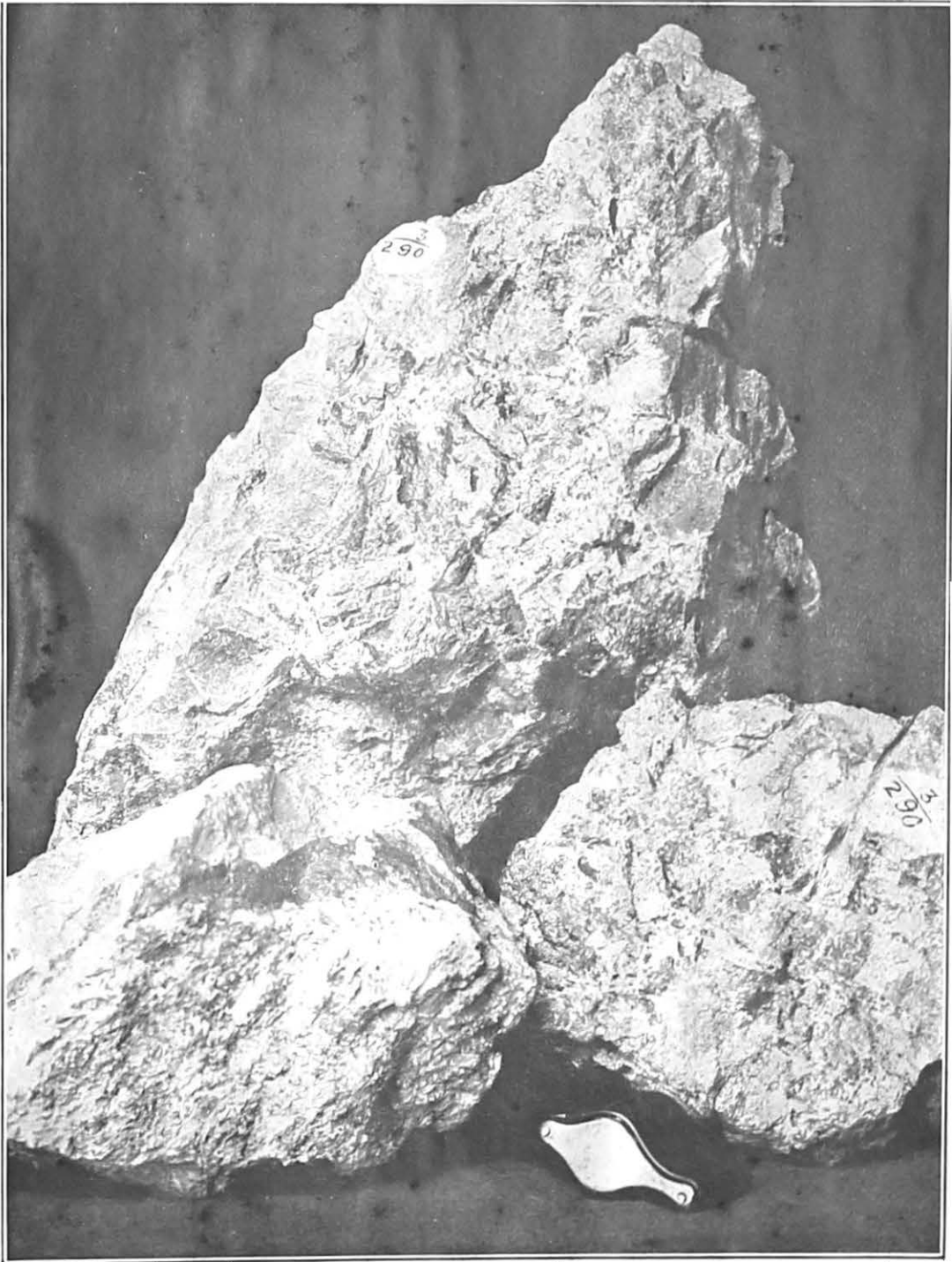
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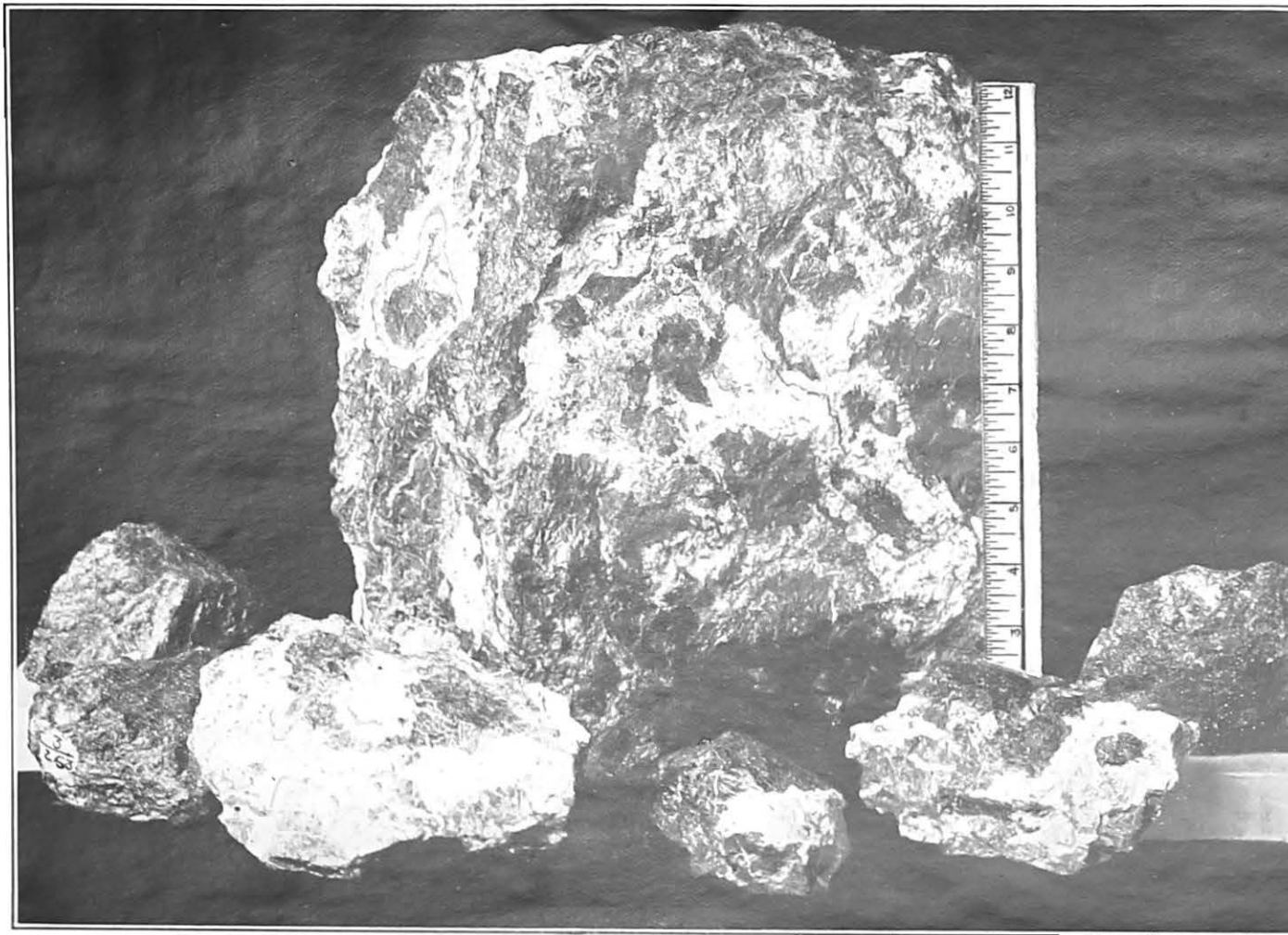
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MINERAL SURVEY OF KASHMIR.

Plate 1



COPPER ORE, GAINTA.



ZINC BLENDE, ANJI VALLEY.