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REPORT No. 226

GEOLOGICAL SURVEY OF JAPAN

GEOLOGICAL STUDY ON THE ANGURAN MINE, NORTHWESTERN PART OF IRAN

By

Ken HIRAYAMA

GEOLOGICAL SURVEY OF JAPAN

Hisamoto-chō, Kawasaki-shi, Japan

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Konosuke SATO, Director

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The study described in this report has been carried out as a part of the Project of United Nations (Special Fund Project) in 1965 at Tehran, Iran. The publication of the report was planned by Geological Survey of Japan after the completion of the publication at the office of the Project of United Nations in Tehran.

The author is very appreciative to Dr. D. A. Andrews, Project Manager, and to other staff members of the Project of United Nations for their effective co-operations through the course of study.

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Abstract

The area surrounding Anguran lead-zinc mine is composed of metamorphic rocks and younger strata of Mesozoic and Tertiary age. The host-rocks of the ore are the metamorphics, which include schist and crystalline limestone. The orebody seems to be in the form of a lens between these two types of rock.

The original ore consisted of sulphides of lead and zinc brought into the limestone metasomatically some time after the completion of the regional metamorphism of the area. Secondary alteration brought about by descending solutions has changed the sulphides almost entirely to carbonates of lead and zinc. The altering solutions reached the ore along fractures in the hanging-wall crystalline limestone.

Ore reserves are estimated at about nine million tons with grades of 3 to 6 percent lead and 20 to 35 percent zinc.

I. Introduction

The Anguran mine is in northwestern Iran in the southern part of the Khavari

Fig. 1 Index map

*Geology Department

Prefecture, at 47° 20′ longitude and 36° 40′ latitude. In the aeronautical series of maps prepared by U. S. Army the mine is in the northeastern part of sheet "Takab" - NJ 38-16 (Fig. 1). The mine is located near a summit east of the Kuh-e-Baradad Shah. From the mine a valley descends to the Rud-e-Halab, a tributary of the Rud-e-Qezel Owzan.

The road to Anguran branches west from the Zenjan-Bijar highway 93 kms west of Zenjan. At present it takes three hours to drive the 83 kms from the highway to the mine, but a new road is under construction and will greatly shorten the distance.

A survey of the Anguran mine was carried out in June and July, 1965 in order to obtain geological information of the surrounding area and detailed information of the area immediately adjacent to the mine. There had been few previous geological studies. In a paper presented to the Mining Geology - Base Metals Symposium of CENTO in 1964, Mr. W. S. Wright discussed the genesis of the Anguran lead and zinc ores and other similar mineralizations in Iran. Dr. E.W. Molly and Eng. N. Taghizadeh of the Geological Survey of Iran made unpublished reports based on a study of the mine in 1964. In addition a Japanese team for Metal Mining Research in Iran discussed the geology and mineralization of this mine in a report dated 1958.

II. Acknowledgements

The writer expresses his appreciation to Dr. Rastegar, Director of the Simiran Company, to Eng. Aliabadi, Geologist to the Company, and to Mr. N. Herriman, Geologist to Fenance and Exploration Ltd., a subsidiary of Rio Tinto Zinc Corporation, for their hospitality during the fieldwork. The air photographs and the topographical maps upon which the study was based, were furnished by the Rio Tinto Zinc Corporation. He also deeply thanks to Dr. T. Yasuda's co-operative work of X-ray diffractmeter for the ore minerals.

III. Geology

A general geological map and a schematic section showing the geological formation in the area are given in Fig. 2, and Fig. 3. The mine area is underlain by pre-Tertiary metamorphic rocks, mainly crystalline schist and limestone with some basic components. Intruded into these are stocks of gabbro, serpentinite and peridotite and dykes of amphibolite. The ore, chiefly carbonates of lead and zinc, is found along the boundary of the crystalline schist and the overlying crystalline limestone. Younger rocks surround these older rocks, separated from them by a faulted contact or by unconformities. The younger rocks are considered to be Mesozoic and Tertiary in age. To the east of the area there are two tablelands of Recent travertine.

III. 1 Pre-Tertiary metamorphic rocks

The schists and crystalline limestones were metamorphosed under conditions of high pressure and low temperature; the metamorphic grade has not advanced beyond that of the chlorite facies. As no organic remains have been found in these rocks neither their age nor that of the metamorphism is known.

The lower 400 metres of these metamorphic rocks consist of many kinds of schist with numerous interbedded layers of crystalline limestone towards the top. Above this lower unit there is a middle unit consisting of 300 metres of pure crystalline limestone with no intercalations of other rocks. Overlying this, in turn, is 40 metres layer of

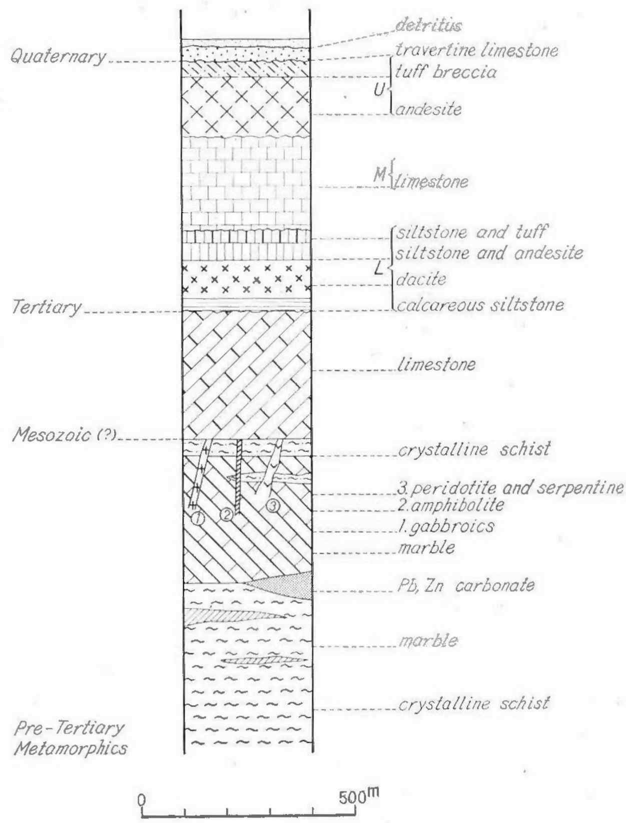


Fig. 3 Schematic geological sequences of the area.

siliceous and argillaceous schist, the megascopic and microscopic characteristics of which are similar to those of the lower schists except that the effects of hydrothermal alteration were not observed in the upper schist.

These rocks may be classified into two main groups: Firstly, siliceous, argillo-siliceous and calcareous members, including graphite-sericite-quartz-schist, schistose sandstone, sericite-quartz-schist, chlorite-quartz-schist, hematite-quartz-schist and crystalline limestone. And secondly, basic members including diabase-schist and actinolite-epidote-chlorite-albite-schist.

Siliceous, argillo-siliceous schists and calcareous members: The microscopic features of these rocks indicate that they have been derived from siliceous members (chert), sandstone, shale and limestone. The graphite-sericite-quartz-schist is black to dark grey in colour and shows micro-drag folds in places. Carbonaceous material (probably graphite), sericite, plagioclase and quartz are the main components. A banding of layers due to varying grain size (0.07 to 0.2 mm) is often observed. In some parts of this rock, rather large (0. 3 mm) quartz and felspar grains are scattered in the bands of graphite and chlorite. These facies seem to be derived from sandy shale.

Schistose sandstone is found in the western part of the mapped area either as a thick layer or intercalated with argillaceous material. The main minerals are anhedral round crystals of quartz and plagioclase with occasional pyroxene crystals. The matrix is composed mainly of minute grains of quartz, plagioclase and carbonaceous material in very thin bands. Quartz grains in the matrix show a preferred orientation in some places, but the larger grains of quartz do not.

Sericite-quartz-schist, chlorite-quartz-schist and hematite-quartz schist are reddish, grey, white or pale green in colour depending upon the constituent minerals. The main mineral is quartz, with carbonaceous material, hematite, sericite, chlorite, tourmaline, apatite and calcite. Quartz is rather strongly oriented and shows a type of B-tectonite. The quartz-schists are intercalated with argillaceous layers.

The crystalline limestone is the dominant rock in the middle part of the metamorphic area. As already noted the upper part of the schists contain intercalations of limestone. The boundary between the lower schist and crystalline limestone is conformable. The ore was deposited along this boundary. The crystalline limestone is dark grey or grey in colour, medium to coarse-grained and generally rather banded, dark and white bands being clearly recognizable in some places. No fossils were found in this limestone. Under the microscope recrystallized calcite 0.5 by 0.2 mm in size is seen to make up all parts of the rock. These crystals are arranged in a mosaic with the longer axes strongly aligned. Small amounts of flaky sericite and chlorite, together with quartz and iron minerals are scattered as accessories.

In the lower part of this limestone there is a white or grey gneiss with large crystals of flaky biotite and sericite, but made up mainly of recrystallized calcite in rather elongated crystals with a mosaic texture and showing typical metamorphic effects. In this rock flaky sericite and biotite, and individual plagioclase, quartz and epidote grains are accessories. The biotite and sericite flakes are bent and do not show a clear alignment as in the schists. If they had been influenced by regional metamorphism, they should be aligned with a banded or linear structure, so that it is considered that they were formed after the regional metamorphism. In some places aggregates of quartz and plagioclase form irregular shaped clots or patches, in which individual quartz crystals show weak wavy extinction and have no preferred orientation as in the schists. They contain inclusions of calcite and biotite. These features are considered to show that the quartz and plagioclase crystals were formed subsequently to the regional metamorphism. It is not considered that the quartz, plagioclase, biotite and sericite occurred originally in the limestone as impurities for in such a case they would be expected to show the features of regional metamorphism as do the calcite crystals. We are thus obliged to postulate some other metamorphosing influence, subsequent to the regional metamorphism. As noted later, there is some evidence of hydrothermal alteration and contamination in the gabbroic rocks and amphibolite in the area; this was perhaps brought about by the invasion of aplitic material. In this area there is an old tunnel from which barite seems to have been obtained. Though the genesis of the barite is not known, it could possibly be linked with such acidic material. We must also give consideration to the relation between this barite and that which occurs as crystals in the lead-zinc sulphide ore: this is discussed later.

Basic members: Diabase-schist and actinolite-epidote-chlorite-albite-schist are intercalated in the siliceous and argillaceous rocks as layers many metres in thickness. These are the strongly recrystallized derivatives of basic tuff or basic intrusives. The diabase schist is a green to dark green homogeneous compact rock with strong schistosity. Relict anhedral augite and plagioclase minerals are common. The main components are fine grains of epidote, chlorite, actinolite and albite. With zircon, clinozoisite, sphene, iron minerals and calcite as accessories. The actinolite–epidote–chlorite–albite–schist is also interbedded in thin layers, with some clots of quartz.

III. 2 Pre-Tertiary limestone

These are widely distributed on the southern side of the metamorphic outcrops from which they are separated by a fault. The limestones are grey to dark grey in colour, fine to medium-grained, with some banding but no schistosity. The limestones have not been recrystallized and contain organic remains such as corals and foraminifera, from which a Mesozoic or earlier age may be deduced. Under the microscope these rocks are seen to be made up mainly of calcite crystals with small amounts of quartz and minute flaky sericite.

III. 3 Tertiary rocks

Tertiary rocks cover the metamorphics on the northern and eastern sides of the area, whilst on the southern side they are bounded by a fault against the pre-Tertiary limestone. The Tertiary rocks clearly overlie the metamorphics along an unconformity which dips gently to the east. (Plate I. a, b) The Tertiary rocks are divided into three groups: a lower group composed mainly of sediments with dacite tuff and flow material; a middle group consisting of limestone, and an upper group comprising andesitic flow, tuff and breccia material. These groups are separated by disconformities whose planes are gently inclined to the east. A fault cuts the lower group, together with the metamorphics and the pre-Tertiary limestone along the southern side of the area, but the middle and upper groups seem to cover this fault on the eastern side.

The lower group: This group may be divided into four units, in descending order:

Siltstone and tuff	30 metres
Siltstone and andesite	40 〃
Dacite	80 〃
Calcareous siltstone	30 〃

The lowermost member (the calcareous siltstone) is exposed intermittently above the metamorphic rocks, striking generally about north–south and dipping about 60° to the east. It is fine-grained and grey to pale yellow in colour. Bedding is not clear. Under the microscope it is seen to consist mainly of fine calcite grains and muddy material, whilst in some areas small fragments of schist and crystalline limestone may be recognized in it.

A dacite normally overlies directly the metamorphic rock but locally it overlies the calcareous siltstone. The plane of the unconformity forms a circular line around the dome–shaped surface of the crystalline limestone. The dacite is largely altered to white clay material, but there is enough fresh rock left to reveal the dacitic character. The fresh material is pink or grey, and rather coarse-grained, the felspar crystals being readily visible macroscopically. Under the microscope mafic minerals are seen to be scarce, the phenocrysts being generally changed to chlorite and calcite but pseudomorphs after hornblende are occasionally recognizable. Phenocrysts of plagioclase (An 20 to 30) and quartz are scattered through the rock. The groundmass consists of minute crystals of plagioclase, quartz, calcite and iron minerals.

Alternate bands of siltstone and andesite lie conformably on this lower dacite. The strike is almost north and south and the dip is rather steep to the east. Both rocks are deeply weathered and white in colour. The unweathered siltstone is grey to pale yellow in colour shows clear banding and is rather calcareous in some places. The andesite is not dissimilar to the dacite below it but weathering has been so severe that practically all minerals are altered to clay.

The uppermost part of the lower Tertiary group consists mainly of siltstone with thin tuff intercalations and conformably overlies the siltstone and andesite. The rocks are well banded in units 5 to 15 cms thick. The siltstone is bluish grey, pale yellow or white in colour and fine to medium-grained, and consists of minute crystals of calcite and quartz scattered in a muddy substance. The tuff is interbedded in thin (10 to 30 cms) layers and is acidic in composition. Crystals of augite and plagioclase can be recognized by the naked eye; under the microscope phenocrysts of these minerals are seen to be mostly changed to aggregates of calcite and chlorite, the matrix being mainly ash with minute crystals of chlorite and quartz.

The middle group: The limestones of this group rest unconformably on the beds of the lower group (Plate I) and are found continuously from the northern to the eastern side of the area but in the southern part only remnants may be seen. Organic remains consisting of foraminifera and oysters indicating a Tertiary age may be found in many places. The rock is grey or yellowish grey and bedding planes are not recognizable. It is readily distinguishable from the older limestones, and moreover, it contains fragments of the older limestones and of the schist (less than 5 cms in diameter). Microscopically the rock is composed of fine aggregates of calcite crystals with quartz grains and chlorite flakes. The maximum thickness of this limestone is 250 metres.

The upper group: In the eastern part of the area this limestone is disconformably covered by an andesitic flow about 140 metres thick. The plane of the disconformity strikes north and south and dips gently to the east. The rock is black in colour compact and hard, and phenocrysts of plagioclase and augite may be seen. The former is clear, 0.5 to 2.0 mm in length (An 30 to 50 in composition) and have both albite and carlsbad twinning; a zonal structure is not distinct. There are inclusions of small grains of mafic and iron minerals, the former being largely changed to calcite. Common augite is occasionally found as phenocrysts; it is 0.7 to 1.5 mm in length and is largely changed to chloritic material. The groundmass shows an interstitial texture, is composed of plagioclase of about the same composition as the phenocrysts and is about 0.5 mm long. Small anhedral grains of augite and iron minerals are present, the former being largely changed to chlorite.

A tuff breccia lying conformably on the andesite flow contains angular or subangular fragments of volcanic rocks cemented in medium-grained ash. The matrix is rhyolitic or andesitic. The thickness is about 40 metres.

III. 4 Igneous rocks and mylonite

Gabbro, amphibolite, serpentinite, peridotite and mylonite occupy small areas or extend along the fault.

Stocks of gabbroic rocks form outcrops in the southwestern and northwestern parts of the area, and similar rock occurs in the form of dykes in the eastern part. The invaded rock is schist and contact effects are difficult to find. The gabbro is medium to coarse-grained and shows a banded structure parallel to the schistosity of the schist. Although the stocks are so small, massive material remains in the form of cores. Generally the massive parts are darker in colour and finer in grain. Megascopically the gabbro is seen to consist mainly of plagioclase, green hornblende and a small amount of monoclinic pyroxene and quartz. Under the microscope poikilitic green hornblende about 1 to 2 mm in length partly changed to chlorite may be seen. Inclusions of apatite and iron minerals are common. The plagioclase is about An 40 in composition, albite and carlsbad twinning are common and zoning is not unusual. Quartz is interstitial and anhedral in form, and where more abundant the rock grades into diorite. Generally the banded parts are more acidic than the compact parts: the included minerals show that these banded parts have been affected not only by regional metamorphism but that they have also been permeated by acidic material.

In the southern part of the area amphibolite occurs in the crystalline limestone as an intruded sheet parallel to the bedding, with a length of 300 metres and a width of 3 to 7 metres. Three kinds of rock may be recognized. One is dark greenish black in colour and shows some schistosity due to the parallel arrangement of the hornblende crystals. Another is a fine-grained gabbro with some schistosity caused by the parallel arrangement of hornblende crystals and felsic grains. The third type is hornblende gneiss or hornblende schist. The three types grade into each other with no distinct boundaries. Under the microscope the first type is seen to be a typical amphibolite with granoblastic texture. The main components are idiomorphic and partly poikilitic green hornblende up to 2 mm in length, and An 55 to 70 subhedral or anhedral plagioclase 0.4 in diameter; clinozoisite, sphene, apatite and iron minerals are accessories. With increasing plagioclase and quartz the rock has the megascopic appearance of a fine-grained gabbro or diorite – the second type mentioned above. The hornblende is more poikilitic and there is an acid mantle round most of the original plagioclase grains. Sphene, apatite and iron minerals appear as accessories. In the third type the hornblende crystals are much more poikilitic and are broken into anhedral fragments arranged along the schistosity planes. Some plagioclases are also broken into anhedral fragments, the twinning planes being bent or crossed; ovoid crystals of plagioclase are left as porphyroblasts. Quartz grains are much more numerous, have mosaic texture, and are elongated with a wavy extinction. Aggregates of calcite and chlorite occur as flakes and pseudomorphs after hornblende. The accessories are the same as in the other two types of rock.

The age of intrusion of the gabbro and amphibolites is not clear but from the observations mentioned above we may assume that basic igneous rocks invaded the limestone before the completion of the regional metamorphism and that they were permeated with acidic material: this permeation is particularly marked in the case of the second and third types of amphibolite.

In the western part of the area there is a small mass of epidote–actinolite rock (a kind of gabbro) in the crystalline schist. The rock is dark green in colour with yellowish epidote crystals which give a spotted appearance to the surface of the rock. Actinolite imparts a fibrous appearance to some parts of the rock. There is a banded structure parallel to the schistosity of the enclosing schist. Under the microscope epidote and interstitial actinolite are seen to be the main components; the epidote is in aggregates and clots of subhedral crystals, and the actinolite is fibrous and pale green in colour. The rock seems to have been affected by regional metamorphism.

In the southwestern part of the area numerous fragments of banded serpentinite and peridotite are to be found at the surface, but the limits of these rocks are unknown. They consist mainly of serpentine with olivine and diopsidic augite as relict minerals and with iron ores along the boundaries with other minerals. This rock also seems to have been intruded prior to the completion of regional metamorphism.

Some mylonites are found along the fault in the southern part of the area; they represent crushed limestone, schist and dioritic rocks, the last named probably being derived from the amphibolites.

III. 5 Quaternary rocks

In the southeastern part of the area there is a narrow stepped plateau composed of pale yellow travertine lying horizontally. (Plate II) It shows a banded structure with some cross-bedding. No organic remains were found in it.

Most of this upland mass is covered with detritus which obscures the outcrops. The bottoms of the valleys are extensively covered with fertile alluvial deposits which, on the northern side of the mine provide good ground water which is piped to the mine.

III. 6 Structure

Tectonically the report area consists of an upheaved half dome of metamorphic rocks surrounded by Tertiary strata. The metamorphic complex forms an anticlinal structure striking north 75° west and plunging gently to the east. It would seem that the upheaval of the area occurred sometime after the Tertiary sedimentation. Accompanying this upheaval typical diagonal fractures were formed over the whole area. These are especially marked in the metamorphic rocks in the core, which deformed much more severely than the Tertiary rocks. Average directions of the diagonal fractures are north 30° west and north 60° east, whilst the inclinations are 80° westerly to vertical. (Plate III)

One fault, carrying a certain amount of mylonite, striking east–west and dipping vertically, is clearly recognizable along the south. The age of this faulting would seem to be Tertiary as indicated by the relationship between the dacite of the lower group of the Tertiary strata and the limestone of the middle group as already explained. From the distribution of strata on both sides of the fault it is clear that the downthrow is to the north.

Some of the fracturing seems to have caused small scale faults and collapse structures. Especially in the crystalline limestone there are many brecciated zones (Plate III. b) parallel to those fractures which strike north 30° west. These brecciated zones occur only locally and are probably small in scale, and no displacement between schist and crystalline limestone was observed along them. Among these brecciated zones, the one marked BZ–B′Z′ is important for it forms the limit to the eastern side of the orebody; it is described later.

IV. Mineralization

IV. 1 Shape of orebody

Stratigraphically the orebody appears to be interbedded between the schist and the crystalline limestone, though in the western part of the area where the boundary between these two rocks can still be traced, there is no ore.

The lower limit of the ore – that is the boundary between the orebody and the schist – has been recognized only in some drill-cores and in Tunnel 1, for a surface exposure of this lower boundary was not found anywhere. From drill-core data the foot-wall is in direct contact with the schist at an elevation of between 2890 and 2910 metres, though it may be higher to the west. Whether the contact is parallel or at an angle to the schistosity planes remains uncertain, though in Tunnel 1, the boundary seems to be irregular in shape and at an angle to the schistosity.

The hanging-wall of the orebody against the crystalline limestone may be seen at

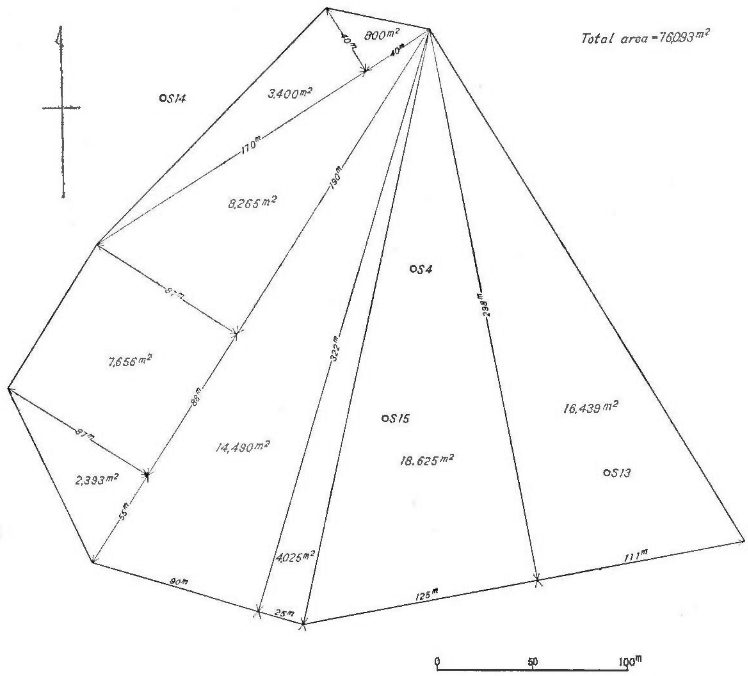


Fig. 5 Data for calculation of reserves.

several places in the open pits and has been noted in some drill-cores. From this it would seem that the surface of the orebody is irregular in shape and gently inclined to the east. The elevation of the hanging-wall in the east is 2950 to 2970 metres, and in the west 2990 metres. The average thickness of the orebody is thus of the order of 45 metres.

The eastern limit of the orebody is not clearly known. This limit may be seen at a point 80 metres inside from the entrance of Tunnel 1, but detailed observations were not possible because it has been built over by rock walls. At this point the limit is a brecciated zone (BZ–B′Z′ on the accompanying map) which was formed by a collapse or a fracture. On the eastern side of this brecciated zone a thick limestone layer may be seen in Tunnel 1 but no ore is known: this area should certainly be prospected.

The limits of the orebody north, west and south are not clearly indicated, the only available data being that revealed in Tunnels 2, 3 and 4. The area occupied by the orebody was calculated at 7600 square metres (Fig. 4; data for calculation are given in Fig. 5 and the shape of the orebody is given in the block diagrams Figs. 6a and 6b).

IV. 2 Composition of orebody

The orebody is composed chiefly of carbonates of lead and zinc, white, yellow, pink and grey in colour, the varying colour probably representing impurities. The ore is fine to coarse-grained, some parts are massive and hard but it consists mainly of a soft clayey substance resulting from the chemical decay of the crystalline limestone. No fractures were observed, as all parts of the orebody are massive. Within the orebody there are some fragments and thick (20 metres) horses of limestone and less commonly

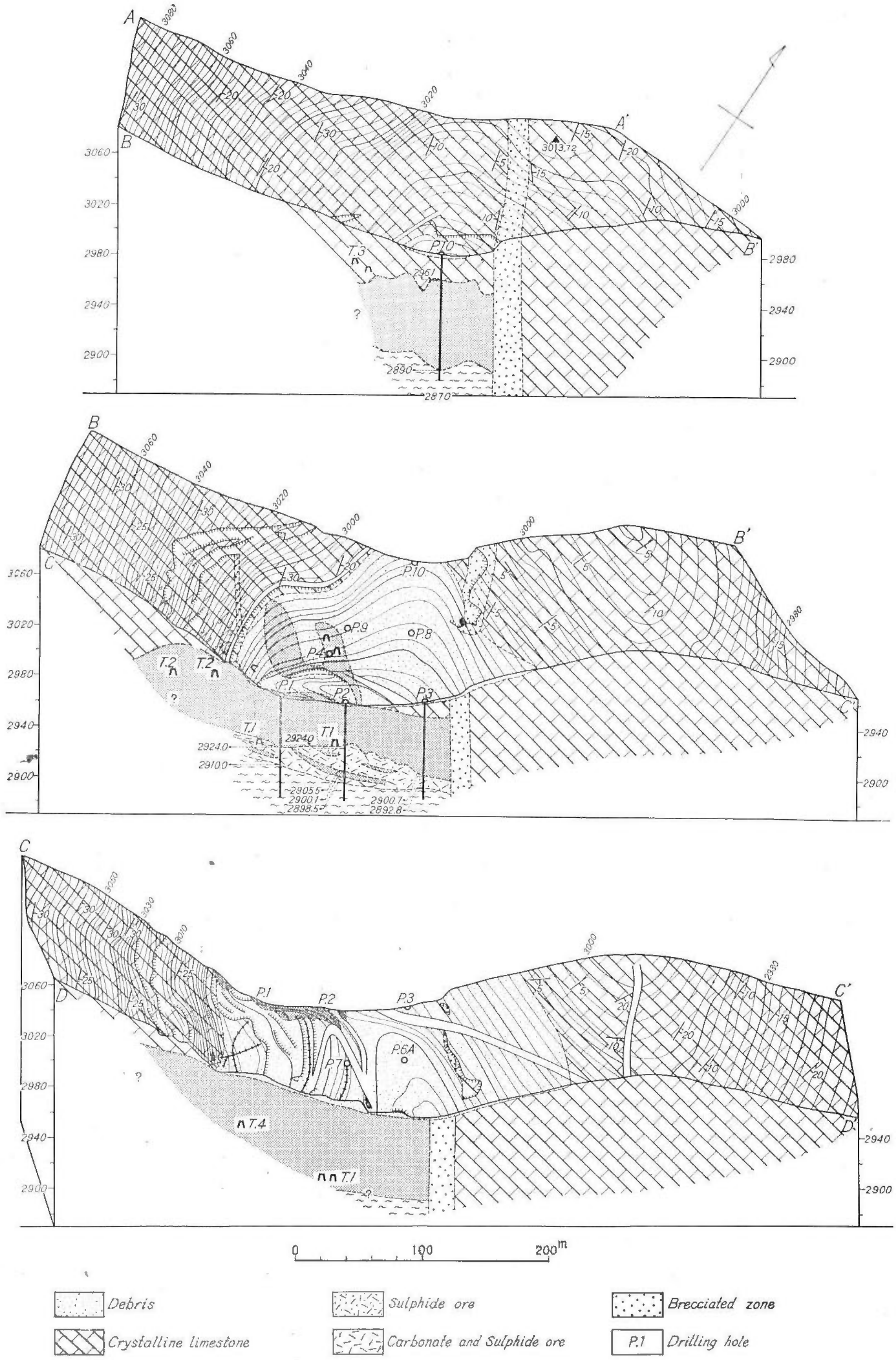


Fig. 6a Block diagram of mining area

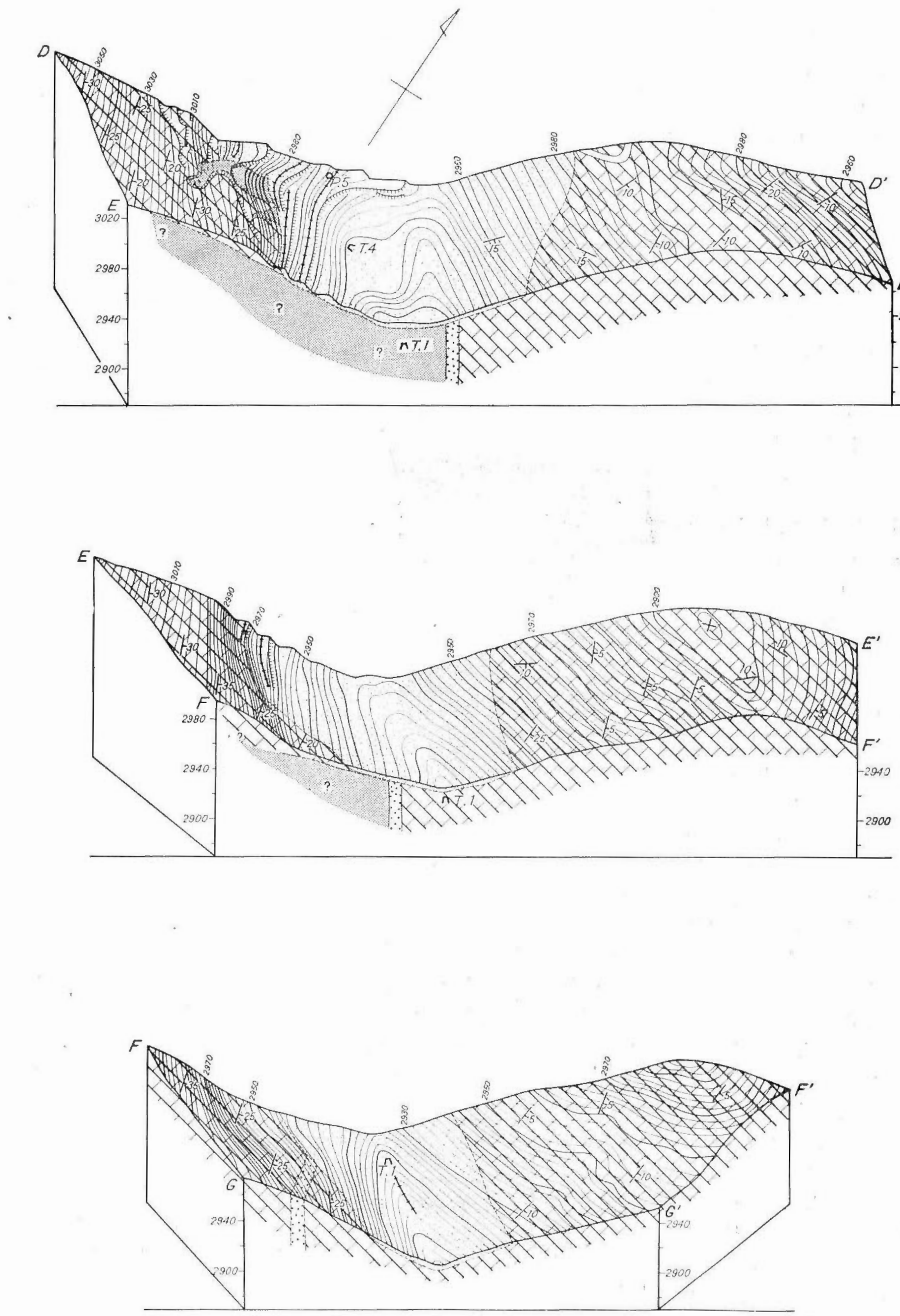


Fig. 6b Ditto.

of schist, the latter often showing carbonatization of the component minerals. Crystals of various carbonate minerals may be seen on the walls of cavities, which are frequently found. In the lower part of the orebody massive hard sulphide ore occurs as remnants within which horses of crystalline limestone may be seen. No evidence that the ore had been influenced by regional metamorphism was found.

The lead and zinc minerals of the carbonate ore are mainly smithonite, calamine, cerussite, zincite and hydrozincite with scarce pyromorphite. Some of them were studied by X-ray diffractmeter by Dr. T. Yasuda of our Survey. Studied samples were that taken from the open pits and the numbers were from 155 to 161. These samples except 159 clearly showed the character of smithonite while 159 showed zincite. Crystal of these minerals are recognizable in the cavities but are difficult to distinguish in the clayey ore. The sulphide ore, consisting of galena and sphalerite, is mainly massive, but locally it may be soft due to partial alteration to carbonate.

A little barite was found near the outcrops of sulphide ore in the open pits; it is considered that this association is of significance when considering the genesis of the sulphide ore in relation to the barite deposit in the northeastern part of the area.

IV. 3 Detailed structure of mine area

Fracture pattern: As already mentioned the most remarkable and characteristic structural feature of this mine is a system of intersecting fractures (Plate IIIa) which are especially conspicuous in the metamorphic rocks. The fracture system in crystalline limestone is shown in the schematic diagrams in Figs. 7a and 7b. These show the distribution of poles of fracture planes in Schmidt's equal area projection, using the lower hemisphere. The diagrams in Fig. 7a correspond numerically with the areas shown in Fig. 8, a standard 25 square metres having been selected at random in each area and the directions and inclinations of all fractures within each area was measured. To show the preferential orientation of the fracture planes the poles of the planes were plotted on Schmidt's net and contour lines showing 1, 2, 3, 5, 10, and 15 percent of the counted numbers were drawn. The number of fracture planes measured in each standard area was as follows: I...130; II....175; III....82; IV....170; V....160; VI....63; VII....29; VIII....108; IX....83; X....200; XI....100.

Diagrams 1 to 6 were made from the northeastern side of the brecciated zone BZ–B'Z', which lies along the eastern limit of the orebody. These diagrams show that there is a double set of fractures, one directed north 30° west and inclined 80° to the west, and another directed north 60°east and nearly vertical, but the latter are less numerous. These features are considered to show the original fracture pattern in the crystalline limestone in the surveyed area.

Diagrams 10 and 11 represent observations made along the road respectively from A–B and C–D as shown in Fig. 9. These two diagrams show a distribution of poles, on average north 34° west and dipping 76° west, and north 55° east and dipping almost vertically. Diagram 10 (A–B) represents an area west of the brecciated zone and Diagram 11 (C–D) an area east of the zone. As the two diagrams have a very similar pattern it follows that these two areas behaved structurally as a single mass before the formation of the brecciated zone. We may also assume that these two diagrams represent the original fracture pattern of the whole area.

Diagrams 7, 8 and 9 represent areas just west of the brecciated zone. The fracture pattern is again similar to those described above in so far as the direction of the fractures is concerned, but important differences in inclination may be recognized. The incli-

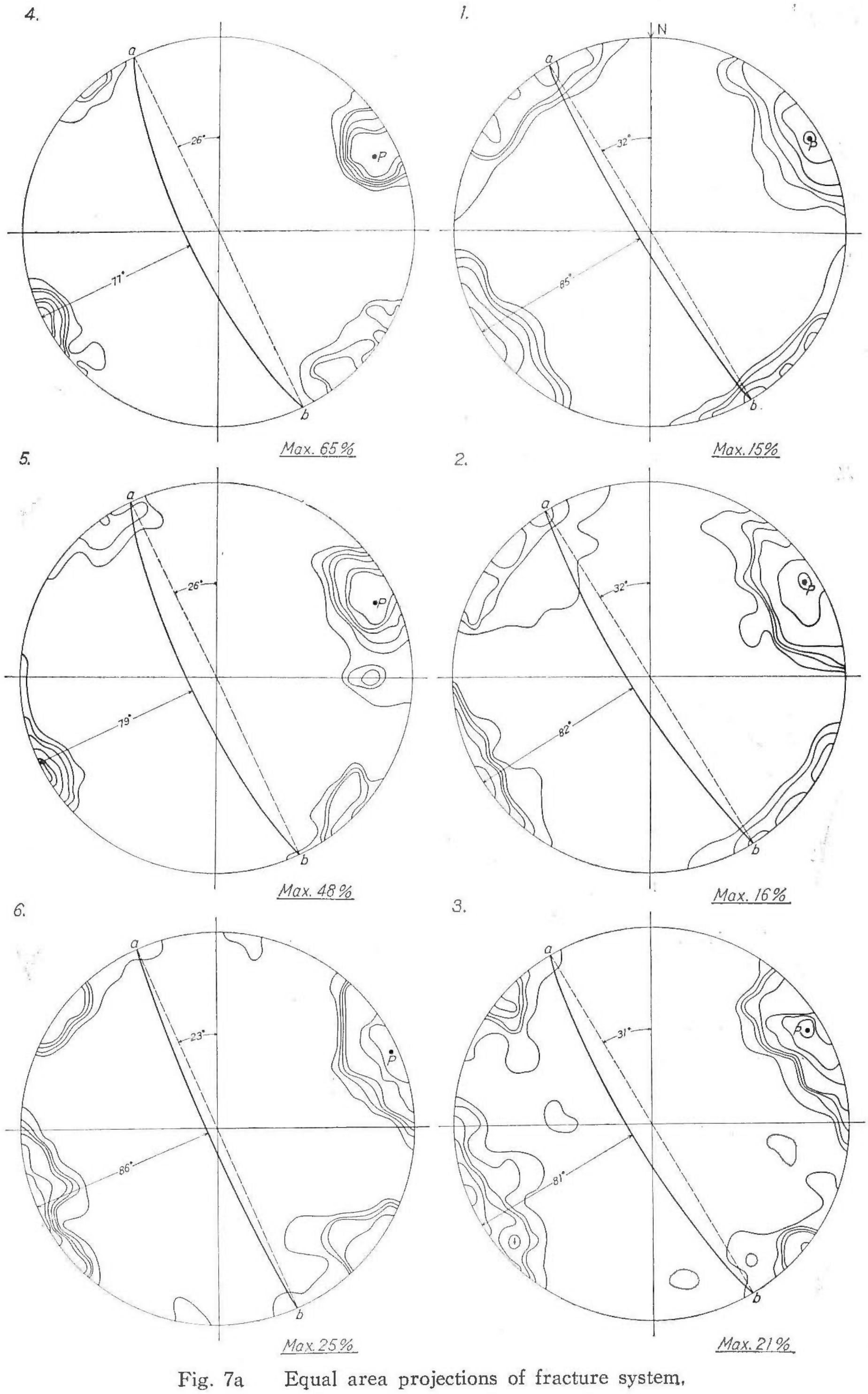


Fig. 7a Equal area projections of fracture system.

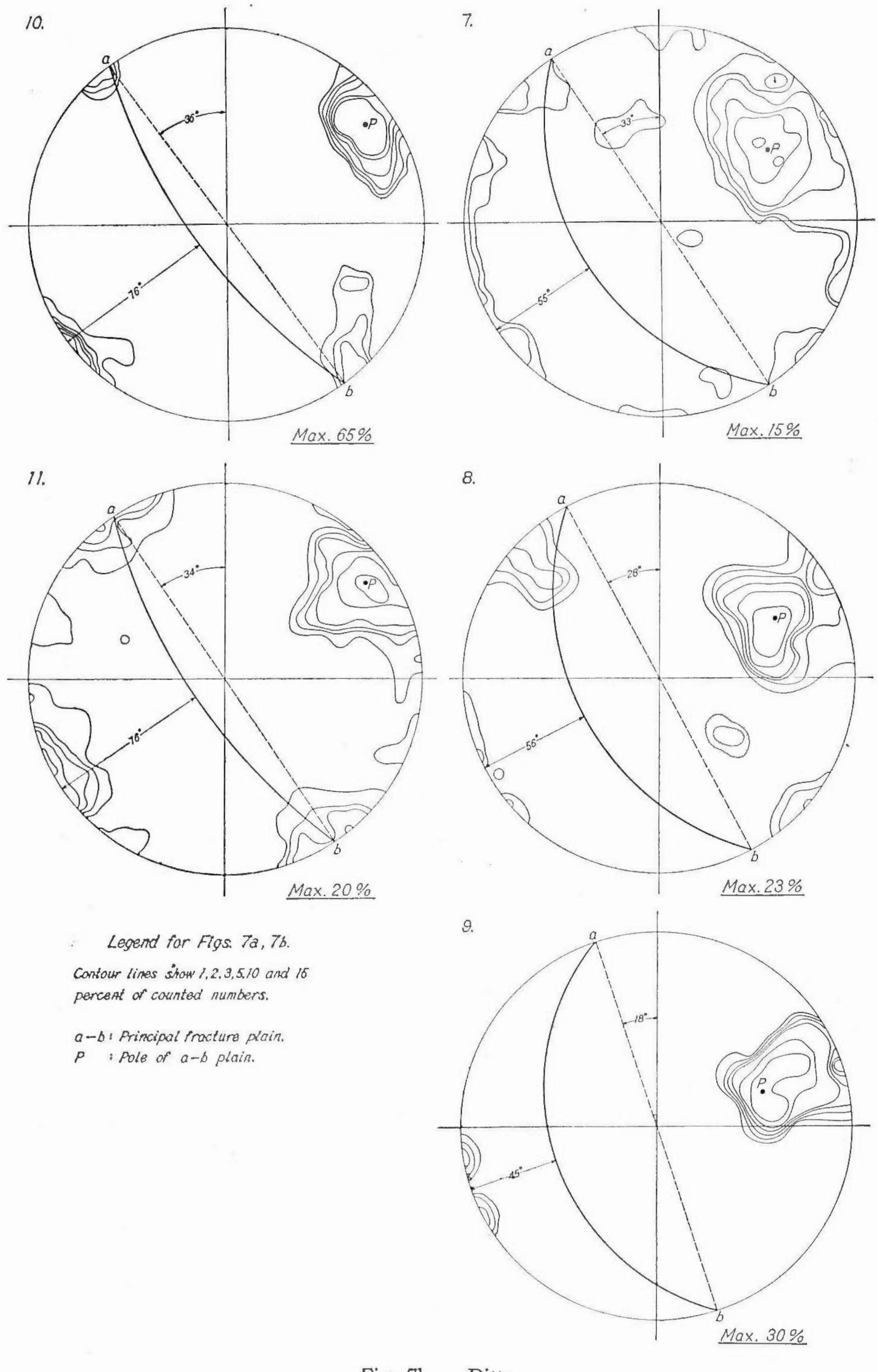

10.
a
36°
P
76°
b
Max. 65%
7.
a
33°
P
55°
b
Max. 15%
11.
a
34°
P
76°
b
Max. 20%
8.
a
28°
P
56°
b
Max. 23%
Legend for Figs. 7a, 7b.
Contour lines show 1, 2, 3, 5, 10 and 15 percent of counted numbers.
a–b : Principal fracture plain.
P : Pole of a–b plain.
9.
a
18°
P
45°
b
Max. 30%

Fig. 7b Ditto.

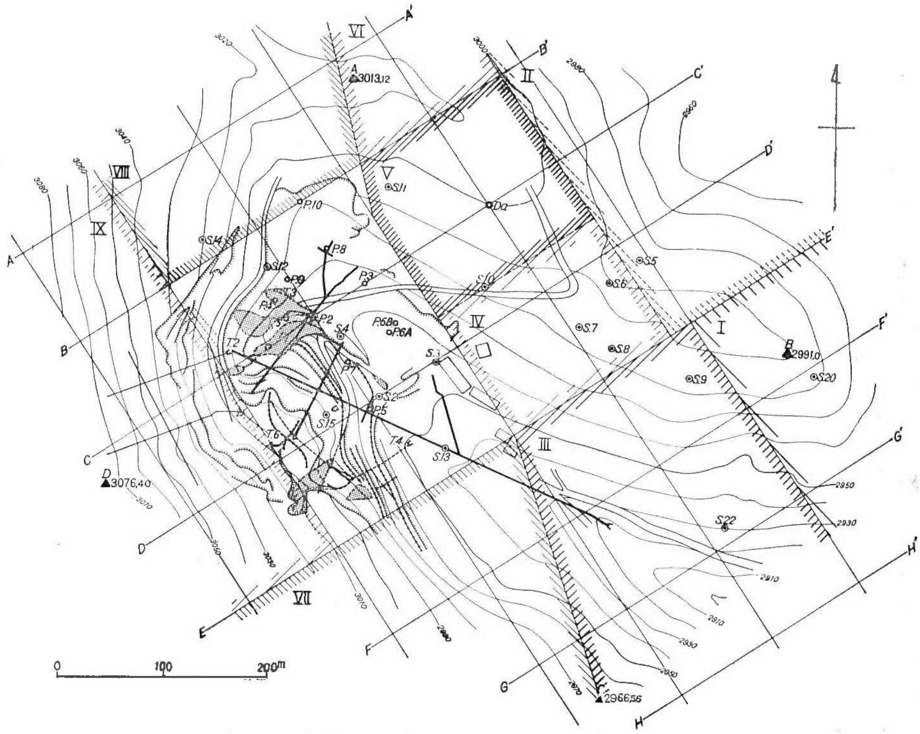


Fig. 8 Map showing area for diagram of fracture system, and sections for block diagrams

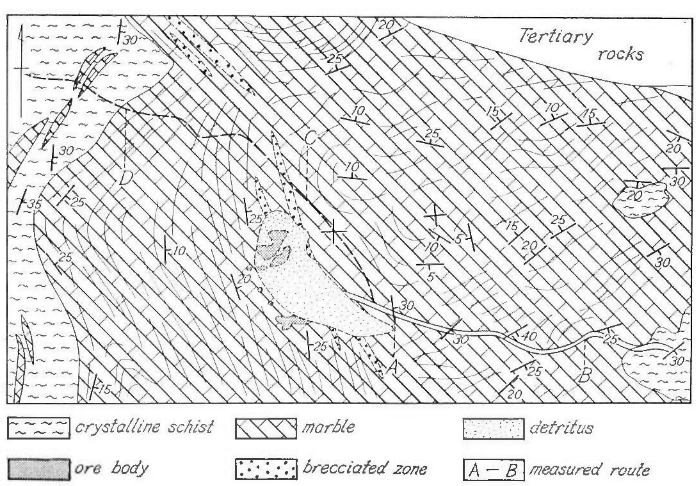


Fig. 9 Structural map around routes A—B and C—D

nation of the fractures which strike north 30° west is 55° to the west, or 25° less than in the other areas, whereas the fractures which strike north 55° east have the same inclination as the others.

Two important conclusions may be drawn from these observations. Firstly, the crystalline limestone in this area was severely fractured diagonally during the formation of the dome. As already noted there are innumerable fractures – over a hundred in some places even in the 25 square metres used as standard areas. Many of these fractures were filled with recrystallized carbonate crystals to form veinlets. It is reasonable to conclude that ground water permeated these fractures in the limestone and underlying sulphide ore to bring about chemical reaction between them.

Secondly, certain interesting structural deductions can be made. Northeast of the main valley in which the mine is located, the overlying limestone forms a syncline on the western side of the brecciated zone (Plate IVa,b). But as this area must be considered to be the centre of the domal structure, the limestone should contrarily show an anticlinal form. The reason for this discrepancy may be deduced from the fracture system as represented in this locality by Diagrams 7, 8 and 9 in Fig. 7b. It has been noted that the inclination of the northwesterly fracture system is about 25° less than the original inclination of this system over the whole area as shown in the other diagrams. Whereas the northeasterly trending fracture system, as shown in Diagrams 7, 8 and 9 retains the same dip as appears elsewhere in the area. This show that the strata represented by Diagrams 7, 8 and 9 were tilted 25° at right angles to the north 30° west strike after the formation of the fracture system. As a result the original anticlinal structure became a gentle syncline in form. In seeking the cause of this eversion we may presume that during and after the formation of the carbonates from the sulphide ore, the mass of carbonate ore was compressed by the weight of the overlying limestone causing this limestone to subside, and in doing so, to become tilted.

Brecciated zones: In the mining area there are two nearly parallel brecciated zones striking north 30° west. The eastern one is stronger than the western one and forms the eastern limit to the orebody. The eastern zone is 20 metres wide and stands vertically. The zone is filled with angular fragments of limestone, several centimeters in diameter, and is cemented with recrystallized calcite (Plate IIIb). As there are no fragments of other rocks the throw of the zone is probably small; no data were obtained to indicate the direction of displacement. The western zone may be recognized in the overlying limestone at the northern side of the portal to Tunnel 2 and continues to the southeast in 7 metres width. The zone was not recognized in the orebody where it may be completely replaced by lead and zinc carbonates.

IV. 4 Hydrothemal alteration

As already noted the country rock would seem to be hydrothermally altered in some places. This alteration in the igneous rocks and the crystalline limestone, has features which are characteristic of metasomatism by permeating aplitic materials. But the areas over which this alteration was observed are limited and they are not near the orebody. In fact no evidence of a connection between the source of the sulphide ore and the hydrothemal alteration of the host rock was found, except perhaps that barite occurs only in the sulphide ore and in the hydrothermally altered area.

The schist on the foot-wall and the crystalline limestone on the hanging-wall are fresh and show no hydrothermal alteration, though there is slight sericitization, chloritization and carbonatization.

Generally it would seem that before the carbonatization of the sulphide ore most of the country rock had been only slightly altered hydrothermally by the ore solutions. After the formation of the sulphide ore the crystalline country rock around the ore was strongly altered to lead and zinc carbonates (Plate Va, b) by surface waters under normal conditions of temperature and pressure.

V. Genesis of Orebody

The lenticular form of the sulphide ore and its conformable position between schist and limestone is suggestive of a sedimentary origin, but there is no proof of this.

V. 1 Sulphide ore

Sulphide ore was found in three places: in Tunnels 1 and 2, in some drill-cores, and as boulders in the carbonate ore in the open pits.

About 20 metres of sulphide is exposed about 320 metres from the portal of Tunnel 1, between a carbonate hanging-wall and a schist foot-wall. The boundary between the carbonate and sulphide is irregular not only megascopically but also in finer detail as seen under the microscope. The boundary between the sulphide ore and the schist of the foot-wall is irregular and roughly parallel to the schistosity. The sulphide ore is massive with no bedding and does not show the effects of regional metamorphism, recrystallization not being evident under the microscope. If the sulphide ore were sedimentary there should be some feature to suggest this, and further, the effects of regional metamorphism should be in evidence.

The writer was informed that there is some sulphide at the end of Tunnel 2, but he could not find it – it probably represents small blocks that escaped carbonatization.

Some sulphide mixed with carbonate appeared in the core of drill-hole 8 at a depth of 70 metres. The boundary between the sulphide and the carbonate is irregular and transitional, the sulphide passing into schist along an irregular line at a depth of 85 metres; the boundary is more clearly defined than that between sulphide and carbonate. In case material from a depth of 80 metres, the sulphide ore cuts white coloured sericite-quartz-schist in the form of a vein, which is 15 mm thick and intersects the schist at an angle of 30° to the schistosity. Small lens-shaped fragments of schist are arranged parallel to the direction of the vein, but no fragment of limestone was found in the vein. Under the microscope it may be seen that the boundary between the schist and the vein is sharp, that this boundary clearly cuts the schistosity, and that in addition to minute fragments of schist there are also scattered flakes of sericite and some quartz grains. On the other hand no ore was seen within the schist outside the vein.

Blocks of sulphide ore within the carbonates in the open pits are undoubtedly remnants of sulphide that have escaped alteration. There is some barite in this material. This sulphide was discarded by the early miners because they were looking for lead only, and moreover they had no technique for smelting sulphide ore. Some of the old dumps may have been recemented by carbonate-containing water.

There is no clear evidence pointing to a sedimentary origin for the sulphide ore. In fact many megascopic and microscopic observations on samples from the tunnels and drill-cores suggest a metasomatic origin though it would be unwise yet to be dogmatic in this matter. Theoretically the vein material might have formed in at least three ways, the ore might have originally been sedimentary and have been remobilized by tectonic movement; ore which may have been formed by replacement might have been transferred at a later time to the vein; the vein ore may have originally formed from solutions as such. Until the relation between the sulphide ore and the schist has been studied in more detail, chemically and petrologically, we are clearly not in a position to decide between these alternatives.

V. 2 Carbonate ore

It is much easier to understand the genesis of the carbonate ore – as an oxidation product of the sulphide ore. WRIGHT (1964) remarked that "Most sulphide orebodies of zinc and lead contain some pyrite as well. It is likely that the original Anguran was no exception since there are limonitic exposures which presumably developed by hydrolizing from ferric sulphate, an oxidation product of pyrite. Some of the ferric sulphate undoubtedly reacted with sphalerite in the following manner:

$$ZnS + 4Fe_2(SO_4)_3 + 4H_2O = ZnSO_4 + 8FeSO_4 + 4H_2SO_4$$

The zinc sulphate, soluble in surface waters. Trickled downward and, in contact with limestone, reacted to form zinc carbonate precipitate and calcium sulphate. The zinc carbonate was left behind while the soluble calcium sulphate was carried away. Continued reactions of this kind presumably enriched the lower ore strata in zinc mixing carbonates with the sulphides. These reactions also account for the chemical decay of the limestone, the residual clay, the removal of support to the overlying strata and inevitable subsidence. The Anguran deposit as it now exists is believed to have been enriched throughout by the migration of zinc sulphate and its reaction with the carbonate rocks as well as by the chemical removal of barren ingredients. The underlying mica schist formed an impervious floor for descending zinc-bearing solutions and thus localized deposition. The original sulphide mantle had been largely removed by solution and erosion. Galena may also have reacted with ferric sulphate to produce lead sulphate. The latter, though not soluble in ordinary ground water, have reacted in place with carbonated waters and yielded cerussite. Secondary enrichment of this nature is not uncommon in arid or semi-arid regions as at Anguran."

V. 3 Geological history

The geological history of the mining area may be summarized as follows:

Deposition of sedimentary rocks
Regional metamorphism
Intrusion of acidic material
Formation of sulphide ore
Tectonic uplift (formation of diagonal fractures)
Permeation of groundwater through fractures
Change of sulphides to carbonates
Subsidence of carbonate ore and overlying limestone

VI. Ore Grade and Reserves

To determine the grade of the ore two hundred samples were taken from surface exposures and tunnels; those from surface exposures were taken at 10 metre intervals as shown in Fig. 10. Fresh surfaces were stripped vertically along 5 cm grooves from which chip samples were taken between 30 and 150 cm above the ground. Chemical analyses of these samples are set out in Table 1. In the tunnels samples were taken at 10 metre intervals in the same way as in the open pits from locations which are shown in Fig. 11, chemical analyses being given in Table 2. Assay maps based on the data in this Table are given in Figs. 12 and 13.

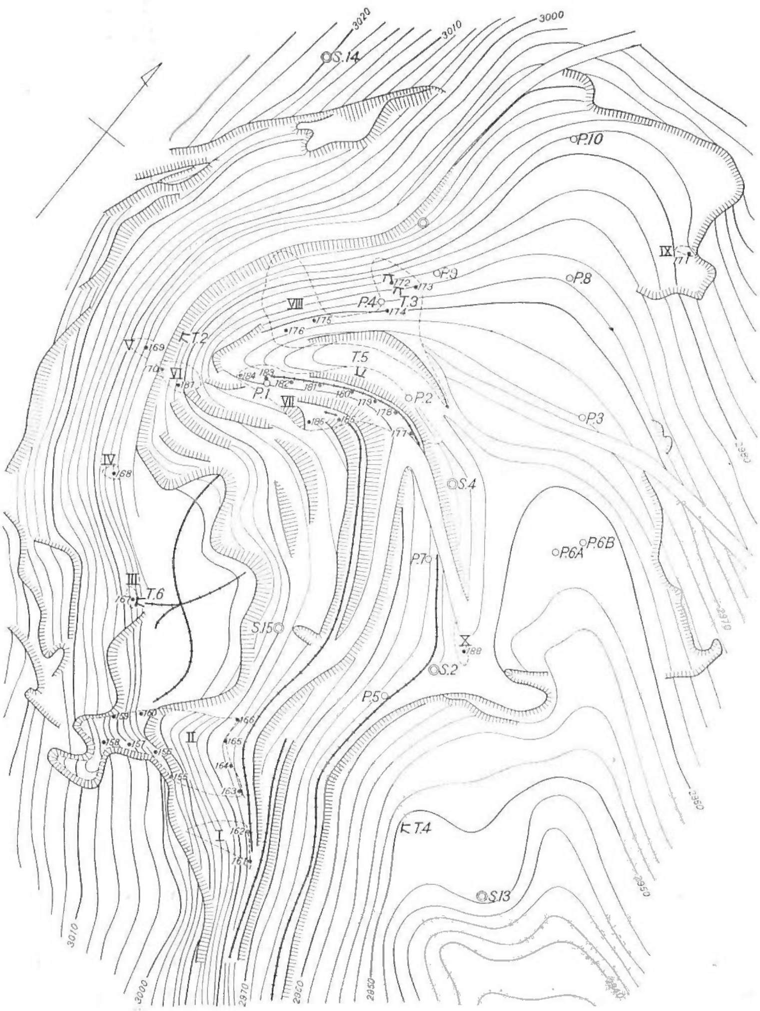


Fig. 10 Map showing sample localities in the open pits.

Table 1 Determination of Total Lead and Zinc on Pb, Zn ore samples from open pits. Analysed in the Chemical Laboratory in the Geological Survey of Iran in 1965.

Sample number	Pb	Zn
155	0.50	25.3
156	6.15	15.2
157	1.00	19.25
158	1.00	15.4
159	12.70	3.76
160	2.70	17.80
161	0.50	21.2
162	0.50	21.4
163	0.50	24.5
164	0.30	24.6
165	4.75	18.1
166	2.35	9.21
167	9.00	13.7
168	11.00	13.6
169	1.00	none
170	15.30	5.59
171	1.90	15.8
172	12.2	16.7
173	4.00	26.1
174	4.00	21.0
175	16.9	3.33
176	4.75	3.33
177	1.90	5.55
178	2.7	2.12
179	7.65	8.79
180	10.7	5.59
181	11.0	1.34
182	3.70	4.08
183	14.2	10.3
184	4.00	12.8
185	1.55	17.2
186	6.15	9.80
187	12.7	7.09
188	2.7	10.10
Average	5.6	12.03

Number of this table corresponds to the locality number in Fig. 10.

Table 2 Determination of Total Lead and Zinc on Pb, Zn ore samples from the Tunnel I. Analysed in the Chemical Laboratory in the Geological Survey of Iran in 1965.

Sample number	Pb	Zn
1	3.23	0.26
2	1.13	20.90
3	0.43	3.59
4	0.14	0.33
5	none	1.90
6	0.30	8.66

7	1.19	16.7
8	1.86	24.7
9	1.94	27.2
10	1.38	7.22
11	0.67	16.54
12	4.37	13.24
13	0.62	11.31
14	0.29	0.95
15	9.96	0.75
16	4.25	29.03
17	1.61	26.84
18	7.77	37.7
19	2.95	36.09
20	1.87	5.72
21	5.62	15.30
22	2.58	7.06
23	0.48	15.73
24	7.93	31.88
25	10.60	10.17
26	2.23	6.61
27	4.17	11.08
28	6.22	2.52
29	2.52	8.53
30	3.46	20.4
31	11.9	14.0
32	9.25	14.87
33	13.9	11.11
34	7.15	35.8
35	7.80	32.7
36	10.3	27.26
37	12.4	22.5
38	7.06	17.27
39	4.11	5.39
40	3.71	2.65
41	2.70	32.7
42	none	0.55
43	5.65	19.84
44	1.05	32.95
45	7.97	35.43
46	12.55	29.55
47	19.07	12.13
48	10.21	5.13
49	4.18	6.11
50	6.29	24.06
51	4.59	13.60
52	4.73	33.54
53	3.74	24.65
54	3.60	43.51
55	12.12	38.64
56	10.13	37.33
57	0.17	4.38
58	none	0.98
59	none	0.59

60	none	1.11
61	7.05	42.9
62	5.79	44.9
63	6.94	44.0
64	9.71	39.16
65	5.51	43.7
66	7.67	44.1
67	33.4	13.1
68	28.7	21.4
69	5.03	33.9
70	3.35	35.7
71	3.59	28.29
72	20.1	23.01
73	21.1	30.0
74	15.13	29.0
75	10.47	11.34
76	11.67	28.6
77	7.47	41.64
78	7.21	28.77
79	6.63	23.6
80	12.86	22.23
81	22.9	19.25
82	13.07	24.45
83	12.53	20.8
84	22.31	18.4
85	5.46	39.5
86	12.25	27.65

Number of this table corresponds to the locality number in Fig. 11.

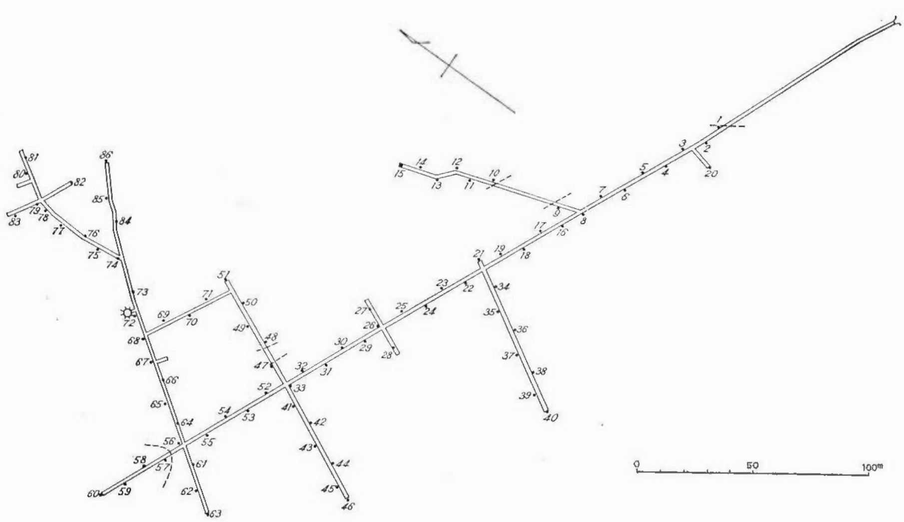


Fig. 11 Map showing sample numbers in Tunnel I.

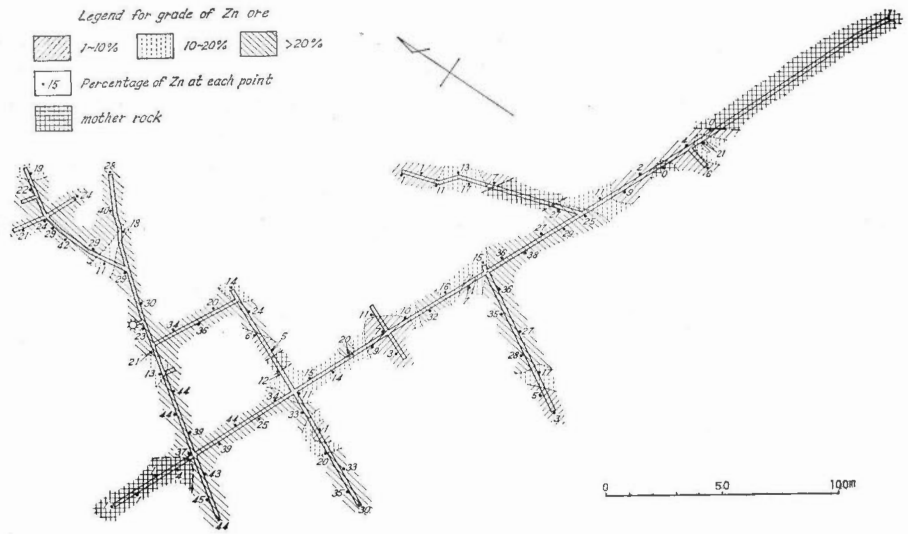


Fig. 12 Assay map for Zinc in Tunnel I.

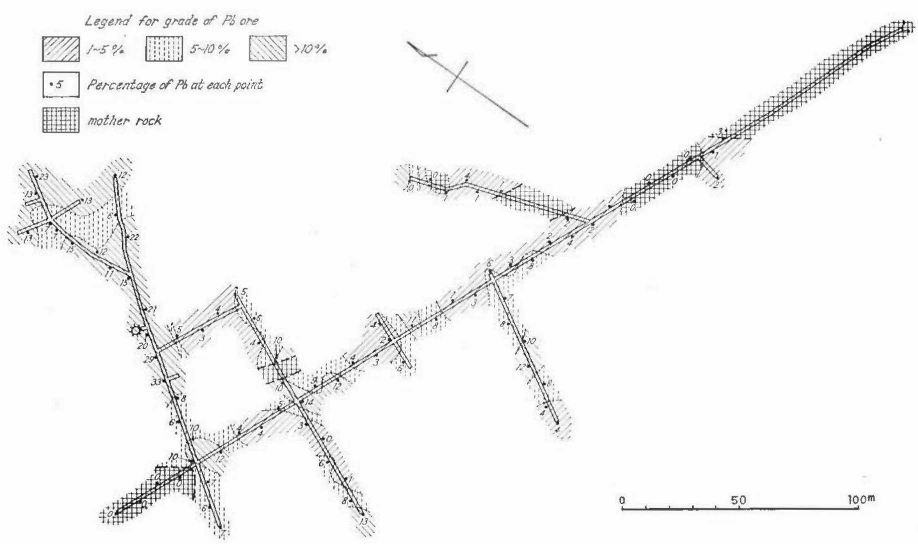


Fig. 13 Assay map for Lead in Tunnel I.

The grade of the carbonate ore was probably determined by the grade of the lead- and zinc-bearing solutions that formed the ore, and seems to have been so irregular that no pattern can be discerned in the distribution of high and low grade ore. It is thus difficult to classify the ore in the field without chemical test, although with some experience, colour and weight can be used as a guide.

The full extent of the ore reserves is still uncertain, but from the information obtained from tunnels and drill holes the mineralized area is estimated to be 76, 000 square metres in area as shown in Fig. 5. To estimate the thickness of the orebody information from drill holes was used, but as the core recovery was incomplete an exact estimate of the thickness was not possible. Roughly however it is considered to lie between 25 and 60 metres, with an average of, say, 45 metres. Using a specific gravity of 3. 0, the total ore reserves become $(76000 \times 45) \times 3 = 10,260,000$ tons. Having regard for erosion and ore already extracted, we may consider the reserves to be of the order of 9, 000, 000 tons.

Data from drill-cores are given in Table 3; it should be noted that on account of core loss the figures are rather different from those given by WRIGHT (1964).

Table 3 State of Drilling Core

Drilling hole No. 1.	
0 - 20m	Carbonate ore
20 - 40	Sulphide ore
40 -120	Crystalline schist
Drilling hole No. 2.	
0 - 37m	Carbonate ore
37 - 50	Carbonate ore and sulphide ore
50 - 83	Crystalline schist
Drilling hole No. 3.	
0 - 13m	Crystalline limestone
13 - 18	Carbonate ore
18 - 33	Sulphide ore
33 - 50	Carbonate ore
50 -111	Crystalline schist
Drilling hole No. 4.	
0 - 47m	Carbonate ore
47 - 88	Crystalline schist
Drilling hole No. 5.	
0 - 66m	Crystalline limestone
66 - 85	Carbonate ore and crystalline limestone
85 -113	Crystalline schist
Drilling hole No. 7.	
0 - 62m	Carbonate ore
62 - 72	Carbonate ore and crystalline limestone
Drilling hole No. 8.	
0 - 77m	Chiefly carbonate ore with some crystalline limestone
77 - 87	Sulphide ore
87 - 94	Crystalline schist
Drilling hole No. 9.	
0 - 57m	Carbonate ore
Drilling hole No. 10.	
0 - 19m	Crystalline limestone
19 - 83	Carbonate ore
83 - 91	Sulphide ore
91 - 97	Crystalline schist

VII. Summary of Conclusions

There is considered to be 9 million tons of ore with an average grade of 3 to 6 percent lead and 20 to 35 percent zinc.

The bulk of the ore is lead and zinc carbonate in the form of cerussite and smithsonite with some hydrozincite, calamine and pyromorphite. These minerals were derived from sulphides by chemical reaction, only cores of the sulphides remaining. There is some barite gangue in the sulphide ore in the northern part of the mine.

There is little definite evidence as to the genesis of the sulphide ore, but field and laboratory observations seem to suggest derivation by metasomatic action in crystalline limestone after the completion of the regional metamorphism.

The carbonate ore was formed from pre-existing sulphide ore by carbonatization brought about by ground water permeating fractures which are widely distributed in characteristic patterns.

It is considered that prospects for the successful development of the mine are promising.

References

WILFORD S. WRIGHT (1964): Types of Lead and Zinc Ore Deposits in Iran. Presented at CENTO Mining Geology – Base Metals Symposium in Turkey, September, 14–28, 1964.

Japanese Metal Mining Research Team for Iran, J.M.I.A. (1958): Report on the Metal Mining Industry of Iran.

イラン国北西部のアングラン鉱山

平山　健

要　旨

アングラン鉛・亜鉛鉱山はイラン国の北西部を占めるカバリ州の南部に位置する。首都テヘランからトルコ方面に向かう国道に沿ったザンジャン市から，南西の方向に別れてビジャールに向かう道路，約 93 km の地点から北方に向かい，約 83 km で鉱山に達する。ザンジャン市と鉱山の間は約5時間を要しているが，現在建設中の新道が完成すれば距離，時間共著しく短縮されるはずである。

現在までこの鉱床についての詳細な調査は実施されておらず，わずかに巻末に記載した文献が資料として存在するにすぎない。

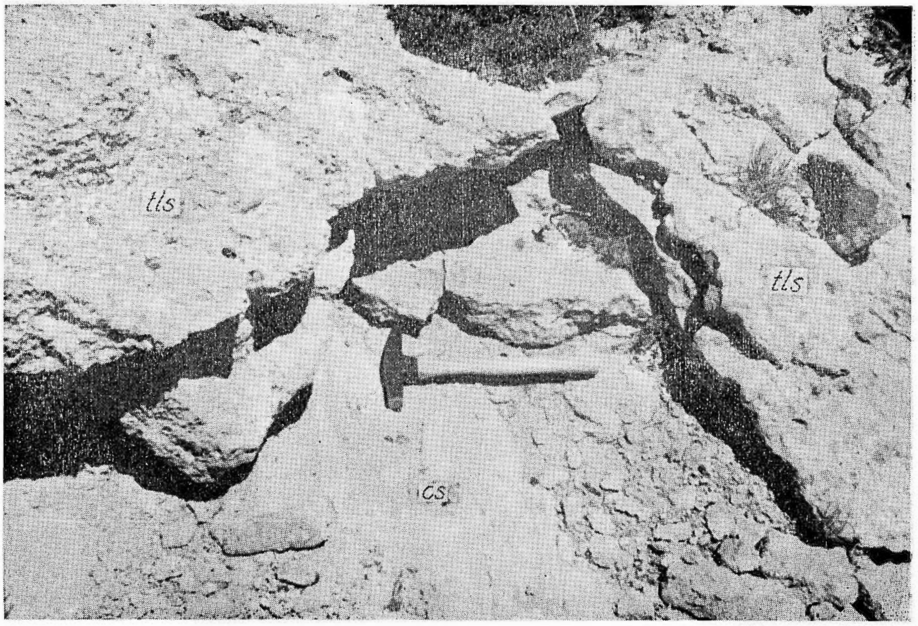
鉱山付近の地質は第2図などに示してあるが，第三紀以前の（前カンブリア紀と云われている）変成岩類とそれを囲んで露出している中生代，第三紀の地層でなりたっている。変成岩類は下部に層厚 400m 以上（下限は未確認）の結晶片岩があって，その上位に整合状に層厚約 300m の結晶質石灰岩がある。下位の結晶片岩は広域変成作用によって形成されたものと思われるが，その変成作用と前後して局部的に貫入したと思われる斑粝岩類，角閃岩類，蛇紋岩類などによって貫かれている。さらに変成作用の終了後にある種の溶液の侵入を受けた事実が一部に存在する黒雲母の特種な性状や重晶石脈の存在から推定される。鉛・亜鉛の鉱体は下位の結晶片岩と上位の結晶質石灰岩との間にレンズ状に存在している。現在は鉱体の大部分が炭酸塩となっているが，本来は硫化物として生成したものと思われる。この硫化物の成因は明らかでないが，第1坑道内や試錐のコアなどにみられる硫化鉱石，母岩，炭酸塩鉱石の相互関係からみると母岩の広域変成作用が完了した後に鉛・亜鉛を含有する鉱液によってこの場に生成したものと考えられる。また硫化鉱石が炭酸塩鉱石に変化したのは母岩中にきわめて特長的に存在する岩石のさけめなどから侵入した地下水の作用によったものであると考えられる。鉱石は主として白鉛鉱，紅亜鉛鉱，異極鉱，菱亜鉛鉱，亜鉛華などの炭酸塩で，方鉛鉱，閃亜鉛鉱が局部的に残留している。品位は別表に示してあるが，平均値は鉛３～６％，亜鉛20～35％で，全鉱量は約 900 万トンと推定される。

PLATES

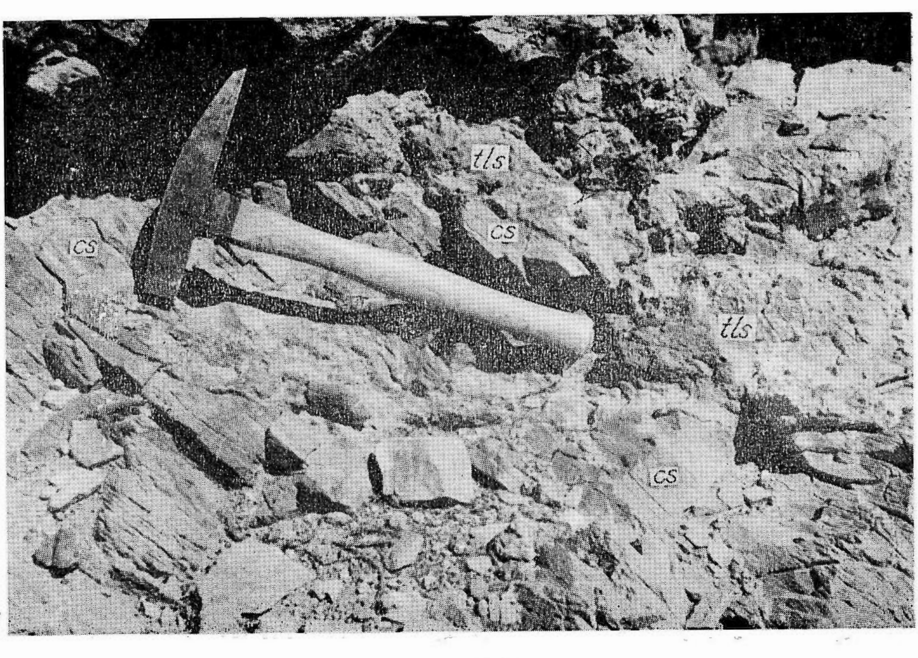
AND

EXPLANATIONS

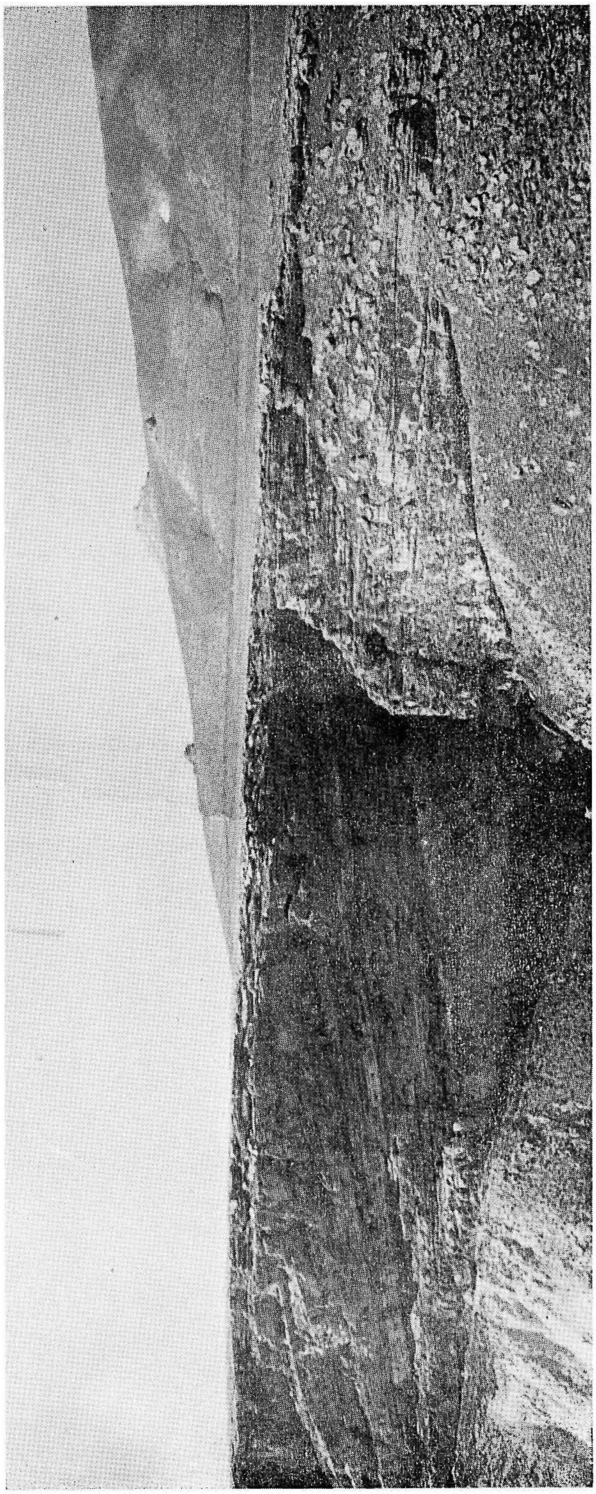
(with 8 Plates)



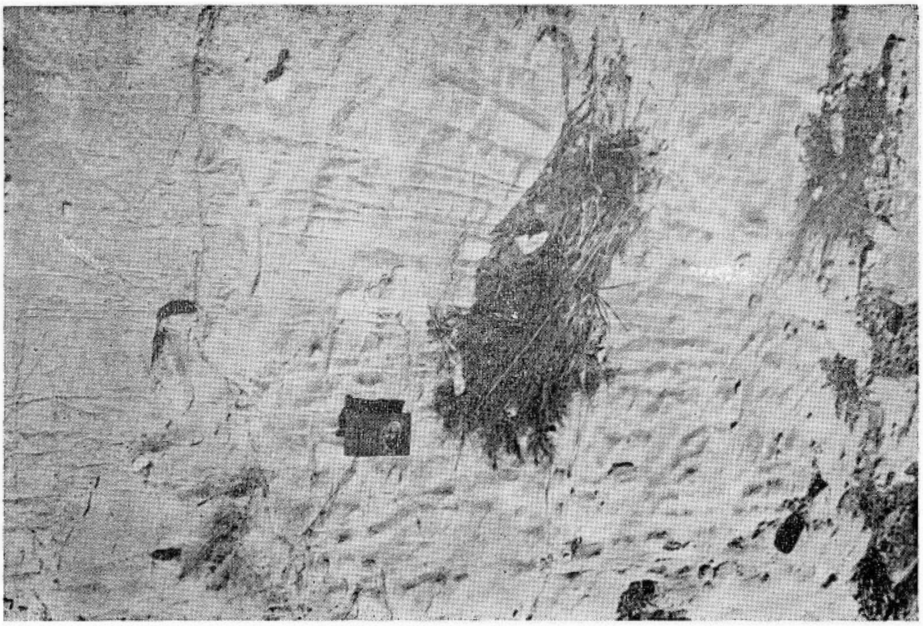
a. Unconformity plane between crystalline schist (cs) and younger limestone (tls).



b. Ditto

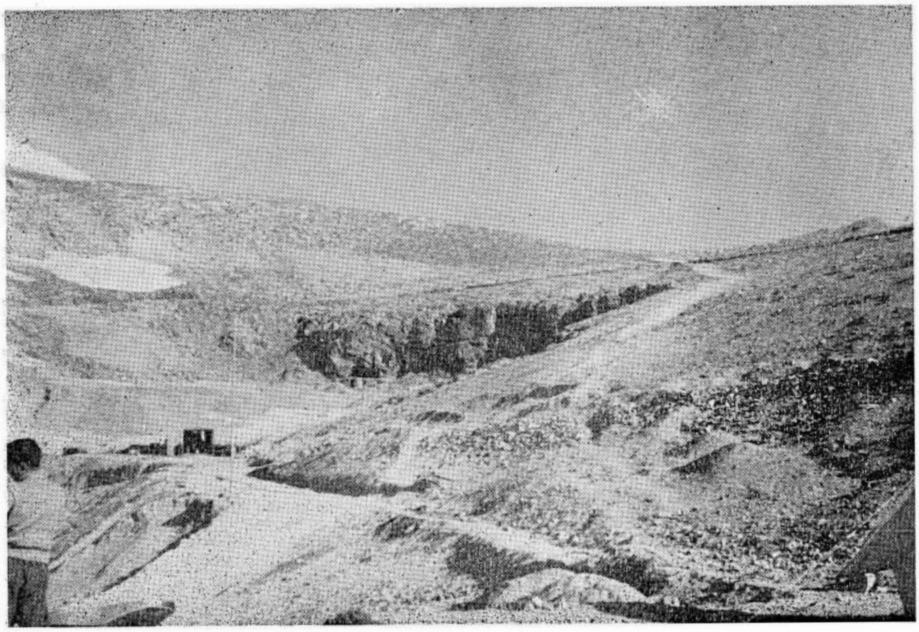


Tableland made by travertine limestone



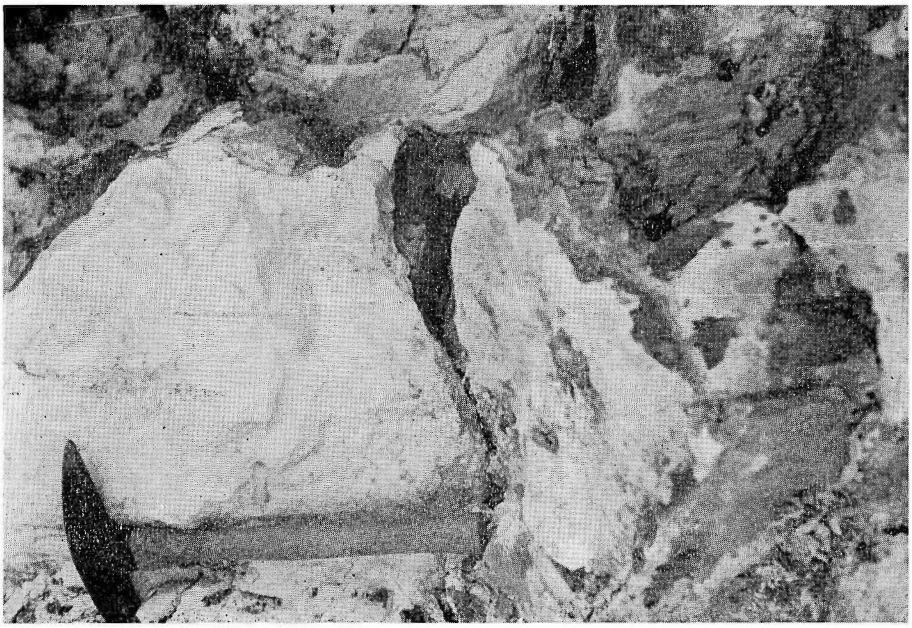
a. Surface of crystalline limestone. Characteristic fractures are observable in the direction of N 30 degrees W.

b. BZ-B'Z' Brecciated zone. Fragments of limestone are cemented in calcareous materials.

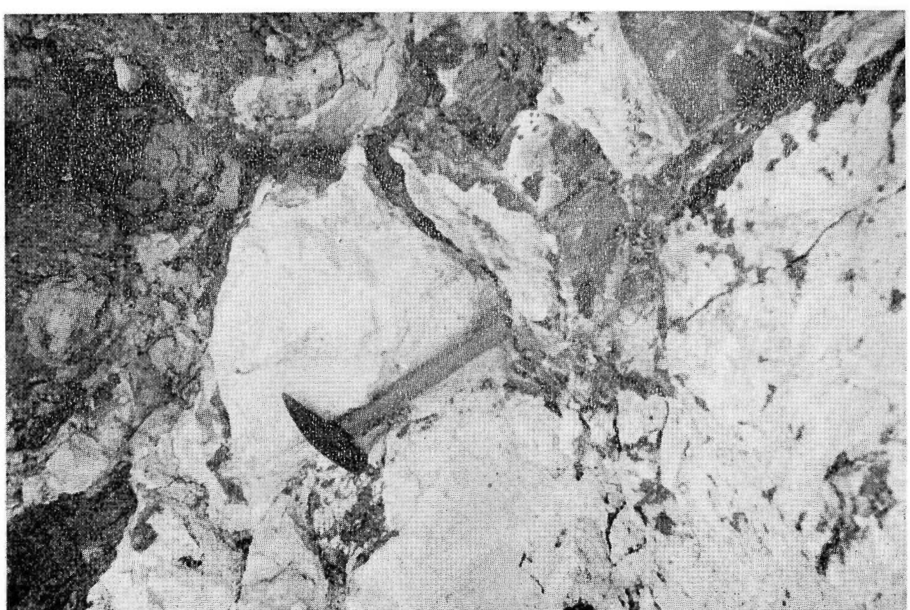


a. Northern view of the mining area. Limestone cliff shows synclinal feature.

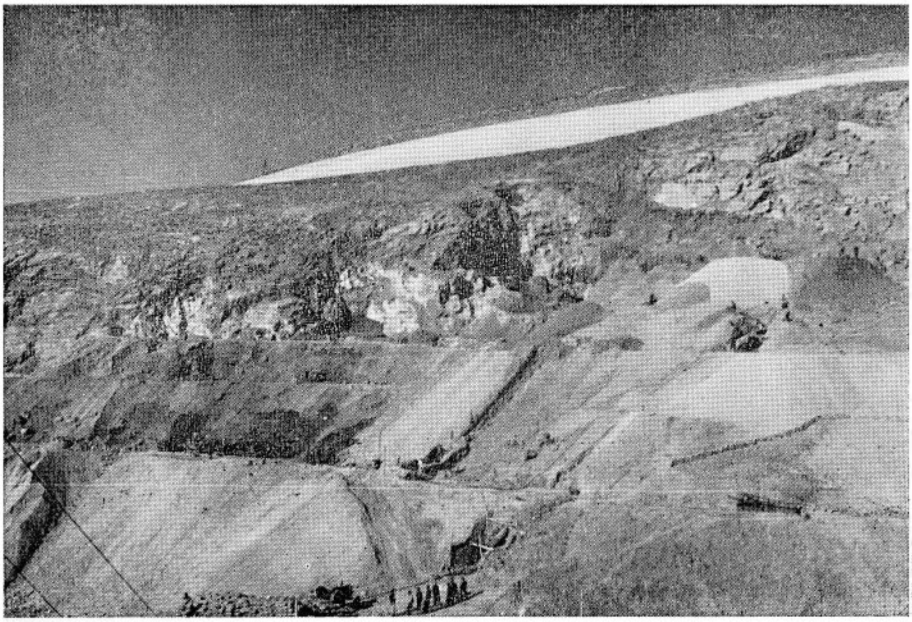
b. Ditto.



a. Carbonate ore at open pit. Limestone having its original bedding planes has entirely changed to carbonate ore.



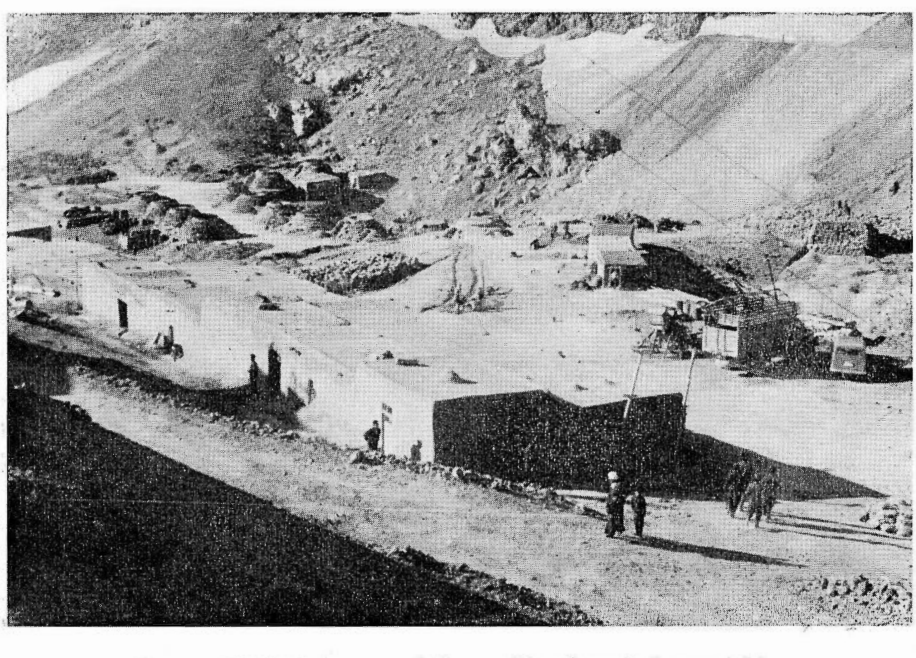
b. Ditto.



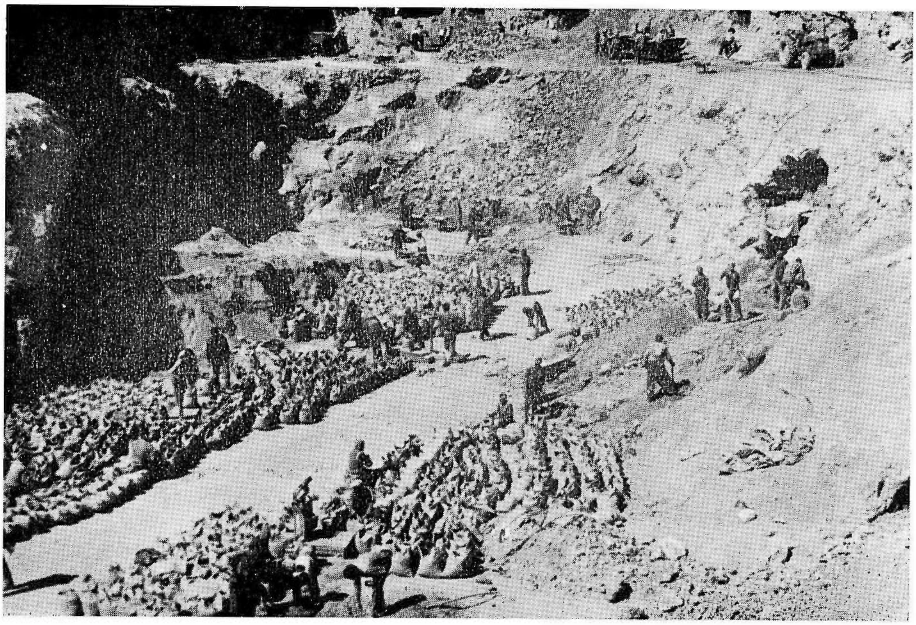
a. View of open pit (Southwestern part)

b. Ditto (Northeastern part)

a. View of mining area. From northwest to southeast.



b. Worker's house and the smelting furnace (upper left).



a. Package of crude ore.

b. Loading of ore to truck.

地質調査所報告は１報文について報告１冊を原則とし，その分類の便宜のために，次のようにアルファベットによる略号をつける。

A．地質およびその基礎科学に関するもの
- a．地　質
- b．岩石・鉱物
- c．古生物
- d．火山・温泉
- e．地球物理
- f．地球化学

B．応用地質に関するもの
- a．鉱　床
- b．石　炭
- c．石油・天然ガス
- d．地下水
- e．農林地質・土木地質
- f．物理探鉱・化学探鉱および試錐

C．そ の 他

D．事業報告

As a general rule, each issue of the Report, Geological Survey of Japan will have one number, and for convenience's sake, the following classification according to the field of interest will be indicated on each Report.

A. Geological & allied sciences
- a. Geology
- b. Petrology and Mineralogy
- c. Paleontology
- d. Volcanology and Hot spring
- e. Geophysics
- f. Geochemistry

B. Applied geology
- a. Ore deposits
- b. Coal
- c. Petroleum and Natural gas
- d. Underground water
- e. Agricultural geology and Engineering geology
- f. Physical prospecting, Chemical prospecting & Boring

C. Miscellaneous

D. Annual Report of Progress

地 質 調 査 所 報 告

第 221 号

BAMBA, T. & SAWA, T. : Spilite and associated manganiferous hematite deposits of the Tokoro district, Hokkaido, Japan, 1967

第 222 号

HOSHINO, K. : Fracture system of Oshima Island, Kyūshū : A study of jointing in brittle sedimentary rocks, 1967

第 223 号

片田正人：長野県木曾地方北部の領家変成帯, 1967

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第 225 号

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REPORT, GEOLOGICAL SURVEY OF JAPAN

No. 221

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No. 224

MIYAMURA, M. : Stratigraphy and geological structure of the Permian formations of Mt. Ibuki and its vicinity, Central Japan, 1967 (in English)

No. 225

SUMI, K. : Hydrothermal rock alteration of the Matsukawa geothermal area, Northeast Japan, 1968 (in English)

HIRAYAMA, K.

Geological Study on the Anguran Mine, Northwestern Part of Iran

Ken HIRAYAMA

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Geological and mineralogical features of the Anguran mine is described. The orebody seems to be in the form of a lens between two types of metamorphics, namely, schist and crystalline limestone. The original ore consisted of sulphides of lead and zinc brought into the limestone metasomatically and the secondary alteration has changed the sulphides almost entirely to carbonates. Ore reserves are estimated at about nine million tons with grades of 3 to 6 percent lead and 20 to 35 percent zinc.

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