Study of Gold Ores from Toh Moh, Krabin and Ta Tago

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FOREWORD.

Gold deposits have been found throughout Thailand. Out of seventy provinces gold has been reported from twenty eight. Many deposits known are, however, geological freaks. In the past there were concessions to work for gold at Lomsakdi (หล่มศักดิ์), Ta Tago (ท่าตะโก), Bangsaparn Yai (บางสะพานใหญ่), Krabin (กระบินทร์), and Watana (วัฒนา). All the mine operations resulted in failures, but nothing is known of the cause. At present, there is only one gold mine in operation in this country, the Litcho Mine in the province of Naradhivas.

The geology of the gold fields just mentioned has not been worked out in details. With samples of ores and country rocks collected we studied the deposits morphologically and microscopically It is strongly hoped that this study, when completed, will be of some help to prospectors looking for gold deposits in Toh Moh, Krabin and Ta Tago.

GOLD ORE FROM TOH MOH.

Toh Moh is a district in the province of Naradhivas. It is a hilly district without adequate transport facilities. The deposit is at Ban Pajo and Litcho near the Malay boundary. It is much more convenient to get to the deposit by way of Kelantan.

Roughly speaking, the gold belt occupies an area extending from Tanyong Mas to the Malayan gold belt at Toh Moh. It is an area of schist intruded by fine grained granite. Dykes of biotitite are found intruding both rocks.

There are lodes in both granite and schist. The ore examined has been obtained from a lode worked by the Société des Mines d'or de Litcho striking N15°E and dipping 20°E. The lode is wholly in granite and traversed by many fault planes (rock slips) which make mining difficult. The ore body is about 3 feet wide and carries from eleven to fifty grams of gold per ton of rock.

Examined by naked eye the lode consists mainly of quartz which is both white and grey. There are fissures in the quartz; and in the fissures gold, pyrite, chalcopyrite, galena, sphalerite and arsenopyrite are seen. The fissures are filled with greenish minerals which effervesce, in part, with dilute hydrochloric acid. Intermingled with the ore are pieces of greenish rock apparently placed inside the lode.

From eye examination, it is evident that gold was introduced later than the quartz of the lode and that some of it is embedded in sphalerite and pyrite. The gold is, in many places, very fine and scarcely perceptible to naked eyes.

A slide of the greenish rock found in the lode shows it to be a granite sheared and intruded by a hydrothermal solution causing alteration of feldspars to sericite. The quartz of the granite was corroded. Minerals brought with the solution include calcite and quartz.

Considering that the wall rock is granite, this greenish material inside the lode should be a horse rock, that is: a fragment of granite enclosed by quartz of the lode.

Slides of the vein quartz show that it had been intruded by epidote-calcite-quartz strings or veinlets carrying gold and the metallic sulphides. Original quartz crystals have been cracked and the boundaries corroded by the solution with the development of aggregates of tiny quartz crystals filling the spaces. In places, gold has been intruded into such cavities formed. Therefore, if the cracks extend far into the original mass of quartz, gold and the other sulphides may be present far from the veinlets. With naked eyes, this happening is not apparent ; and the mistake might be made that gold also occurs in the mass of quartz, being seen apparently within it.

In the veinlets, there is seen something like a flow structure. Most of the gold occurs at the rim of the veinlets, very little appearing in the middle. Some of it occupies cracks in or around quartz crystals. The sulphide minerals are similarly placed. The kinds of minerals in the veinlets prove the deposit to be of mesothermal origin (i. e. one formed at medium temperature and under an intermediate thickness of rocks), although the original quartz vein in granite had been formed under hypothermal condition (i. e. high temperature and pressure).

With regard to the mineraliser, granite, being well consolidated before the breaking of the quartz vein in it, cannot be responsible for the cause of such mesothermal solution. The rest of the igneous rock is biotitite and the mine's geologist considered it to be the mineraliser. A gold assay of this rock has been made and it gives a value of less than 4 grams of gold per ton of rock, and so it can't be the mineraliser as thought of.

The study has shown definitely that the gold bearing solution came much later than the original quartz of the lode and is not in anyway genetically related to it. Before the incoming of such hydrothermal solution (hot watery juice) there should be a general earth movement, (a movement which affects all rocks within the area) which is responsible for the occurrences of faults and fractures in both the lode and the country rock. As gold is found in the fractures in quartz, it should also be found in fracturing zones of both granite and schist.

Gold Ore From Krabin (กระบินทร์)

The samples of ore and rocks were obtained from Ban Bo Tong (บ้านบ่อทอง) near Nong Sung station (สถานีหนองสัง). The area is within easy reach from the Eastern railway line; in fact it is the most accessible of all ore deposits in this country. Ban Bo Tong (บ้านบ่อทอง) is in the district of Krabin Buri (กระบินทร์บุรี). It is a flat country but well drained.

The deposit is in a gold belt extending from Lerya (เลย) to Aranyaprades (อรัญประเทศ). In this belt limestone is predominant and it is intruded by granites, diorites and porphyries, causing metámorphism in many parts of the region.

At Ban Bo Tong (บ้านบ่อทอง) gold has been found in a quartz vein in limestone striking East-West. From the vein a rock specimen had been obtained. Samples of the lode and wall rock were taken.

On inspection by naked eye the lode consists mainly of quartz, well crystallised; in places, good crystals are seen. Probably the lode is vughy (full of cavities lined with quartz crystals) with crystals of quartz of the high temperature variety protruding into the vugh (cavities in ore veins). Gold is apparently embedded in the quartz. Nuggets of gold are common in this lode and have given an erroneous understanding that the lode is exceptionally rich. The contact rock consists of a green mineral, quartz and calcite. Gold has been spotted among the green mineral also.

A slide of the contact rock has been examined petrologically and was found to consist of calcite, quartz, green calcium garnet and wollastonite. The garnet is yellowish green and occurs mainly as rhomb-dodecahedral crystals. By qualitative analysis, the garnet appears to be a silicate of aluminium, iron and calcium. So it is a cross between glossularite and andradite. With crossed nicols the garnet gives anomalous colour interference with an isotropic core. It has been observed generally that in Thailand most of the calcium garnets formed by contact metamorphism are not isotropic. Wollastonite occurs in minute radiating needles in both quartz and garnet. By its acicular habit the mineral may as well be sillimanite.

The polished section of a specimen of ore near the wall has shown that gold is the latest mineral to crystallise so that it occupies spaces around the boundary of quartz crystals. Gold is also later than calcite. Some quartz is included in the gold, and tiny specks of gold have been seen inside quartz crystals. Therefore quartz and gold must have come together, the calcite belonging to the limestone. No calcite has been found in the middle of the vein.

The igneous rock found in the vein has been found to be a hornblende-diorite porphyry. Hornblende occurs as porphyritic crystals (large crystals on a fine mass) in a dioritic mass. Phenocrysts (large, well-formed crystals) of plagioclase feldspar are not clearly seen in the hand specimen, but under the microscope they appear as clear sections with zonings and striation twinnings. Specks of pyrite have been found in the rock as accessory constituents.

With the presence of hornblende-diorite porphyry, side by side with the gold-bearing quartz, it may be assumed that the rock is the actual mineraliser (one that comes along side with ore-bearing solutions). Owing to the presence of green garnets at the wall, the vein is evidently of high temperature but association with dyke rock depicts medium pressure. So the deposit is one of high temperature and medium pressure.

GOLD ORE FROM TA TAGO (ท่าตะโก)

Southeast of Paknam Poh (ปากน้ำโพ) in Nakorn Swan (นครสวรรค์) is a village called Ban Bo Tong (บ้านบ่อทอง). The locality is in Umpur To Tago (อำเภอท่าตะโก) and may be approached from both Chan Sane (จันเสน) and Ban Mi (บ้านหมี่) stations. There is a cart track from Lopburi passing through Umpur Kok Sum Long (อำเภอโคกสำโรง) to the spot. Transportation is rather difficult, but in dry season a car can be taken there from the town of Lopburi (ลพบุรี).

This place has been known to be gold bearing for more than fifty years ago. It is surrounded by limestone hills of medium altitude. The country is gently undulating and practically dry. There are numerous streams, but in the absence of rain they are all dry. Natural springs occur in many places.

The geology is simple. It consists of an intrusion of quartz-monzonite porphyry into limestone. Both rocks were intruded later by quartz-diorite. Gold lodes occupy fault fissures in the porphyry.

The quartz-monzonite porphyry consists of an equal amount of plagioclase and orthoclase pheno-crysts in a ground-mass of monzonitic composition. Other phenocrysts include quartz and hornblende which in places predominate over all others. Magnetite occurs as an accessory mineral.

The intruding rock occurs in the gold vein and, examined by eyes alone, it appears to be spotted with black patches. Pyrite is an accessory constituent of the rock. It is found in the lighter mass but close to dark minerals. Petrological study has shown the rock to be a quartz-diorite consisting of andesine felspar, quartz, hornblende and some pyroxene. Some feldspar crystals are set in larger crystals of quartz. The structure suggests that quartz is the last mineral to crystallise. Magnetite is present as an accessory mineral. The black patches appear to be xenoliths of shale physically altered to magnetite and chemically changed to crystallo-blasts of orthoclase feldspar, hornblende, chlorite and biotite. The shale has been found under the limestone and, at the contact between the porphyry and limestone, shale masses have been found enclosed in the mass of porphyry. So the dark patches are without doubt altered shale masses digested by the quartz-diorite.

The lodes are of two types, white and green. White lode is a mixture of quartz and calcite, the latter being well crystallised. Pyrite is present in a considerable percentage and some gold has been found in it. The green lode is composed mainly of green, yellowish green and dark green calcium garnets. Calcite is present, admixed with the garnets in small amount. Examined by eye, the garnets crystallise in two habits: the rhomb—dodecahedral and the trapezohedral. It has been observed that crystals smaller than half a millimetre have rhomb-dodecahedral habit while larger crystals acquire the trapezohedral one. Larger crystals occur where there is calcite. Pyrite also occurs in contact with calcite. After dissolving the calcite out the garnet crystals may be seen to be formed inside the hollow as it is a vugh (cavity). Therefore it may be reasoned that garnet is the first mineral to crystallise while calcite and pyrite crystallise later to occupy vughs left by the crystallisation of garnet. In this portion garnet can crystallise under least resistance and therefore the crystal is large and of trapezohedral type. In the mass only rhomb-dodecahedral crystals are present because in such form the crystals grow easier. A little pyrite and calcite are embedded in the crevices between garnet crystals.

Gold is seen, in polished section, to crystallise later than the garnet so that it occupies the boundary between garnet crystals; therefore it is in the form of thin concave plates. Rarely, it has been found to crystallise in the cubic system with paralled cubic growth. Garnet crystals have been seen in gold and tiny specks of gold have been seen inside garnet crystals. It is a rarity that gold is present where the garnet crystals are large. The same thing has happened with vughy gold lodes of the quartz type where gold has never been found in the vugh. The presence of gold in garnet and garnet in gold proved that before the lode existed both were in the same melt.

The petrological study of the green garnet ore is extremely interesting. Calcite appears also in the centre of granet crystals, showing a reaction between silica and calcium carbonate to form the garnet. Where the section is greenish brown the garnet is completely isotropic, but, if colourless or greenish, the garnet seems to be composed of anisotropic zones arranged parallel to the crystal faces. It is a common occurence that isotropic and anisotropic zones are arranged in successions. The anisotropic zones are divided into layers meeting at the bisectors of the facial angles of the garnet crystal, clearly seen even under ordinary light.

Garnet crystallising in the trapezohedral habit is nearly completely isotropic. The section is octagonal with small anisotropic zones also with octagonal boundary near the rim of the crystal. The anisotropic zones are composed of layers parallel to the octagonal sides. Each set of layers meets at the bisectors of the facial angles of the crystal. Four sets, being parallel and perpendicular, extinguish in the same position (i. e. parallel to either layer). The colour of the various zones is, according to the rule found out above, greenish brown in isotropic zones and greenish in anisotropic zones.

Thick sections of the rhombohedral crystals show them to be divided into three parts representing each face of the rhombs. These faces are anisotropic and, when the stage of the microscope is rotated with the nicols crossed, each face extinguishes in successions. In thin sections, the boundary of each crystal is seen to be hexagonal with an isotropic hexagonal core. The bisector of the angles divide the crystals into six portions, alternate ones of which extinguish in the same position. Each zone is again divided into layers parallel to the hexagonal boundary.

Rarely a square cross section has been seen with a square isotropic centre. The crystal extinguishes in the position parallel to either side. This is so because the four zones formed by the bisectors of the angles are parallel or perpendicular. Similarly the zones are composed of layers parallel to the sides. It is an extreme rarity that garnet should crystallise with a cubic habit.

Qualitative chemical analysis has proved the garnet to be a silicate of aluminium, iron and calcium. So it is a cross between glossularite and andradite with a composition approaching that of andradite. The density of large isotropic trapezohedral crystals is about four and this is very near to the density of andradite.

The study has shown that the garnet has been formed by the interaction between calcium carbonate and silica under high temperature. Each crystal is composed of pyramids whose bases coincide with the faces. Each pyramid behaves as one optical unit.

The anisotropic pyramid shows successive growths or layers similarly orientated inside it. These layers give low interference colours in yellows and greys with straight extinction. They are biaxial, sometimes uniaxial, and optically negative. Therefore we think the garnet is composed of pyramids with compositions and physical properties of idocrase. This may be possible, considering that idocrase occurs also in contact metamorphic deposits like garnet. There might be conditions controlling the occurrences of the two minerals, and, when the two set of conditions overlap one another, both minerals are formed as one. The latter explanation failing, the mineral may be just taken to be a solid solution of andradite and glossularite.

In contact with the ore is a rock which has been determined petrologically to be composed of plagioclase feldspars, epidote, hornblende and pyroxene.

Some specimens of the white ore have shown that green garnet has been formed from it. Therefore the occurrences may be interpreted thus: movement of the limestone had caused the intrusion of quartz-monzonite porphyry which at the contact had dragged pieces of shale or slate under the limestone with it. Later on there was another movement resulting in a Northwest-Southeast fold. The porphyry was faulted in many places along the same direction. The fault zones were occupied by pyrite, quartz and a lot of calcite of mesothermal origin. Soon afterwards, quartz-diorite carrying gold and pyrite broke into the same fissure causing the occurrence of gold-bearing garnet ore. The heat of the quartz-diorite caused the reaction between originally existing quartz and calcite. Silica, leached from the intruding rock, attacked the remaining calcite to form garnets. Gold and pyrite accompanying the silica then occupied crevices between garnet crystals. The residual rock, after the silica had left, remained with the green garnet ore.

Evidently the deposit was formed under medium pressure and high temperature. The green garnet ore has a mean density of 3.3 and therefore is without doubt the world's new and densest gold ore. It has been proved for the first time also that gold has been carried in a solution alongside with quartz-diorite.

Conclusions.

(1) At Licho (ลี่ชอ) and Pajo (ปาโจ) villages in the Toh Moh (โต๊ะโม๊ะ) district gold occurs in quartz vein in granite and schist. A gold lode in granite has been found to be associated with biolitite. The gold has evidently been introduced with a hydrothermal solution containing quartz, epidote, calcite and sulphides of commonmeta ls into fissures in original quartz of the lode. Granite is sericitised (changed with the development of white mica) by the solution. The

deposit is of mesothermal (medium temperature and pressure) character.

(2) A gold lode has been found at Ban Bo Tong (บ้านบ่อทอง) in Krabin Buri (กระบินทร์บุรี). The deposit is in limestone and was formed under medium pressure and high temperature. Quartz is the main gangue and it is well crystallised. Gold has been found to have come with the quartz, which was leached from a hornblende-diorite. porphyry being found in the same vein. High temperature of the intrusion has caused metamorphism of the limestone wall with development of green garnet and wollastonite.

(3) A gold deposit at Umpur Ta Tago (อำเภอท่าตะโก) in Nakorn Swan (นครสวรรค์) has been formed by the instrusion of a quartz-diorite into an original mesothermal quartz-calcite vein with gold in quartz-monzonite porphyry. The ore consists mostly of green calcium garnet. Calcite, pyrite and gold are present in the garnet. The ore is new to the world and it has been proved that it is the quartz-diorite that came alongside with gold solution. The deposit was formed under medium pressure and high temperature.

It may be mentioned here that in this part of the world gold has been found to be associated closely with rocks of the diorite family. In Burma and also in the Philippine Islands gold is associated with diorites and andesites. Some gold in Thailand has been found near granite intrusions but the occurrence is infrequent.

Detailed geological studies of the three deposits are forth coming, and all ideas arising from the microscopical studies have yet to be proved by definite geological reasonings.

Fig. 1. Krabin Gold Ore, showing white patches of gold enclosing quartz. Black spots are calcite, grey quartz and white specks of gold.

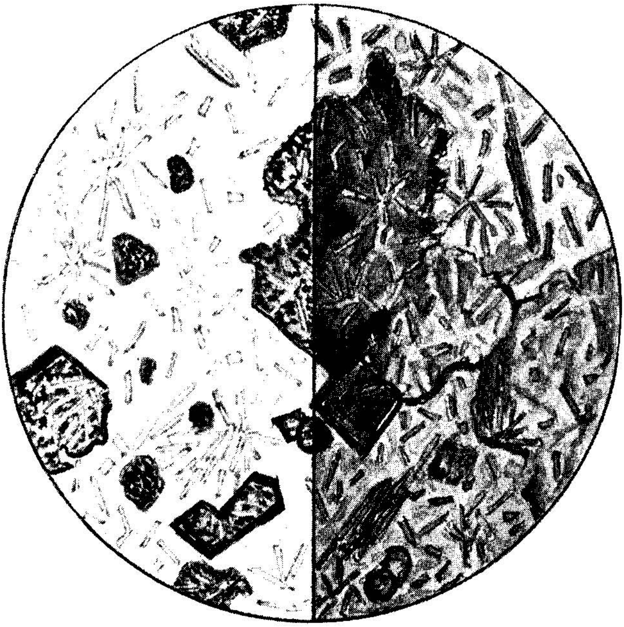

Fig. 2. Contact rock from Krabin, showing development of green garnet and wollastonite in a mass of quartz and calcite.

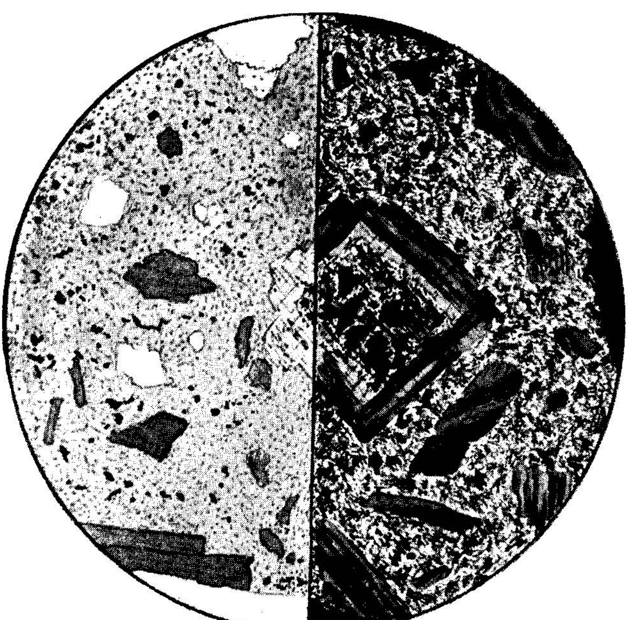

Fig. 3. Hornblende-diorite porphyry from Krabin, showing phenocrysts of feldspar and hornblende on a dioritic groundmass.

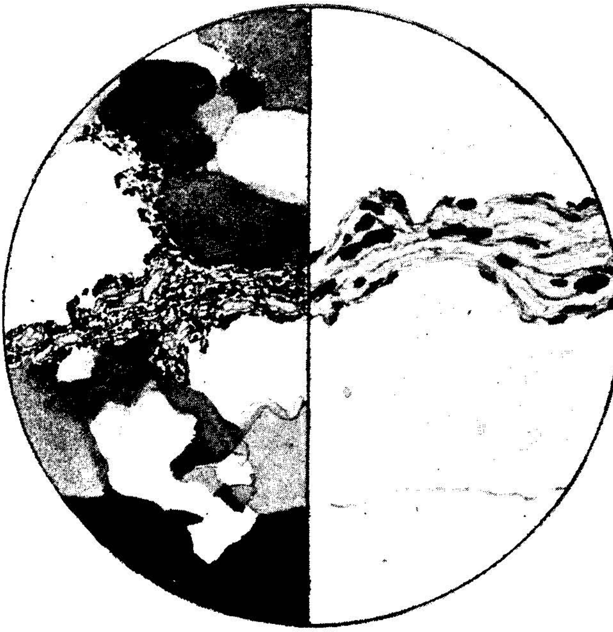

Fig. 4. Quartz ore from Toh Moh showing intrusion of gold bearing solution containing epidote, calcite, pyrite and quartz into the original quartz of the vein. The gold is shown as black spots.

Fig. 5. Sericitised granite horse rock in gold lodes from Toh Moh. Note the alteration of feldspar and corrosion of quartz crystals.

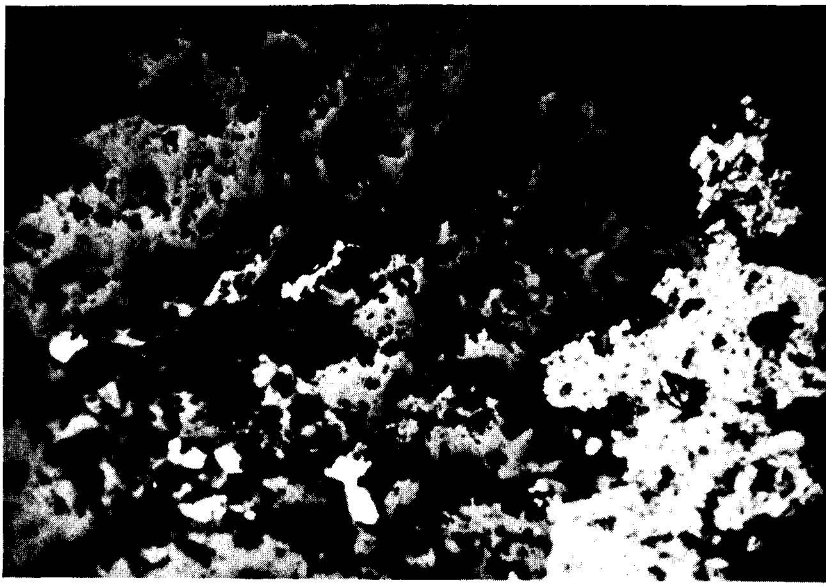

Fig. 6. Ta Tago green garnet ore showing gold in white patches, occupying interstices between garnet crystals, shown in grey and dark tones.

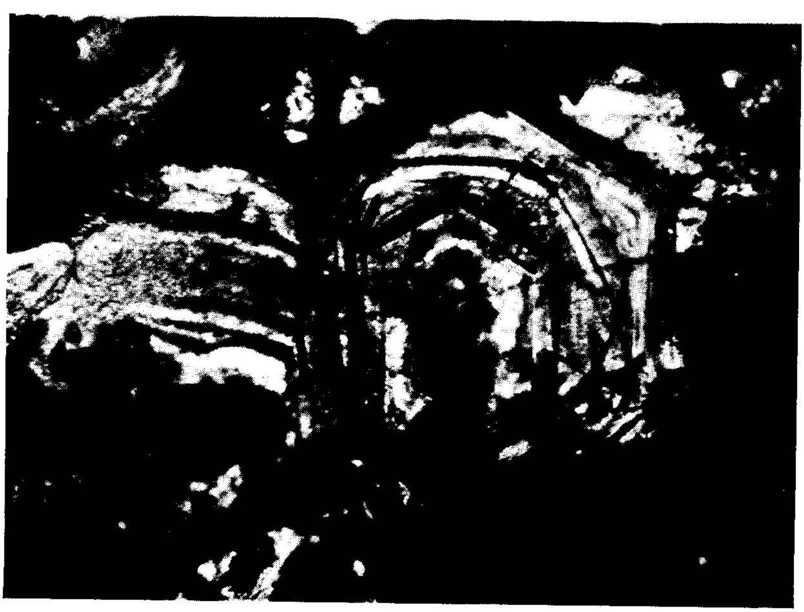

Fig. 7. Zoning in Ta Tago garnet. The central portion is green and anisotropic, the next zone brown and isotropic, and the last green and anisotropic.

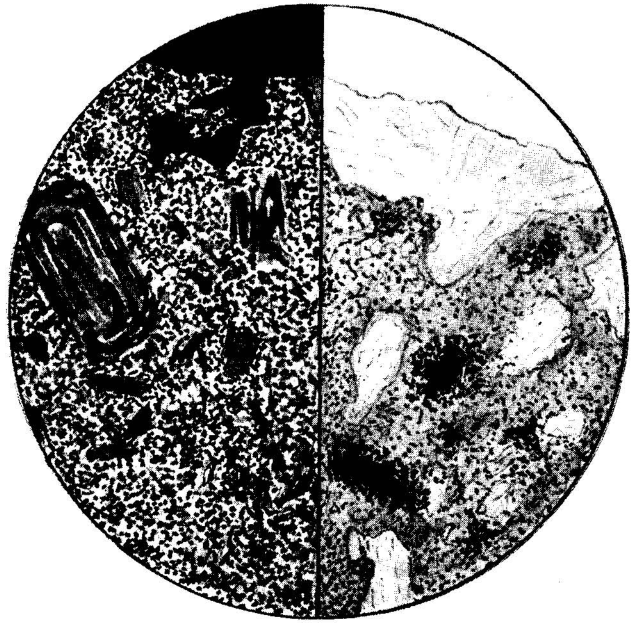

Fig. 8. Quartz-Monzonite Porphyry from Ta Tago, showing phenocrysts of plagioclase feldspar, quartz and hornblende on a ground mass of monzonitic character.

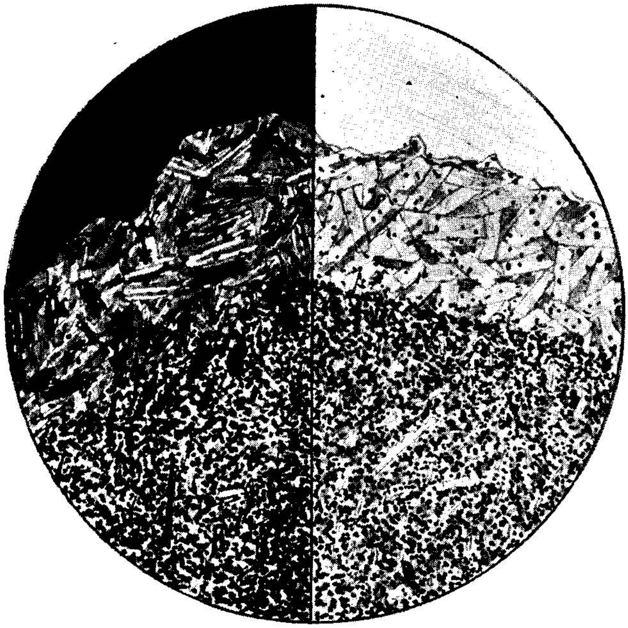

Fig. 9. Quartz diorite with altered shale from Ta Tago. Black spots are magnetite.

Fig. 10. Gold bearing garnet ore from Ta Tago, showing octagonal, hexagonal and square cross sections of garnets between crossed nicols.