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THE BLACK SANDS OF LOUTRA ELEFTHERON NEAR KAVALA, GREECE

by

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Abstract: *At the beach of Loutra Eleftheron near Kavala (Creece) and for a distance of more than three kilometers appear concentrations of heavy minerals in sands forming Black Sands. These formations are highly radioactive. Light minerals (quartz, feldspars, calcite, mica) from these Black Sands were separated and the rest studied optically under the ore microscope (polished sections) as well as under the usual polarization microscope (thin sections). The minerals were also examined with* X*-rays and microanalyzer.* These *examinations showed that from the opaque heavy minerals the following are main constituents of the Black Sands: magnetite, goethite, lepidocrocite and hematite. In small quantities there exist also routile, ilmenite, pyrolusite, psilomelane, and sparsely wolframite, cassiterite, uraninite and natural gold. Besides these were observed pyrite formations as "Framboidal Pyrit" and artificial products in significant amounts (Artifacts). They are slags from ancient foundries consisting greatly of skeleton-like crystals of magnetite formed in silicate glass (artificial). From the transparent heavy minerals were observed orthite, epidote, garnets, hornblende (hanstingsite) sphene and sparsely zircon and monazite.*

The detailed investigation of the optical and other constants of these minerals allow guesses as to the conditions of their genesis. Opinions are also expressed about their origin, i.e. which were the formations from which these minerals were derived and later were earried to the sands. Magnetite was mainly formed pneumatolytically-metasomatically in the contact zone of granite with calcitic rocks. The goethite-lepidocrocite grains which always show regular interchanges between these two minerals in the form of gel structure with intersections of small pyrolusite crystals, were formed secondarily in gossan of B.P.G. sulphide ores (or of pyrite). Hematite, appearing in lamellae with or without quartz, was formed hydrothermally in veins connected genetically with the granite of Mount Symvolon. The minerals wolframite and cassiterite were formed in pegmatitic-pneumatolytic veins connected genetically with the same granite. For all the above formations is suggested a sustematic mining research of the larger district of Black Sands and mainly of the district around the limits of granite of the Symvolon mountain.

The occasionally appearing uraninite derives from hydrothermal veins connected genetically with the granite. The very small proportion in which the mineral exists in the Black Sands does not sugggest any economically exploitable veins. The same can be said about the gold sparsely appearing in hydrothermal quartz. The radioactivity of Black Sands is due except to the sparsely and in some only samples appearing uraninite, *is due to sphene, rutile, zircon and monazite which include radioactive elements. Opinions are expressed for both the conditions of genesis and origin of transparent heavy minerals.*

INTRODUCTION

The term Black Sands is applied (Bateman 1951) to local enrichments of some sands in heavy minerals, among which magnetite and other dark coloured minerals are responsible for the characteristic black colour. Such formations appear at the seaside and are due to selective withholding of heavy minerals in the zone of tide waves. Many times they consist ore deposits of cassiterite, magnetite, sphene or rare minerals (monazite). Besides their use as ores, they are often indications about the existence of ore bearing concentrations at the district around them especially when they are far from the mouths of rivers carrying materials from other districts. Black Sands in Europe are found in some beaches of the Mediterranean (El-Hinnawi 1964) and of Black Sea (Petraschek 1961). In Greece the existence of Black Sands is known in the coast of Loutra Eleftheron, Kavala. This occurrence extends for three and more km in length, with 3-8 m in width and varying depth.

Their proportion in heavy minerals ranges between large limits. Down to this coast reach the southern slopes of Mount Symvolon and the whole morphology of the district is characterized from the lack of rivers able to carry materials from other areas. So the study of the Black Sands of Loutra Eleftheron, Kavala, besides their importance as a local appearance, give indications about the presence and the conditions of genesis of ore bearing concentrations in the Mount Symvolon district.

The geology of the Mount Symvolon district is characterizedby the existence of three systems:

1. The metamorphic background, consisting of gneisses, mica schists, rarely amphibolites and intersections of marble, belonging to the metamorphic mass of Rila-Rodope (Kockel und Walther 1968).
2. The granitic intrusion of the Symvolon mountain with the corresponding parimagmatic, apomagmatic and telemagmatic ore deposits or occurrences. According to Osswalt (1938) this is tertiary and according to Fischer (1964) it shows a clear metacrystalline distortion.
3. The overlying sedimentary rocks of Neogene, for which no study exists nor indicated on the geological map of Greece (Irey 1954). Obviously, the greater part of the heavy minerals is derived from the two first systems.

For the study of the heavy minerals of the Black Sands they were separated from the light minerals (quartz, feldspars, calcite, mica) and polished sections as well as thin sections were prepared. Besides the study of the polished sections under the ore microscope and that of thin sections under the usual polarizing microscope, additional study has been carried out on some minerals by X-Rays and by microanalyses. The results and the conclusions are exposed in details in the following sections.

B. OPAQUE MINERALS

Magnetite

It is the main constituent of Black Sands and it amounts up to 30--40% of their heavy minerals. The characteristic colour of the sands is due to magnetite. It is easily distinguished macroscopically. In thin sections under microscope it appears as euhedral crystals, of 2-3 mm in size or as round grains of different size. Some times this grains are altered. The type of this alteration is irregular and usually is limited to the rim of the grains. Consequently this has nothing to do with the replacement of another phase, as for example in the case of an exsolution product or of a myrmekitic intergrowth. Cataclastic phenomena of the grains and twinning (or multitwinning) due to stress were not observed.

The colour of the sections is grey with a clear brownish tint. Brownish pink tint was never observed as it happens in magnetites including a significant quantity of titanium in solid solution. Moreover, the study of the sections in the microanalyzer (Fig. 71) showed that the quantity of Mn in the structure is rather high, (Fig. 72) in contrast to the traces of Ti present (Fig. 73).

Characteristic is the absence of exsolved minerals such as ilmenite, hematite (not martite), spinels etc, which is so usual in magnetites of orthomagmatic origin. The polished sections of the minerals show the usual moderate reflectance. Besides, all the sections appear isotropic, which shows that there are no submicroscopic inclusions as irregular mixed crystals (RAMDOHR 1975) or other factors cansing internal tensions.

A constant rule in all the samples of the mineral forms is the existence of martitization phenomena. In most samples martitization has just begun, (Fig. 1, 2) but in some cases it has quite progressed or very much developed. This martitization appears in the form of tabular (0001) small crystals of hematite arranged parallel to the (111) faces of magnetite

(Fig. 3, 4, 7). Usually martitization is limited or is connected with the border of the magnetite grain or with breaks crossing it. This martitization must have taken place in temperature lower than that of the magnetite formation. Nevertheless it is not a martitization due to alteration conditions, since nowhere occurs with martite geothite or lepidocrocite, even in traces. According to Colombo etc (1968) the oxidation of magnetite never takes place directly to hematite but comes through an intermediate stage. If the structure of magnetite is not entirely ordered, it can easily be oxidised to γ - Fe_2O_3. Since in the samples under examination no maghemite (γ - Fe_2O_3) was observed, we may conclude that the case of the not entirely ordered magnetite does not appear here.

In the magnetite grains sometimes are observed intergrowths with other minerals (Fig. 2, 5, 6). The intergrowth with calcite predominate and calcite can appear as inclusions in magnetite. In one case was observed deposition of magnetite in the $(10\bar{1}1)$ cleavage of calcite (Fig. 5, 6). Such phenomena have great importance for finding the origin conditions of magnetite. Intergrowths with other minerals were also observed, mainly with horhblende, rutile and sphene, but they are limited.

As regards the origin of magnetite, which occurs in great quantity in the Black Sands, bearing in mind all its above characteristics described in detail, we conclude that its greater part was derived from one (or more) existing pneumatolitic contact matasomatic magnetite ore deposits in the district. This (or these) must occur in the contact zone of Mount Symvolon granite with marble (or limestone). This is deduced from the relatively low temperature of its formation, as it is shown from the absence of exsolution phenomena and the lack of not exsolved titanium in its grains. Finally, the frequent intergrowths with calcite lead to the same conclusion. A small part of the mineral's grains, especially its exceptional euhedral sections, probably derive also from the granite constituents, that is, it may be an orthomagmatically produced magnetite during the original crystallization of the magma.

From an economical point of view, it is not easy to characterize the Black Sands as deposits of magnetite or iron in general. Of course, if we consider the surface extention of the Black Sands, their depth and the percentage of magnetite, we come up with an amount of some hundreds of tones of iron ore of good quality, which could be extracted by magnetic separation. However this quantity is considered as small for such a separation unit plant. But on the other hand the magnetite inside the sands shows, as was exposed above, the existence of ore deposits or occurrences in the district of pneumatolytic contact metasomatic origin.

So a magnetic research of the district is needed to discover them and asset their possibilities for exploitation.

GOETHITE - LEPIDOCROCITE

These minerals, which occur as constituents of limonite, are both dealt with here, because in the Black Sands are always observed intergrowths of these two minerals. As constituents of the Black Sands the intergrowths of goetite - lepidocrocite occupy a significant proportion, between 30% and 40% sometimes even 70% of the heavy minerals. They appear as round or ellipsoidal grains, which in polished sections under microscope show an impressive image of regular interchanges of the type of gel texture and in a great variation of forms and shapes (fig. 8, 9, 10, 11, 12, 13, 14). In the regular interchange takes part goethite which predominates in quantity, and lepidocrocite, with thin dark bands, intersecting them many times. With a high magnification these dark bands are seen to be empty spaces (Fig. 9, 10). The regular interchange is not random. In most cases it follows a certain orientation and especially two perpendicular directions (fig. 13). In some sections these two directions appear to intersect obliquely (Fig. 14). In many grains of goethite - lepidocrocite are observed some remains of pyrite crystals (Fig. 15) covered again regularly by the interchanges of the above minerals. In some cases are also observed remains of other sulphides, mainly chalcopyrite. Finally in several cases it was observed that in the regular interchange of goethite-lepidocrocite there exist as third member, a mineral with strong bireflectance and very strong anisotropy. It is pyrolusite (Fig. 16, 17) which takes part in these rhythmites as small crystals. Sometimes it occupies the center of the rhythmites.

Goethite appears, as it was mentioned, in a larger proportion. It is gray with a slight bluish tint and a very weak bireflectance, which however changes from grain to grain and sometimes even in the same grain of the various rhythmites. It is easy to observe under crossed Nicols internal reflections of brownish-red colour. Their distribution, however, varies largely in the different rhythmic zones, from total absence to numerous internal reflections. Lepidocrocite is gray and is easily distinguished due to its stronger reflectance and (under crossed Nicols) its quite stronger anisotropy.

Reflectance, bireflectance and anisotropy differ from one rhythmic zone to the other. This shows that the two minerals mix further in submicroscopic scale. Using oil immersion the distinction of the two costituents is easier, because lepidocrocite takes a gray-greenish tint. Its internal reflections appear with a slightly darker colour than that of goethite.

The way in which these two minerals occur, that is in rhythmic interchanges following two nearly perpendicular directions with intersections of pyrolusite and surrounding pyrite remains or other sulphides, shows that they derived mostly from changes in preexisting pyrite or occasionally chalcopyrite or other iron sulphides with manganese paragenesis. The two perpendicular directions (fig. 13) correspond to the (100) cleavage of pyrite, a direction along which it is easily affected by alteration phenomena to other minerals. The appearance sometimes of oblique directions (Fig. 14) of the cross-section of the two main directions correspond to the $(10\bar{1}0)$ rombohedron face of a preexisting carbonate mineral, probably manganese-siderite.

It must be mentioned that according to the investigations of Chokhbov etc (1973) the formation of lepidocrocite et the hypergene zone takes place in two stages. In the first proto-lepidocrocite is formed by partial oxidation of Fe^{++} and later it changes to lepidocrocite.

Except for the remains or sulphides many times appear in the grains of goethite-lepidocrocite inclusions of other minerals (fig. 18, 19, 20). These are usually quartz and sometimes mica (fig. 19). For these inclusions we must accept that initially they were inclusions in pyrite or in the other iron sulphides, which, because of their resistivity, remained included also after the change of the surrounding mineral to the rhythmites of geothite-lepidocrocite.

Of special interest is a type of myrmekitic intergrowth of thythmite goethite-lepidocrocite with quartz (fig. 20).

It is difficult to imagine myrmekitic intergrowth in type of eutectic texture between the original pyrite and quartz. As a possible explanation it is suggested the existence of the original myrmekitic intergrowth of pyrite with other sulphide, which was later displaced by a following hydrothermal action and was replaced by quartz which remained of course after the alteration of pyrite to a rhythmite of goethite-lepidocrocite.

As regards the origin of the observed rhythmites of goethite-lepidocrocite we must accept that their majority at least derives from gossan of pyrite ore deposit or of B.P.G. sulphides. The existence of pyrolusite in the thythmites supports this point of view, because as it is known in the gossans enrichment in manganese is observed. A part of the rhythmites possibly comes from a sedimentary deposit, although no oolites were anywhere observed.

As regards the possible exploitation of the rhythmites of goethite-lepidocrocite appearing in the Black Sands in significant proportion, we don't think that there is any such perspective. The deposits are small, some hundred tons, the separation from the other constituents expensive and the quality of iron (if it is considered so) bad, because of the included pyrite, other sulphides and sometimes baryte. The district must however be examined for possible existence of one or more gossans under which there are possibly expoitable deposits of B.P.G. sulphides.

HEMATITE

Except for the hematite found in the magnetite in the form of martite, there appear also numerous grains consisting of independent aggregates of hematite crystals. In this form the mineral constitutes the 5% and sometimes the 10% of the heavy minerals of the Black Sands. The aggregates consist of lamellar crystals of hematite parallel to (0001) (Fig. 21, 22, 23, 24). These lamellae are parallel and sometimes slightly bent. Their aggregates are easily recognised from their strong reflectance, the slightly bluish tint of the mineral (especially when it is observed under oil immersion) and mainly from its strong anisotropy. Under crossed Nicols besides the anisotropy are observed internal reflections of deep red colour, which are clear in oil immersion. These reflections are limited to the borders of the lamellae and frequently in the space between them.

Again the lack of exsolution phenomena is characteristic. In the majority of the crystalline aggregates no exsolution of ilmenite is observed. On the other hand, a microanalyzer study for possible existence of titanium in the cell of hematite (in the form of mixed crystals $FeTiO_3$ - Fe_2O_3) proved negative. This indicates a low formation temperature.

Under crossed Nicols there is often observed a multitwin development of the tabular crystals parallel to $10\bar{1}1$. These multitwins appear always with their elongation perpendicular to the pinacoid (0001). Their width changes from grain to grain. Given that this multitwinning is usually observed only in the lamellae which show a slight bending or curving (Fig. 21) we are led to the conclusion that the phenomenon of multitwin development is due here to stress on the hematite crystals during their formation.

In many cases coexistence or intergrowth of quartz was observed with the tabular crystals of hematite (Fig. 22, 23, 24). It appears either in small quantities surrounded by hematite lemallae, or in larger quantities, in which case the size of the hematite crystals decreases. In some cases appear tiny crystals of hematite dispersed in a quartz-mass in the form of impregnation (Fig. 24).

In very rare cases are observed hematite crystals (not lamellae) including exsolutions of ilmenite, as well as parallel intergrowths of ilmenite with hematite including exsolutions of ilmenite. The so exsolved crystals of ilmenite are arranged with their elongation nearly parallel to the pinacoid (0001) of hematite, with small deviations. For the hematite crystals with exsolutions of ilmenite we must accept different conditions of formation from those of the hematite crystals appering as lamellae, and specifically a higher temperature.

Sometimes are observed intergrowths of hematite with magnetite. They are intergrowths and not martitization products, a fact deduced from the microscopic image. For these crystals of hematite we must accept pneumatolytic origin as we accepted for the largest part of the magnetite crystals inside the Black Sands.

For the greater part of the hematite crystals we accept hydrothermal origin. To this conclusion we arrive from their low temperature formation (lack of exsolution phenomena) as well as from their tabular development parallel to (0001) (Friedrich 1966). Finally, the coexistence of quartz in most cases shows again hydrothermal origin. Such hematite veins of hydrothermal origin have been described many times and they are always of no economic importance. The existence of such veins is probable in the district of the Black Sands. The absence of shanges of hematite to magnetite in all the sections indicates the absence of metamorphic phenomena in the above veins.

For the few cases of occurrence of hematite with exsolutions of ilmenite (Fig. 27) we must accept orthomagmatic crystallization with its origin from the granite of Mount Symvolon.

ROUTILE

It appears in proportion up to 5% of the heavy minerals of the Black Sands. It is always euhedral with long crystals, multitwins on (101) and (301) (Fig. 25, 26). Its cleavage parallel to (110) is easily distinguished. Because of its strong bireflectance the multitwinning is visible without analyzer. It appears with its usual moderate reflectance grey in colour with a brown to brownish pink tint. Under crossed Nicols is observed its strong anisotropy as well as numerous internal reflections (Fig. 26) covering the whole surface of the mineral. The colour of the internal reflections is white to orange-red. Many times this colour changes in a section, showing zonal texture of the crystal. As it is known (RAMDOHR 1975) the colour of the internal reflections depends on the trace element content and especially on niobium and tantalium. For these elements we must accept zonal distribution in the crystal. According to MEYROWITS (1973) zircon enters in roulile as trace element with a maximum content up to 0,47% in ZrO_2.

For the origin of the mineral we accept that it originates either from pneumatolytic ore deposits of magnetite (as we have accepted in the chapter on magnetite) or from pegmatitic tin veins. Both formations probably surround granite of Mount Symvolon.

ILMENITE

It occurs in the Black Sands in small proportion, almost sparsely. It is distringuished by its grey colour somewhat darker than that of magnetite with a brownish tint, especially in oil immersion, but mainly by its very high bireflectance and anisotropy.

Many times it shows intergrowths with hematite. The intergrown hematite shows thin exsolutions of ilmenite and thus we accept that both minerals originated by exsolution of an original homogenous mixed crystal (Fig. 27, 28, 29). In one case was observed myrmekitic intergrowth of ilmenite-hematite. DUCHESNE (1973) accepts from study of on anorthosite system of South-Bogoland (Norgway) that exsolution products of hematite in ilmenite occur when the molecular proportion of hematite is greater than 7-9%.

As regards the conditions of formation of the mineral, its intergrowths with hematite crystals and the exsolution phenomena in hematite show that both are products of magmatic rejection.

Hence we come to the conclusion that the othomagmatically rejected ilmenite (with hematite) derived from the granite of Mount Symvolon. Isolated crystals of ilmenite, without intergrowths with hematite may have derive also from the metamorphic background. The ilmenite in the Black Sands is of no economical importance nor can be used as indication for the presence of titanium ore deposits. On the other hand the small content of ilmenite in the Black Sands does not make it harmful for possible exploitation of the included magnetite as iron deposit.

PYROLUSITE

Except for the pyrolusite in the rhythmites of goethite-lepidocrocite, are also observed independent crystals of the mineral in the Black Sands. These occur only sparsely and consist of aggregates of xenomorphic crystals. They are creamy white and they show the moderate reflectance of the mineral, distinct bireflectance and (under crossed Nicols) strong anisotropy. Many times intergrowths with quartz grains are observed (Fig. 30, 31).

As it is known (RAMDOHR 1975), pyrolusite appears usually either in sedimentary ore deposits or in gossans including manganese minerals. For these reasons we consider the pyrolusite appearing in the Black Sands as originating from a gossan of the district.

Besides pyrolusite were observed in the Black Sands some grains of a strange form of a manganese mineral. In their rims these grains (Fig. 32) turn into an especially fine crystalline pyrolusite. This mineral shows strong reflectance, white colour with a slight yellowish tint and is isotropic, without internal reflections. These indications are not enough for its idendification, which for the members of the series of manganese oxides is very difficult (with the exception of pyrolusite). On the other hand, because of the small quantity of the mineral, it is not possible to take a powder diagram. So we are restricted to simply mentioning the mineral as a not entirely identified manganese oxide, of the same origin as pyrolusite.

PSILOMELANE

It occurs sparsely and in grains consisting of aggregates of botryoidal psilomelane (Fig. 33, 34) in pure goethite or even in overgrowths of botryoidal masses on rhythmites of goethite-lepicocrocite. The reflectance of these aggregates of fibrous crystals of the mineral, is moderate to strong and the colour greyish white.

Under crossed Nicols is easily visible the characteristic cross in the global aggregates (botryoidal masses). Intergrowths with other manganese minerals were not observed.

As it is known (RAMDOHR 1975), this mineral is formed as a product of errosion near the surface and under the influence of the atmospherical agents. As original material are considered to be manganese minerals such as braunite, haousmanite, manganese siderite, rodochrosite and rodonite.

From these data and taking into account the abundance of goethite-lepidocrocite grains in the Black Sands, for which we accepted that they derive from a gossan, we conclude that psilomelane comes from the same gossan nnder errosion conditions.

WOLFRAMITE

It occurs only sparsely in the Black Sands. It appears in nearly euhedral crystals or in broken pieces. Usually it shows plenty of pores, (Fig. 35) which we attribute to the difficulty of polishing the mineral. It appears with weak reflectance, very weak bireflectance and with distinct anisotropy, which does not change essentially during the observation in oil immersion. Internal reflections of dark brownish red colour are rather rare. Never has been observed zonal structure or multitwinning.

As it is known, (RAMDOHR 1975) wolframite can occur in pegmatitic, pneumatolytic and hydrothermal veins, while in the pneumatolytic contact metasomatic ore deposits it is absent, being replaced by scheelite. Since, however in none of the examined grains of wolframite was found intergrowth with other mineral (for example magnetite or quartz), from which we could reach definite conclusions for the conditions of its genesis, these latter can not be surely deduced. Evidently wolframite derives from veins surrounding the granite of Mount Symvolon, which could belong to one of the above three categories or even from small mixed occurrences of wolframite-cassiterite.

Taking into consideration the relative rareness of the mineral in the Black Sands we think tbat there is no hope of finding exploitable concentrations of wolframite in the district of the Black Sands. It is possible, however, that the few samples of wolframite have come from another district, where the presence of a wolframite ore deposit may not be excluded. This district cannot be very far from the limits of the Mount Symvolon granite and to this direction research must turn.

CASSITERITE

This mineral also occurs sparsely only in few samples. It appears always in small and rather euhedral crystals, twins on (101) (Fig. 36). Because of the distinct bireflectance of the mineral these twins are visible even without the analyzer. The reflectance of the mineral is weak and lowers considerable in oil immersion. Under crossed Nicols the mineral shows very distinct anisotropy. Internal reflections are abundant and usually white.

Cassiterite, as it is known, (RAMDOHR 1975) is a typical mineral of the pneumatolytic phase, but it appears also in pegmatitic veins. It is always connected with granitic occurrences and sometimes occurs in the granitic mass in small quantities. Consequently it is not easy to find out where the few sparse grains of cassiterite in the Black Sands come from. It is certain that genetically they are connected with the granite of Mount Symvolon and probably they derive from pegmatitic-pneumatolytic veins, surrounding the granite, together with wolframite. It is suggested that both the district of the Black Sands as well as the larger area of the granite limits be investigated in order to find such veins, possibly exploitable.

URANINITE

This mineral is very rare; in all the examined samples of the Black Sands were found only two grains of uraninite. This fact leads to the conclusion that the observed in all samples of the Black Sands strong radioactivity is due to other minerals and mainly to the relatively plentiful sphene, as well as to zircon and monazite.

The two samples of uraninite consisted of isolated crystals with a rather irregular shape and clear fissures of contraction, (Fig. 37) usual in sections of the mineral (RAMDOHR 1975 - UYTENBOGAARDT et al 1971). The reflectance appears to be moderate and decreases significantly in oil immersion. The colour of the sections is grey with a slight brownish tint. Under crossed Nicols it is isotropic except for some tiny inclusions of another mineral the nature of which was not possible to be identified. Internal reflections of a deep brown colour are rarely observed.

For the origin of the mineral we accept that it was carried to the sands from differentiated veins of the granitic magma, which formed the igneous rock of Mount Symvolon. As it is known (MAUCHER 1962) uraninite occurs in pegmatitic and in hydrothermal veins, being genetically connected to granitic masses. In the last case it is associated with minerals of the system Co-Ni-Ag-Bi (Cobalt - nickel-silver-bismouth). Yet, given that in the Black Sands no such mineral was found we must accept that uraninite came from pegmatitic veins. However, we must not exclude the case of its origin from erroded sedimentary layers, containing the mineral in significant proportion. In any case a careful investigation with a counter (scintillometre) of both the district of the Black Sands and the larger area around the granite is suggested, in order to find possible existing concentrations and probably uranium ore deposits.

The small number of the crystals found is not an indication about the absence of significant veins, since, as it is known, uraninite is very soluble during errosion. (DALL AGLIO et al 1974).

GOLD

The mineral was found in one only case as inclusion in quartz. The dimensions of the grains are small. It is euhedral with the characteristic strong reflectance and the known white-yellowish colour. Unter crossed Nicols it shows the phenomenon of incomplete extinction and it remains isotropic with a green colour.

From a genetical point of view the gold is connected with hydrothermal quartz veins. Whether these veins come from the granite of Mount Symvolon is not sure. Also the rareness of the mineral is circumstantial, since quartz in which gold was found usually is absent from the studied concentrations of heavy minerals of the Black Sands. The case of the mineral deriving from erroded gold-bearing layers must be excluded, since in such layers gold appears usually isolated.

The existence of gold in quartz veins in Macedonia generally has often been ascertained (MARATOS 1974). Mostly, these veins have no economical importance. Especially in the Pangaion district were found largely ranging concentrations of gold in the quartz veins with pyrite and arsenopyrite. Significant concentrations of gold in the ancient slags were also observed (MACK 1964).

FRAMBOIDAL PYRIT

As in other parts of the beaches of Chalkidiki, Eastern Macedonia and Thrace, here too, occur formations of "Framboidal Pyrit". By this term we mean concentrations of a special type consisting of well formed microscopic crystals of pyrite arranged in global aggregates, so as to give them the shape of strawberry (Fig. 38) (RUST 1935 LOVE and AMSTUTZ 1966). The occurrences of this type are fairly common in the Black Sands. Such formations are investigated today all over the world, because through them the explanation of the genesis mechanism of the biogene and sedimentary, in general, ore deposits of pyrite and other sulphides is attempted.

Becauses of the importance of the subject, the Greek occurrences of "Framboidal Pyrit" in the district of the Black Sands, as well as in other places will make a subject of special research.

C. ARTIFACTS

In the Black Sands, except for the natural opaque minerals occur also in significant proportions opaque artificial materials. These are always remains of ancient smeltings. From the abundance of the appearing grains it is concluded that in this district the ancients had developed a significant ore exploitation. During the examination of the grains of these formations one is amazed at the variation of the shapes found because of the development of skeletal crystals or myrmekitic intergrowths and often at the symmetry and beauty of the formations.

The skeletal crystals of magnetite in silicate glass (Fig. 39, 40, 41, 42, 43) as well as the myrmekitic intergrowths of magnetite with silicate glass (Fig. 44, 45, 46, 47) predominate. Sometimes the surrounding material (matrix) is not glass but pyroxene (artificial).

The skeletal crystals of magnetite are developed always in one row one after the other along their (100) direction. Sometimes is observed second and even third generation of them. It is not a rare case the simultaneous coexistence of skeletal crystals of magnetite in the glass, as well as myrmekitic intergrowths of magnetite-glass (Fig. 48). The pictures given here show only a small number of the infinite variation of types and intergrowths. As it was mentioned, these formations consist of remains of ancient smeltings, which usually took place near the place of mining. The exact points of the mines have not yet been ascertained in many cases.

Consequently, we consider necessary the investigation of the district also from this point of view, i.e recognizing the place of the ancient minings and ascertaining their probable exploitation. We must not forget that both the rich ore deposits of Eastern Chalkidiki as well as the ore deposits of the porphyry copper at Skouries of Chalkidiki, were exploited in ancient times.

D. TRANSPARENT MINERALS

Orthite

It appears in considerable proportion in the Black Sands and in some cases it reaches 30% of the transparent heavy minerals. It appears in general in two types. One type gives completely euhedral crystals (Fig. 49, 50) while the other less euhedral to xenomorphic. The euhedral crystals have well developed the faces (100) (101) and (201). The xenomorphic are either isolated grains or constitute the core of a zonal intergrowth with epidote, which surrounds them (Fig. 52, 53). Twinning on (100) is frequent, (Fig. 51) more so in the euhedral members. A good (001) cleavage is distinguished. It shows a strong pleochroism:

n_α = light yellowish-brown
n_β = brownish-red
n_γ = deep brownish-red

The extinction angle ranges between $n_\alpha : c = 30° - 38°$ and the optic axial angle $(-2V) = 82° - 85°$. Positive optic character was rarely observed in the not euhedral members.

In none of the orthite crystals were noticed pleochroic aureoles. Given that the mineral is strongly radioactive, as indicated by a counter, we conclude that the radioactivity is due to the mineral itself and not to radioactive inclusions.

For the origin of the mineral we accept that the more abundant euhedral variation comes from pegmatitic veins surrounding or crossing the granite of Mount Symvolon. The other type, not euhedral, should have originated from the granite where it was formed during a later autopneumatolytic phase, from the constituents of granite. This view is supported by the fact that mineral in this second case is usually surrounded by epidote.

EPIDOTE

Except for the epidote surrounding orthite cores, (Fig. 52, 53) occur also some isolated grains of the mineral. Here also we have two types: one completely euhedral (Fig. 54, 55) and one xenomorphic (Fig. 56, 57, 58). The euhedral crystals show the usual elongation along the b axis. Twins on (100) are not so rare as mentioned in the literature (TROEGER 1968). The pleochroism is distinct to strong:

n_α = light yellow to yellowish-green
n_β = greenish yellow
n_γ = yellowish green

The extinction angle $n_\gamma : a$ ranges between 25° — 28°. The optic axial angle ranges between $-2V = 68° - 80°$. The birefringence is 0,015 — 0,025. It often shows zonal structure visible from the slight difference of colour between the core and the marginal zones. As a rule the core shows a darker colour.

Generally the optical data of the euhedral crystals of epidote occurring in the Black Sands range between large limits, which leads to the supposition that these euhedral crystals are of different origins.

In the xenomorphic epidote grains, which are more than the euhedral, the measurement of optical constants is very difficult, if not impossible. Where this was achieved, a large range of values was also observed.

For the genetical conditions and the origin of these two variations of epidote we consider that the euhedral variety derived from one or more skarn occurrences of the district, whereas the xenomorphic varieties comes from the alteration of mafic minerals of the granite of Mount Symvolon.

GARNETS

They are quite abundant as constituents of the Black Sands. They always appear as euhedral, but often their euhedral shape is not easily distinguished, because of deterioration and mainly rounding of the grains during carrying (Fig. 59, 63). Under the stereoscope their crystaline shape is distinguished, usually either rhombic dodecahedron (110) or a complex from rhombic dodecahedron and icositetrahedron (211) with the first predominating.

Examination under microscope and measurements of their constants lead to the result that they belong to two groups: The first group contains garnets of the Pyralspit series while the second of the Grandit series.

The garnets of the Pyralspit series (Fig. 60) are always isotropic. They show a slight pinkish to pinkish-yellow colour. Their index of refraction, measured by the method of refractive liquids was found to range between 1,75 — 1,78. Their d values for the (420) reflection range between d = 2,5746 to d = 2,5897 Å. Hence the unit cell constant α ranges between α = 11,52 to α = 11,58 Å.

The garnets of Grandit group occur in nearly equal proportion with those of the first group. They show a similar euhedral shape and crystaline form as the latter. But here it is observed that the core of the mineral consists of melanite, which is distinguished easily from its deep brown colour (Fig. 61,62). The rims of this zonal mineral, as well as of the other members of the series, show a slight yellowish colour or they are completely colourless. It's index of refraction ranges between 1,75 — 1,85, while the d_{420} value lies between 2,6577 — 2,6970 Å, i.e. the unit cell constant is α = 11,86 — 12,06 Å.

As regards the origin of the garnets appearing in the Black Sands we accept that the members of Grandit group come from occurrences of Skarn type or from pneumatolytic ore deposits of magnetite, the existence of which we accepted, as mentioned in the chapter on magnetite, and the appearence of garnets of this group constitutes an additional proof about their existence.

The explanation of the origin of the melanite cores in the garnets, is more difficult. As it is known (TROEGER 1968) the melanites occur usually in foyaitic or alkaline generally magmas, the corresponding rocks of which do not exist in the district, nor in Greece generally. Yet it may not be excluded that melanite has been rejected during the initial phase of formation of Skarn, as it happens in Cornwall (TROEGER 1968).

For the members of Pyralspit series we accept that they derive from the metamorphic background of the district.

HORNBLENDE. (HANSTINGSITE)

It occurs fairly well distributed in the Black Sands, but in proportion not exceeding the 10% of their transparent heavy minerals. It appears as grains, which either consist of single crystals (Fig. 65) or aggregates. In them are frequently observed inclusions of apatite (Fig. 64) zircon sphene and magnetite. Generally the hornblende is rather euhedral elongated along the C axis and with well formed faces (100) (010) and (110). It shows pleochroism:

n_α = light greenish yellow
n_β = green to greenish-subbrown
n_γ = olivegreen to bluishgreen

The extinction angle $n_\gamma : c$ ranges between 13° and 16° and the optic axial angle (— 2V) between 72° and 85°. Sometimes are observed twins on (100), but multitwins are not observed. The bireflringence is moderate to strong.From these data it is concluded that the mineral is hanstingsite.

For the origin of the mineral we accept that at least for the greatest part, the grains appearing in the Black Sands are concentrations derived from the granite of Mount Symvolon. Hornblende with equal or nearly equal constants was observed also in the igneous rock of the district Serai Drama (PAPADAKIS 1965).

SPHENE

It is included in significant proportion in the Black Sands, exceeding sometimes that of hornblende. Its crystals are usually euhedral (Fig. 66) with well developed faces (110) and (111). Many times the characteristic "envelope like" form of the mineral (TROEGER 1968) is also observed (Fig. 67). As a rule a perfect (110) cleavage is observed (Fig. 66, 68) and also twinning and multitwinnin.

The mineral is either colourless or slightly coloured with distict pleochroism:

n_α = colourless to light subbrown
n_β = light brownish yellow
n_γ = yellowish brown

The dispersion $\rho \gg \upsilon$ is so strong that in some sections is obvious also under orthoscopic observation. The angle 2V of the mineral, measured under conoscopic observation on the universal stage with a filter for the different wavelengths, was found to be:

λ 449 2V = 16° 30 - 18°
λ 559 2V = 25° - 27°
λ 663 2V = 28° - 30°

Generally, the optical constants and features of the mineral range between large limits, a fact observed, as it has already been mentioned, also in other constituents of the Black Sands. This shows different origins of sphene. We accept that a part of its grains derived from the granite of Mount Symvolon and probably a very small part from pegmatitic veins of the granite. A significant part of the grains must derive from the metamorphic background of the district.

Part of the appearing strong radioactivity of the Black Sands is due to sphene grains including small quantities of radioactive elements.

ZIRCON

The mineral is observed sparsely and only as inclusion in other minerals, mainly hornblende. Isolated zircon crystals, common in Black Sands concentrations, were not found. The inclusions of the mineral are of small dimensions 0,05 - 0,1 mm and often are surrounded by pleochroic aureoles in the hornblende crystals. They are usually euhedral with the characteristic prismatic-bipyramidal form and more rarely rounded in the form of a barrel. It always shows very strong refringence and birefringence. Decrease of these constants because of radiation damage was not observed.

For their origin we must accept the same as for the surrounding hornblende, i.e they derive from the granite of Mount Symvolon. A small part of the radioactivity of the Black Sands is possibly due to the inclusions of zircon.

MONAZITE

It occurs only sparsely and in few samples in the Black Sands. It occurs always as well developed single crystals of 1-2 mm length or even longer. Twinning on (100) was observed only once, whereas the cleavage of the mineral on (001) is distinct in all sections.

In transparent sections it appears colourless with strong refringence and birefringence. The extinction angle is $n_\gamma : c = 3° - 5°$ and the optic axial angle about 10°.

In polished sections it appears with many internal reflections, which gather characteristically in the rims of the mineral, giving the image of a halo (Fig. 69, 70).

For the origin of the mineral we must accept that the significant size of its crystals as well as their euhedral shape constitute indications that it comes from pegmatitic veins surrounding or crossing the granite of Mount Symvolon.

Part of the radioactivity of the Black Sands must also be due to monazite.

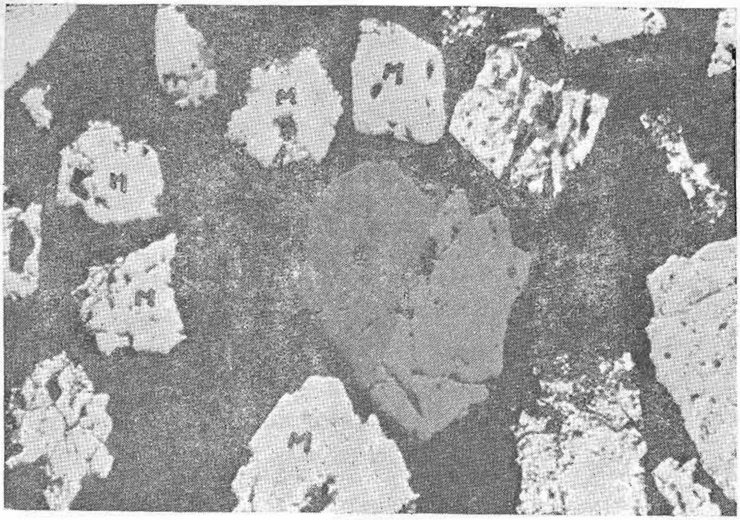

Fig. 1. Magnetite hypidiomorphic crystals (M) around a cassiterite twin (crystal)(C). In lower part, magnetite with beginning martitization along the cracks. Polished section 35X.

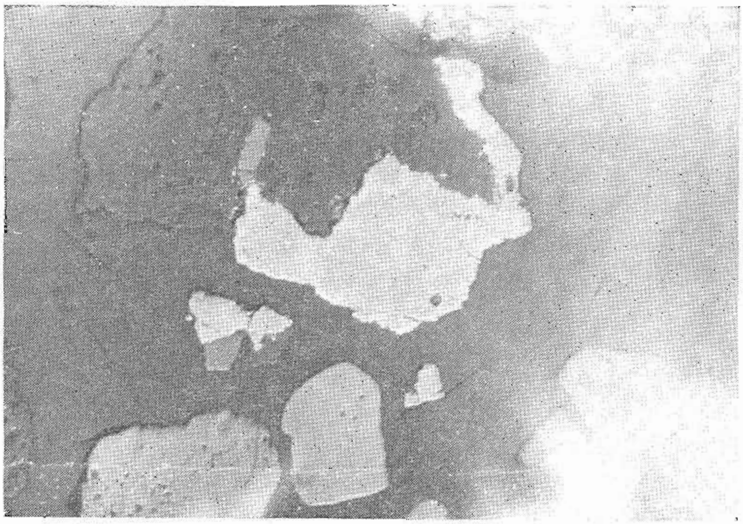

Fig. 2. A magnetite crystal intergrown with quartz and with beginning martitization along the cracks of the mineral. Polished section 75X.

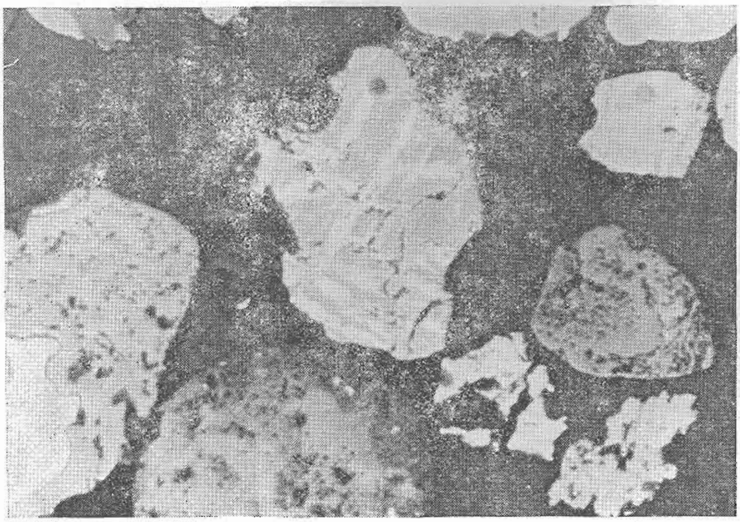

Fig. 3. A magnetite grain with advaneed martitization//(111). Polished section 75X.

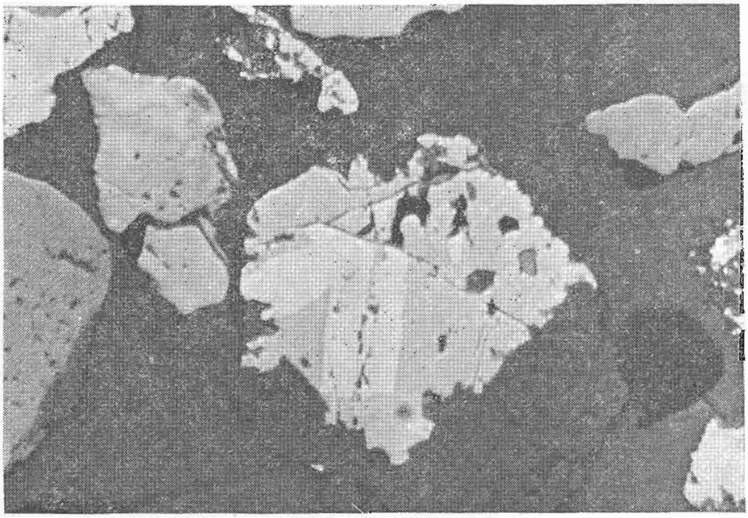

Fig. 4. A magnetite crystal with advanced martitization in two bands parallel to (111). Polished section 75X.

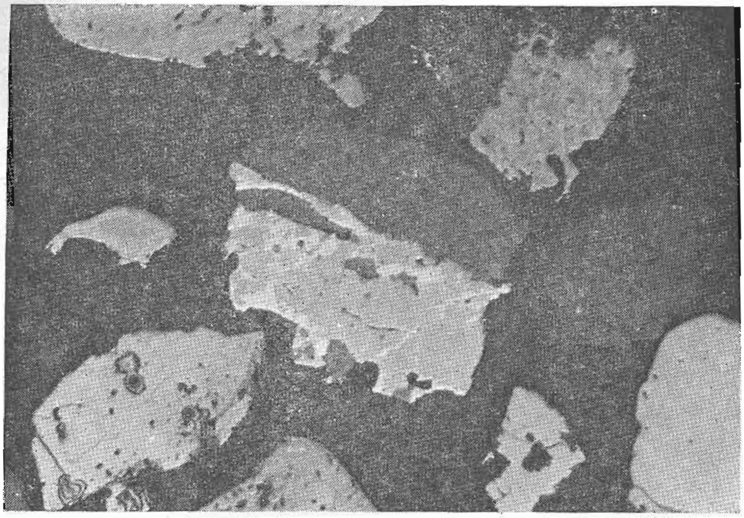

Fig. 5. Magnetite intergrown with calcite in its lower part. The cleavage $(10\bar{1}1)$ of calcite is discernible. Polished section 75X.

Fig. 6. The same as in fig. 5 under crossed Nicoles. The internal reflections of ealcid are discernible.

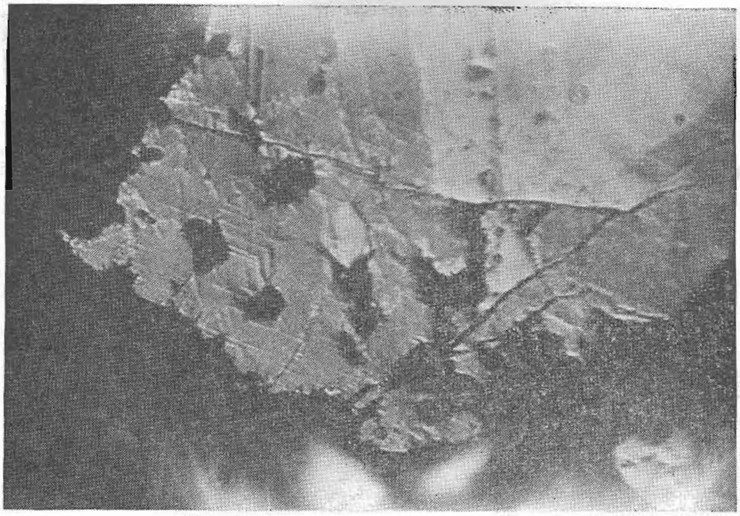

Fig. 7. A part of a magnetite crystal with clear beginning martitization on the left *ant advanced martitization in two bands parallel to (111) on the* right *Polished section 150X. Oil immersion.*

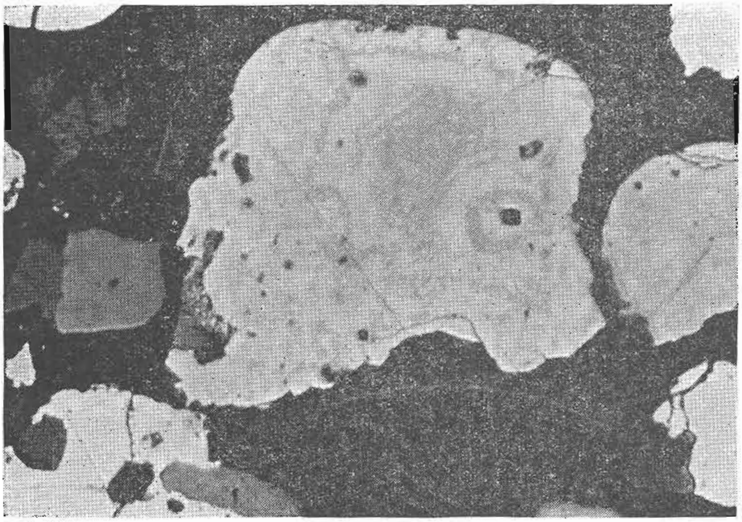

Fig. 8. Phythmites of goethite (grey) and lepidoerocite (light grey) Polished section 75X.

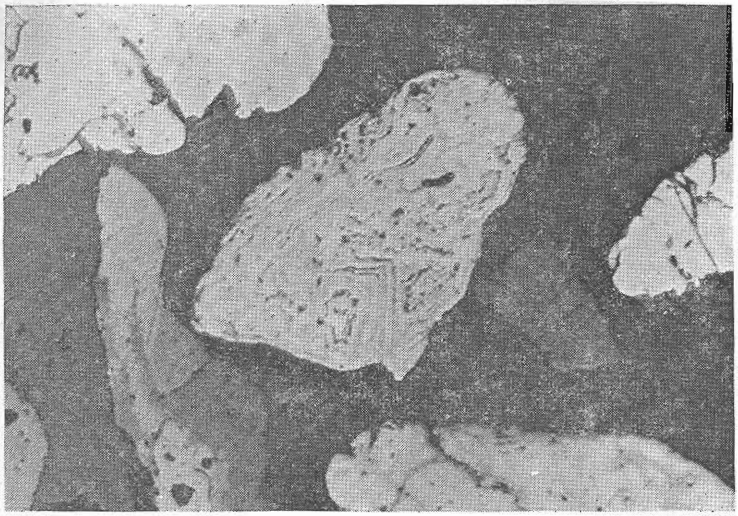

Fig. 9. Rhythmites of geothite-lepidocrocite with empty spaces (dark bands). Polishde section 75X.

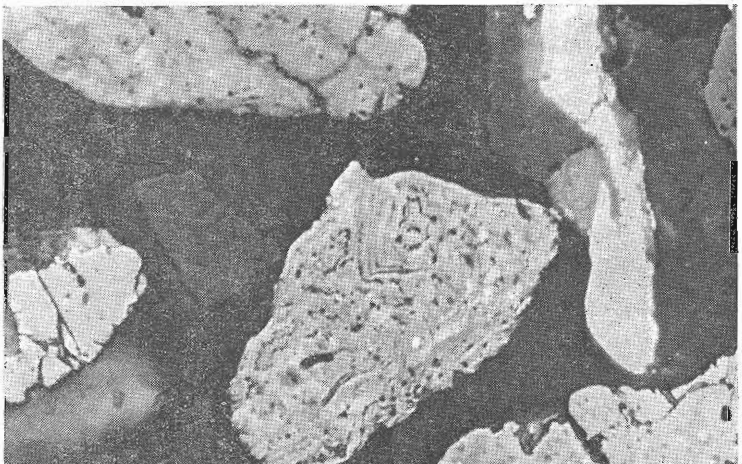

Fig. 10. The same as in fig. 9 under crossed Nicols.

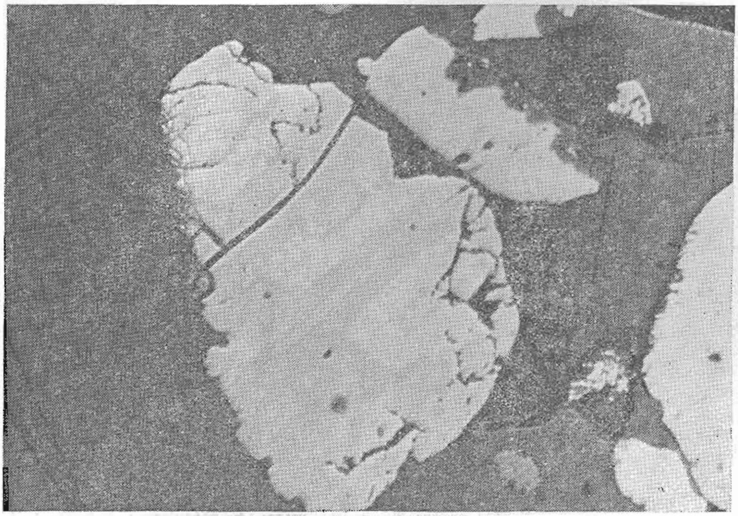

Fig. 11. Rhythmites of goethite-lepidocrocite in parallel bands. Polished section 75X.

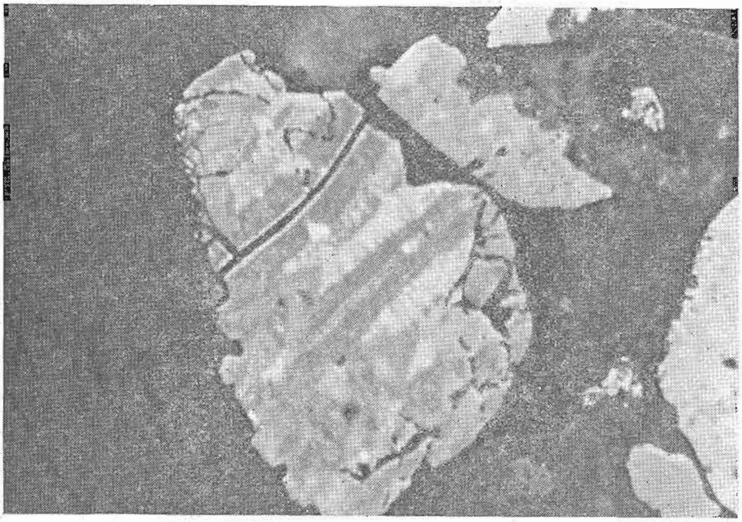

Fig. 12. The same as in fig. 11 under crossed Nicols.

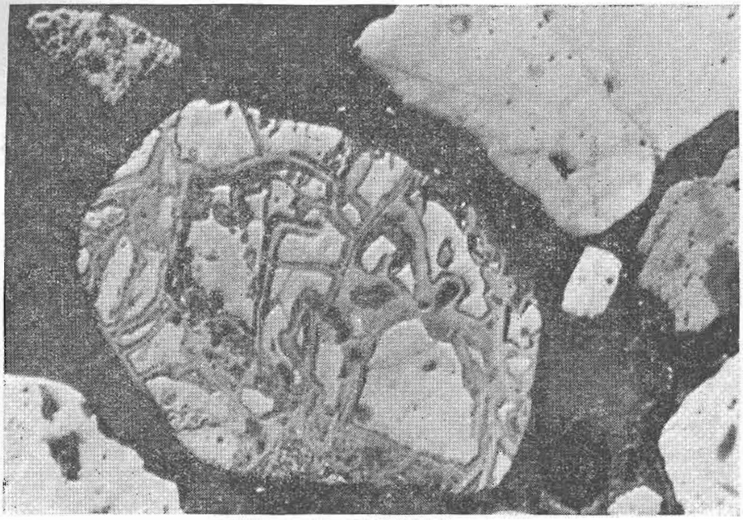

Fig. 13. Rhythmites of geothite-lepidocrocite arranged in two perpendicular main directions. Polished section 75X.

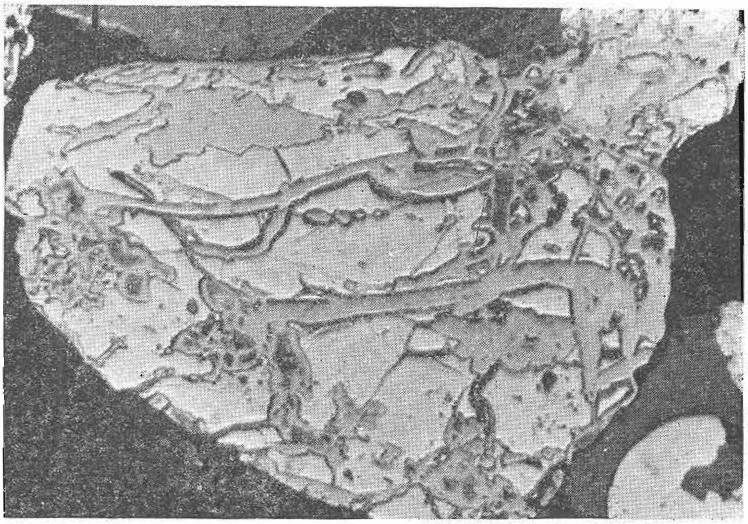

Fig. 14. Rhythmites of geothite-lepidocrocite arranged in a direction somewhat inclined from the perpendicular. Polished section 75X.

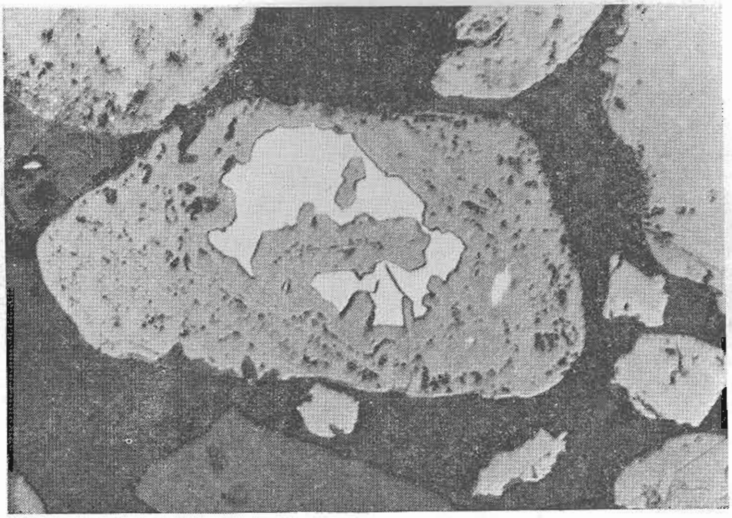

Fig. 15. Remains of pyrite in goethite-lepidocrocite. Polished section 75X.

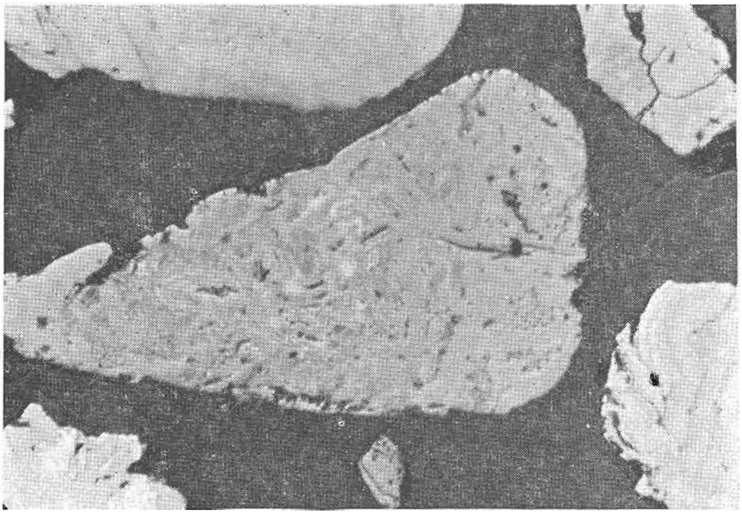

Fig. 16. Rhythmites of geothite-lepidocrocite with interposed pyrolusite. Polished section 75X.

Fig. 17. The same as in fig. 16 under crossed Nicols. Pyrolusite is distinguished due to its strong anisotropy (white parts).

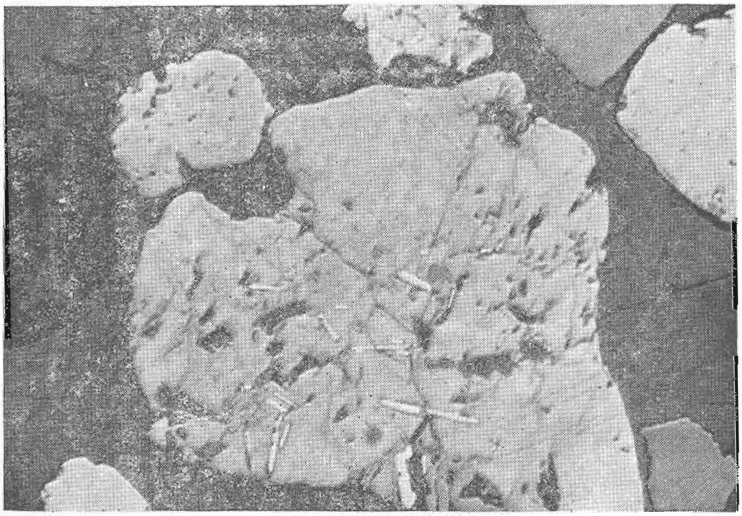

Fig. 18. Elongated inclusions of hematite in geothite-lepidoctocite. Polished section 75X.

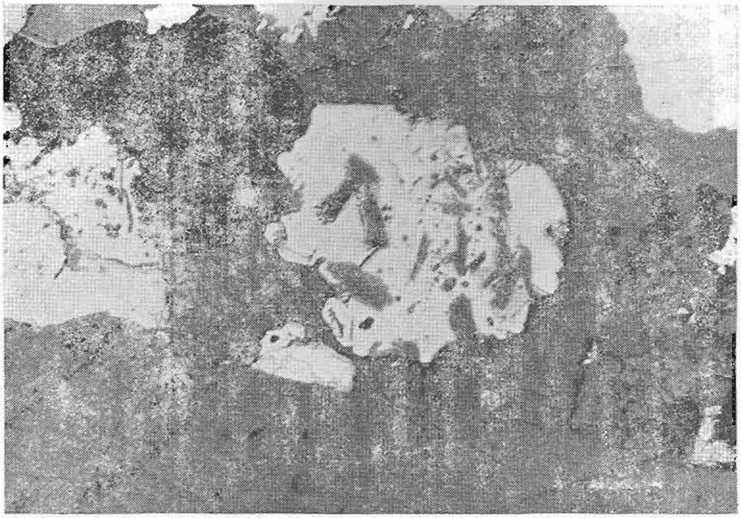

Fig. 19. Inclusions of mica (dark bands) in a geothite-lepidocrocite grain. Polished section 75X.

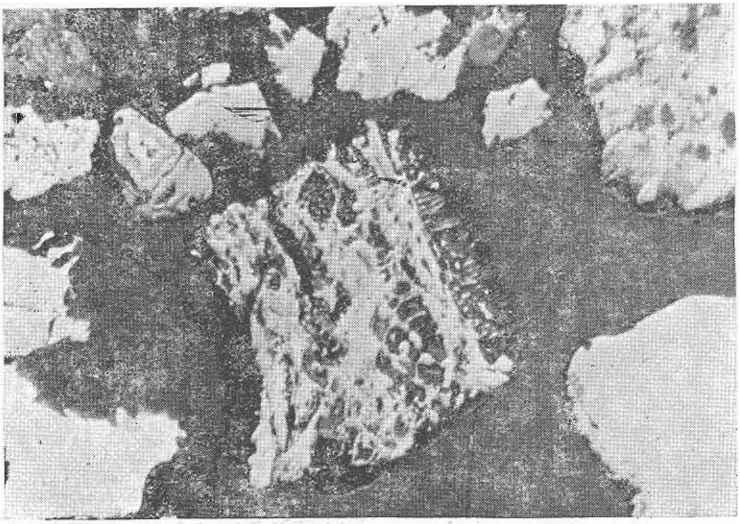

Fig. 20. Myrmekitic intergrowth of quartz with geothite-lepidocrocite. Polished section 75X.

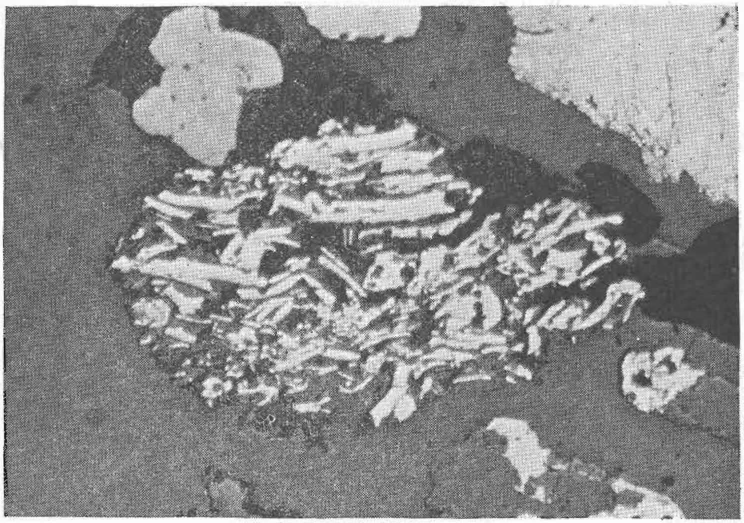

Fig. 21. Hematite in elongated parallel or slightly curved lamellae. Polished section 75X.

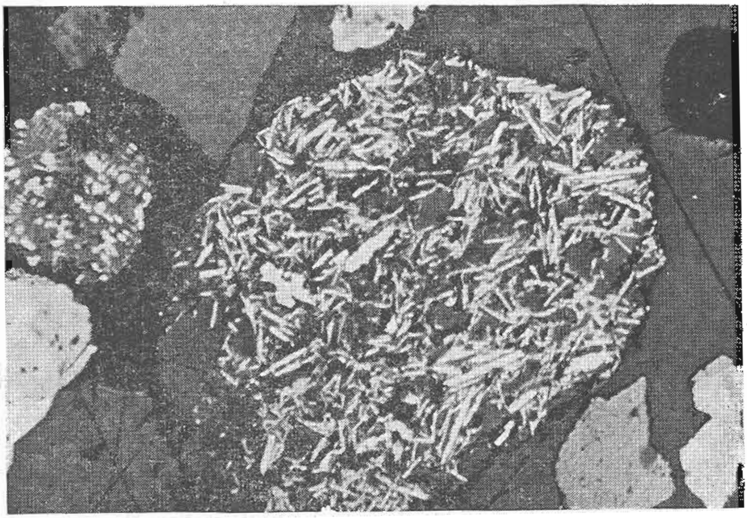

Fig. 22. Hematite in rather regularly arranged lamellae in quartz. Polished section 75X.

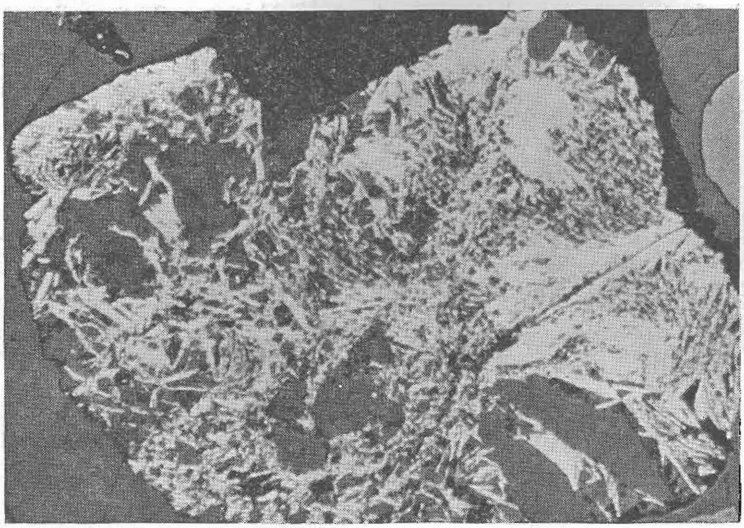

Fig. 23. Hematite in irregularly arranged lamellae intergrown with quartz. Polished section 75X.

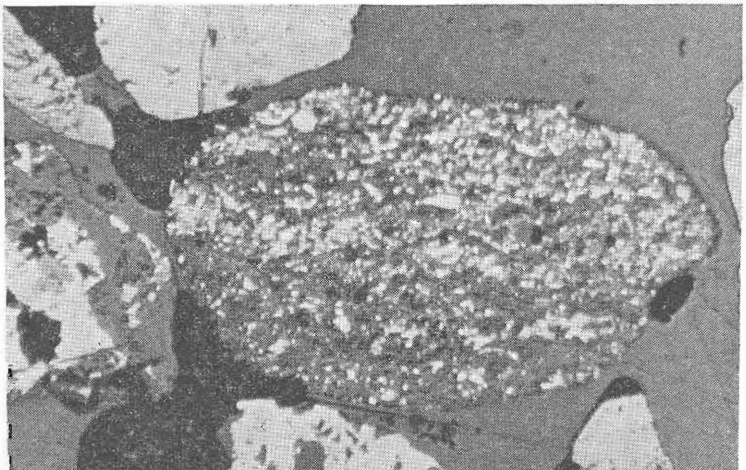

Fig. 24. Hematite dispersed in quartz. Polished section 75X.

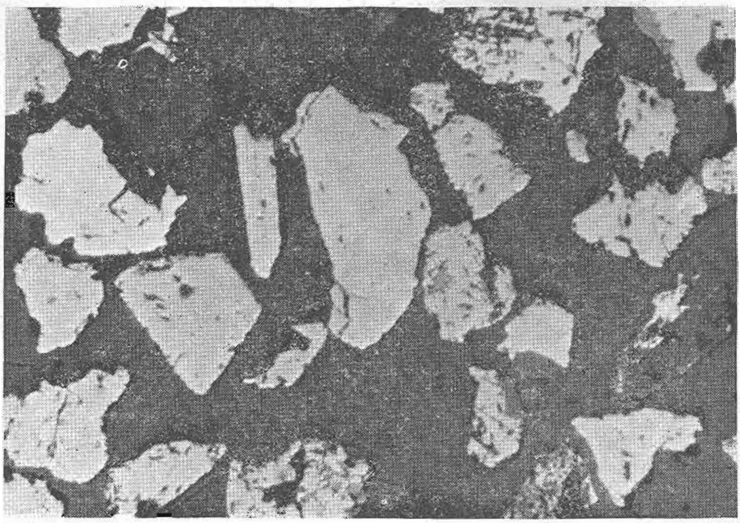

Fig. 25. Routile (the large grain in the centre of the figure). The multitwinning on (101) is discernible. Polished section 35X.

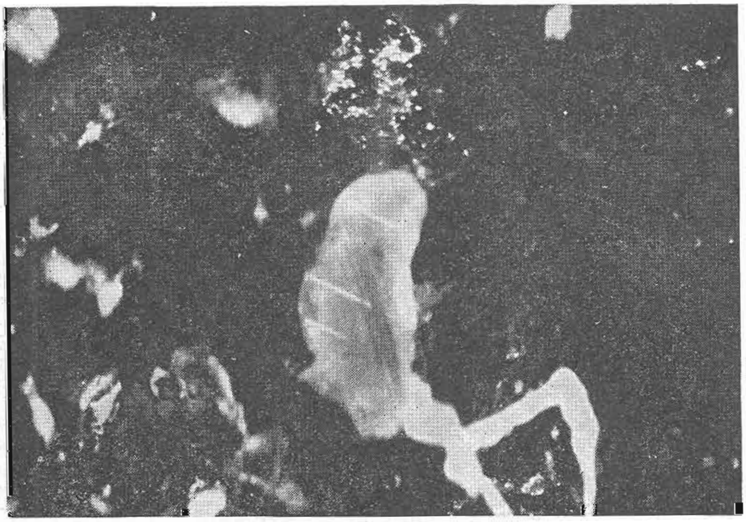

Fig. 26. The same as in fig. 25 under crossed Nicols. The internal reflectians of routile are discernible and also multitwinning on (101) (dark bands) and (301) (light bands).

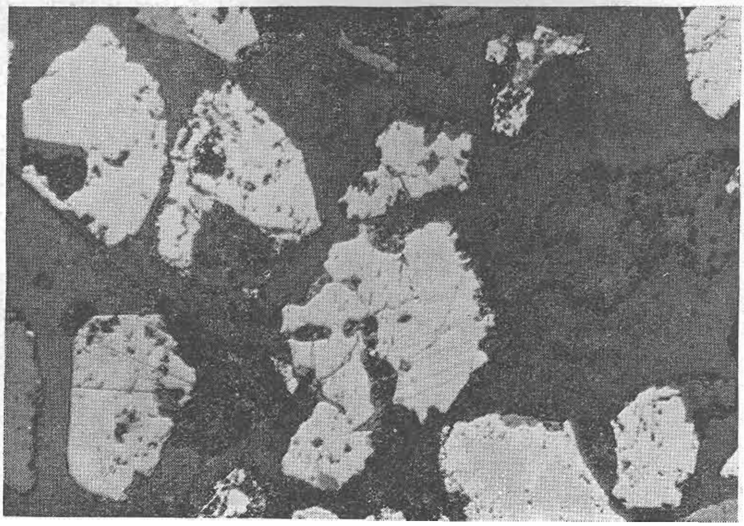

Fig. 27. An hematite grain (in the centre of the figure and downward) with exsolutions of ilmenite (dark parallel lines). Polished section 75X.

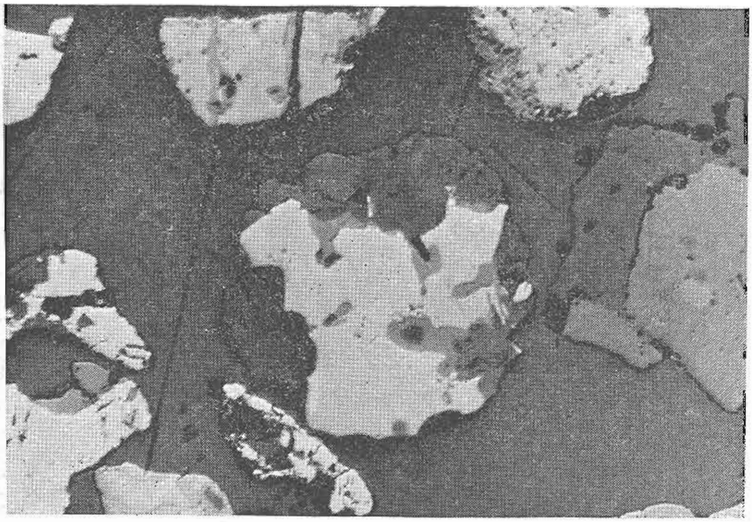

Fig. 28. An ilmenite grain with exsolution bodies of hematite (light parallel lines). Polished section 75X.

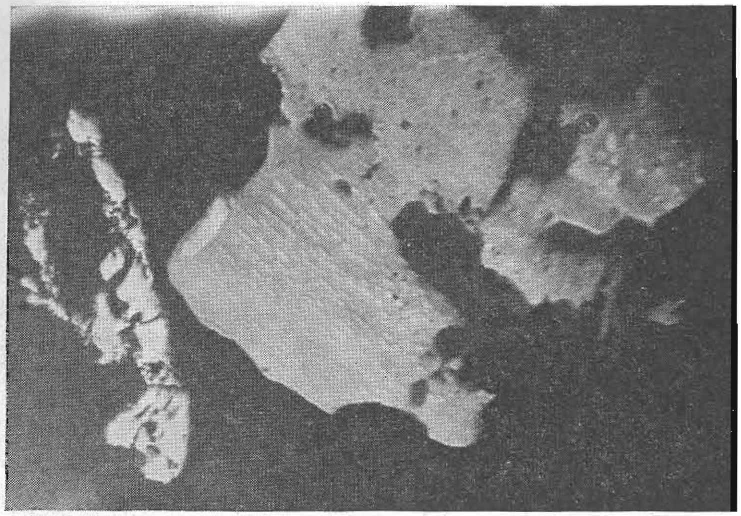

Fig. 29. A part of figure 28 in oil immersion and with magnification 150X. The exsolutions of hematite are clearly distinguished.

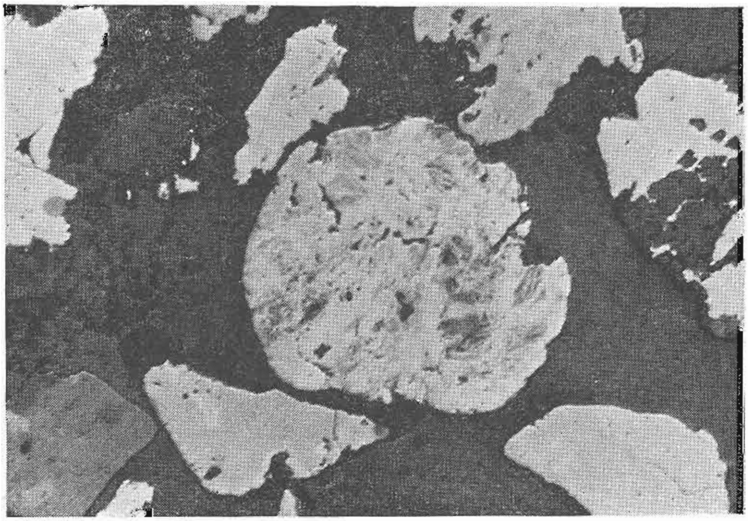

Fig. 30. A grain consisting of intergrowths of pyrolusite and some quartz. Polished section 75X.

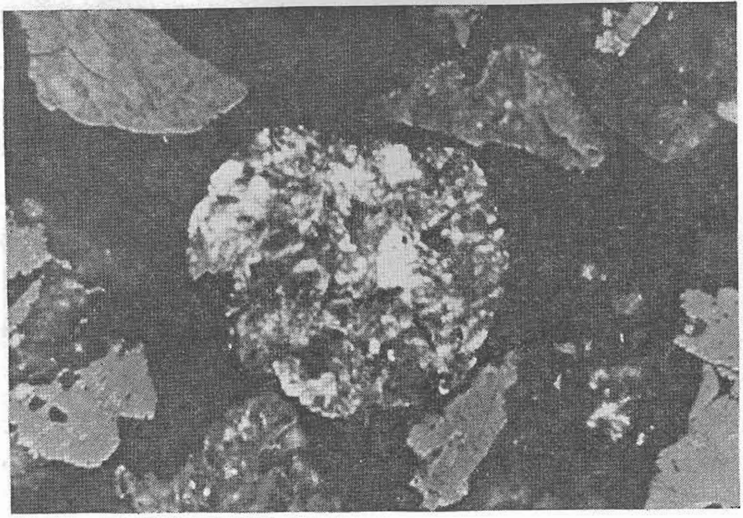

Fig. 31. The same as in fig. 30 under crossed Nicols. The strong anisotropy of pyrolusite is distinguished.

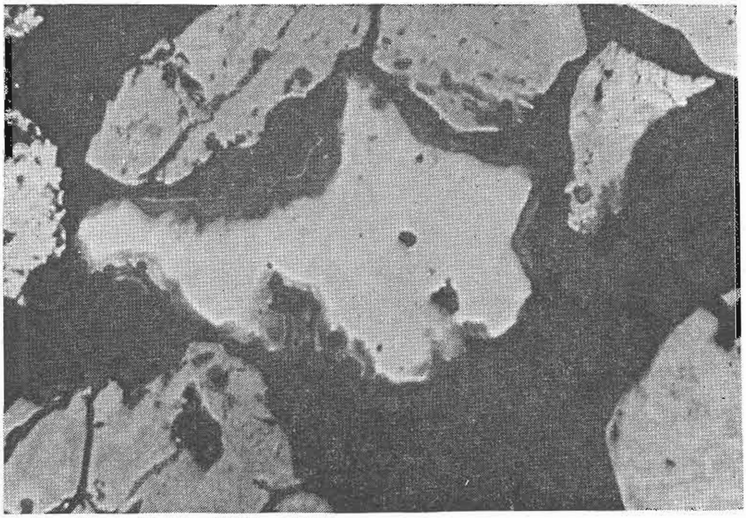

Fig. 32. A grain of a manganese mineral changing at the rim into fine crystals of pyrolusite. Polished section 75X.

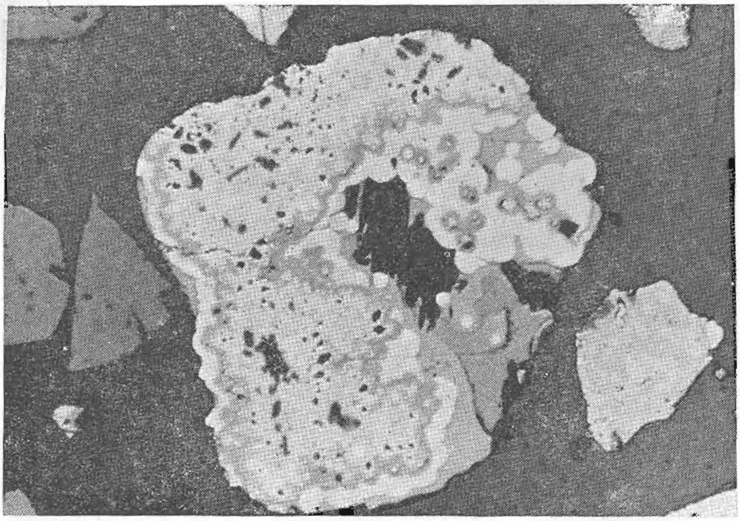

Fig. 33. Aggregates of botryoidal psilomelane. Polished section 75X.

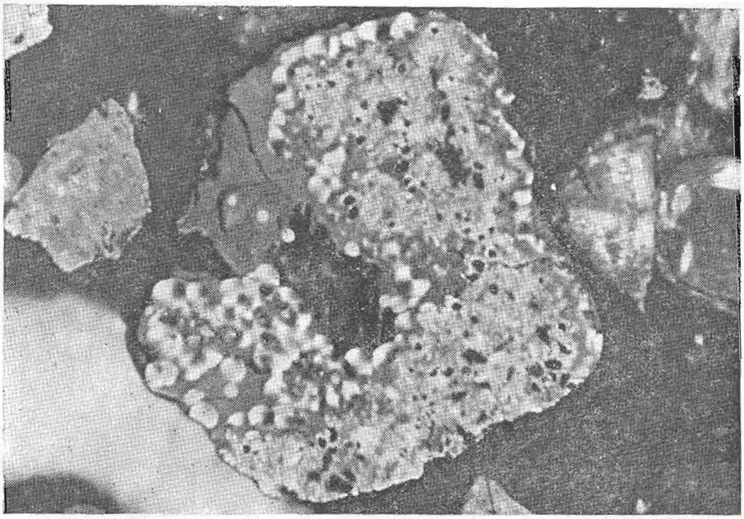

Fig. 34. The same as in fig. 33 under crossed Nicols. In the botryoidal masses crosses are distinguished.

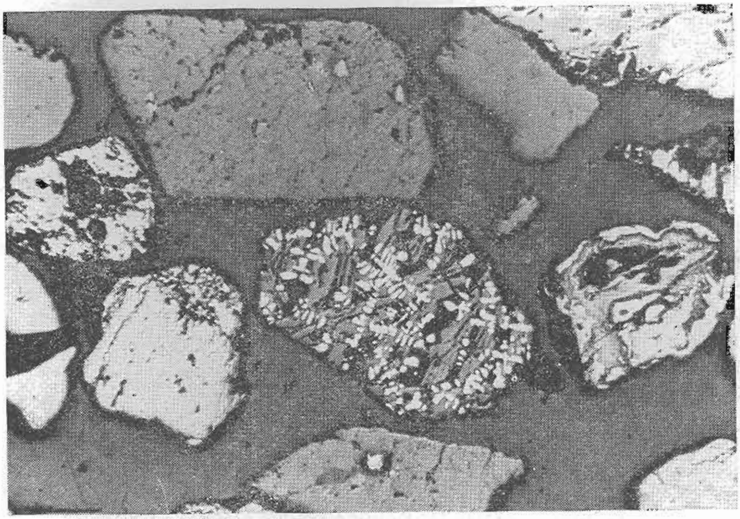

Fig. 35. A wolframite crystal (in the upper *part of the fig.). Polished section 75X.*

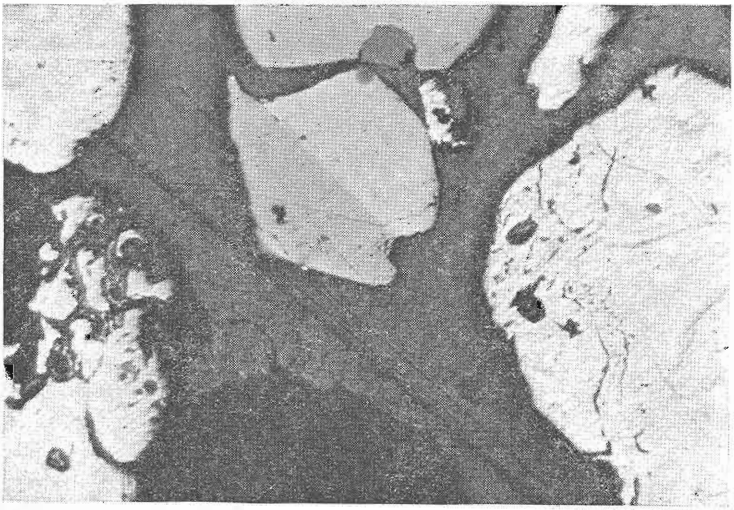

Fig. 36. A cassiterite twin (crystal). Polished section 75X.

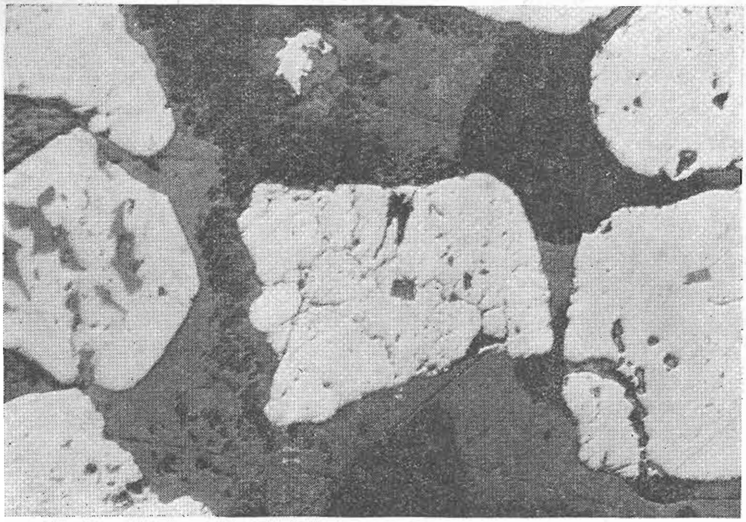

Fig. 37. An uraninite grain with shrinking cracks. Polished section 75X.

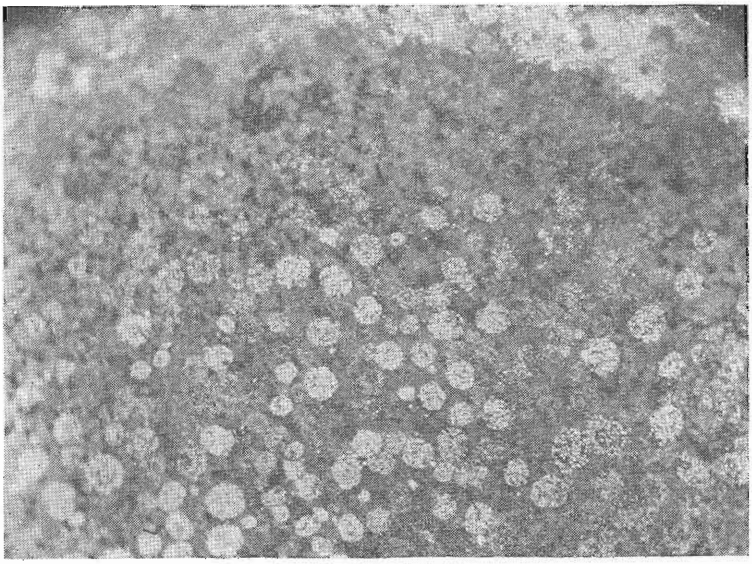

Fig. 38. Framboidal pyrit. Very small pyrite grains are discernible in round aggregates. Polished section, oil immersion 250X.

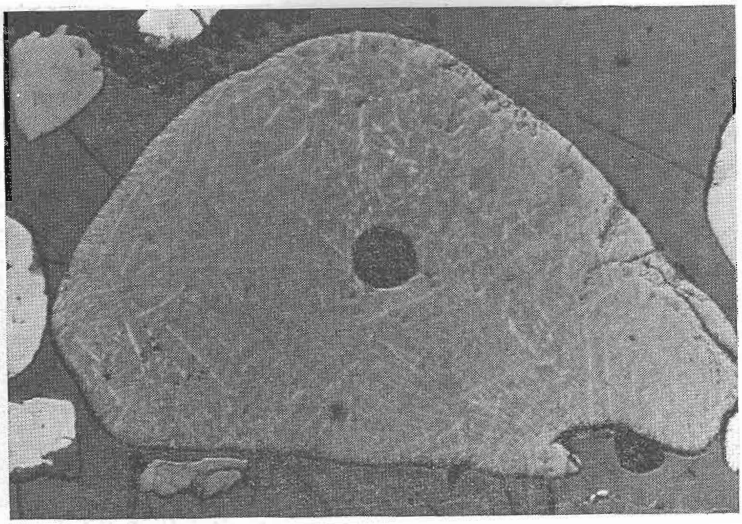

Fig. 39. Magnetite skeletal crystals in silicate glass (artificial). Polished section 75X.

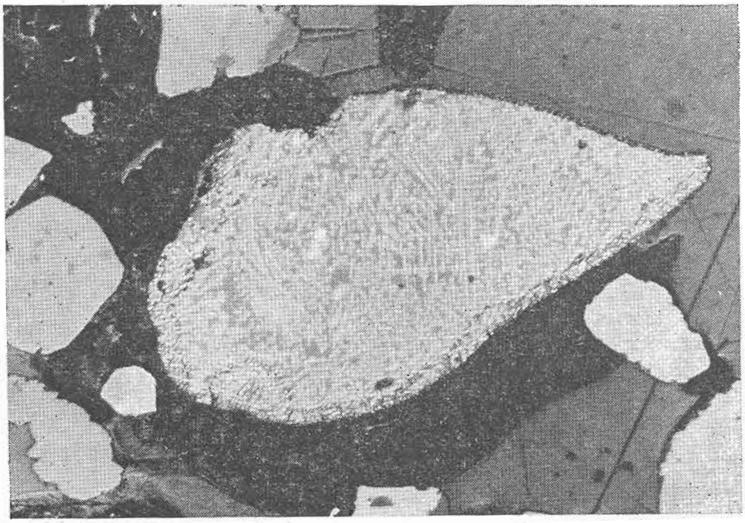

Fig. 40. Magnetite skeletal crystals in silicate glass (artificial). Polished section 75X.

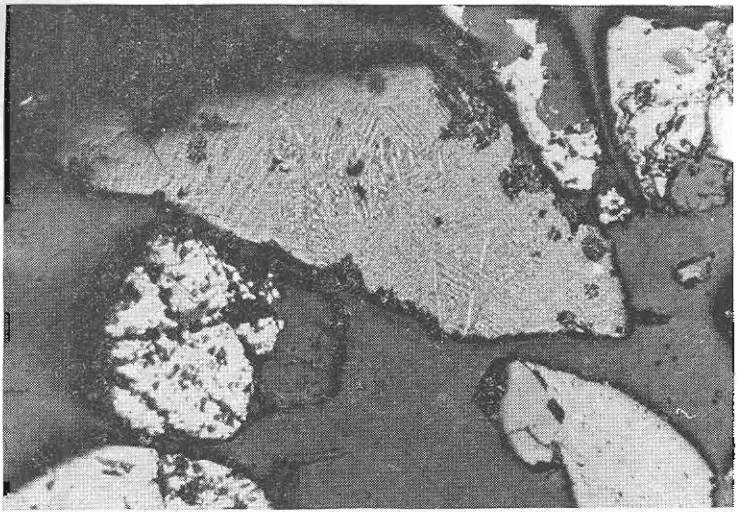

Fig. 41. Magnetite skeletal crystals in silicate glass (artificial). Polished section 75X.

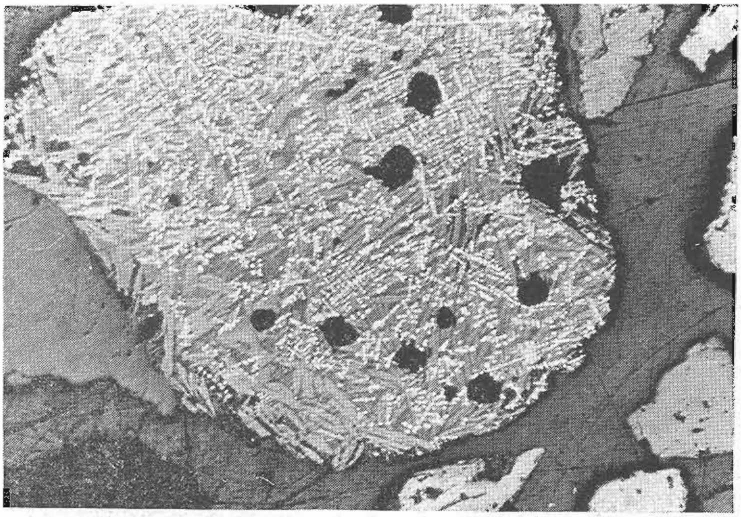

Fig. 42. Magnetite skeletal crystals in pyroxene (artificial). Polished section 75X,

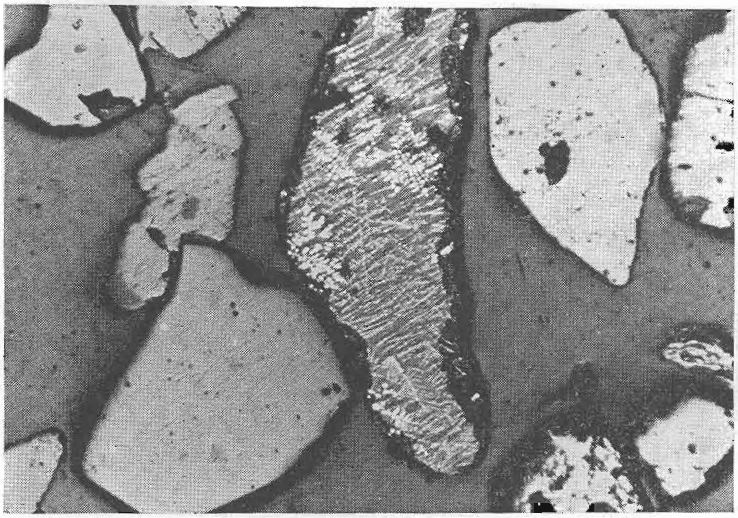

Fig. 43. Magnetite skeletal crystals in silicate glass (artificial). Two generations are distinguished. Polished section 75X.

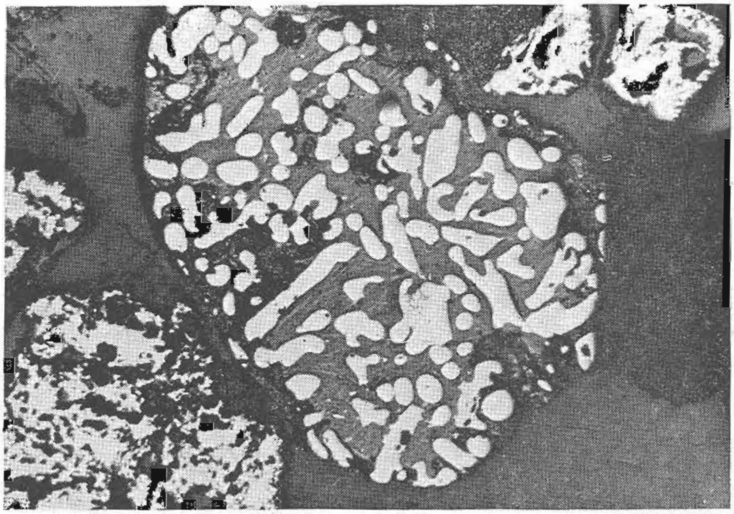

Fig. 44. Myrmekitic intergrowth of magnetite with silicate glass (artificial). Polished section 75X.

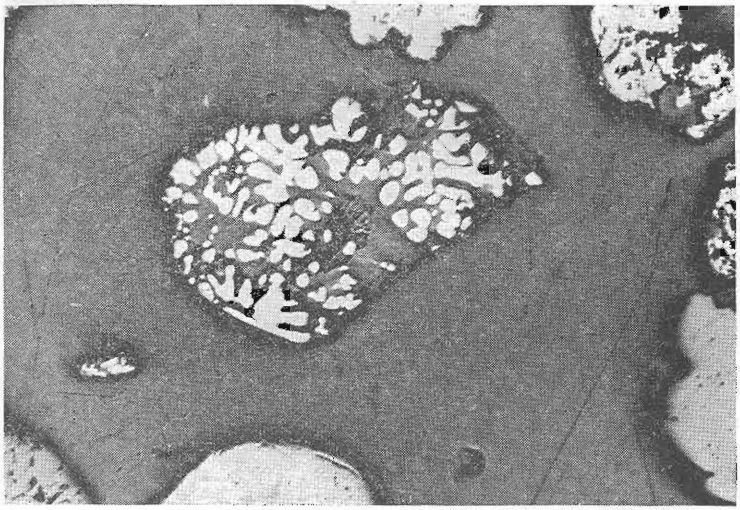

Fig. 45. Myrmekitic intergrowth of megnetite with silicate glass (artificial). Polished section 75X.

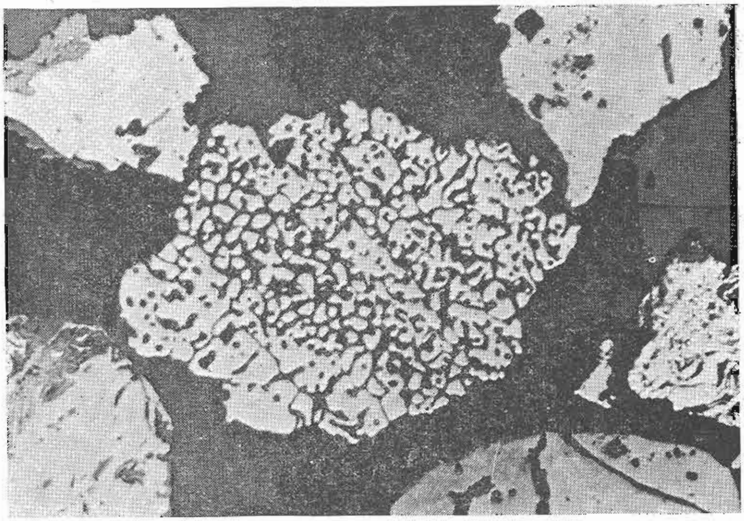

Fig. 46. Myrmekitic intergrowth of magnetite with silicate glass (artificial). Polished section 75X.

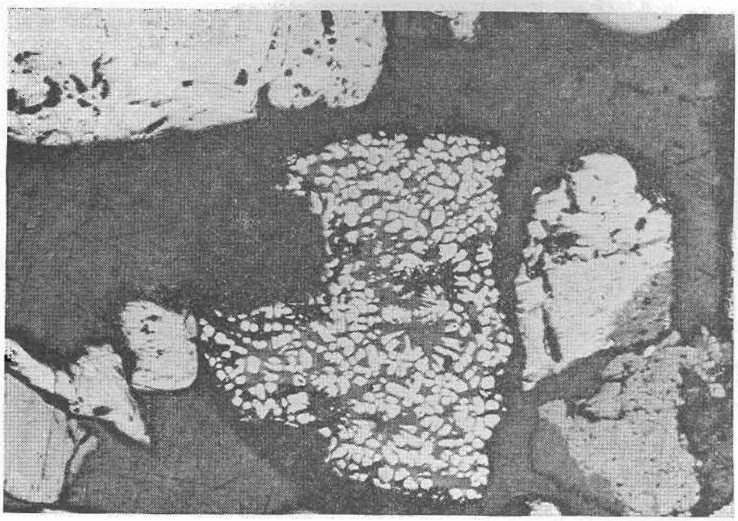

Fig. 47. Myrmekitic intergrowth of magnetite with silicate glass (artifieial). Polished section 75X.

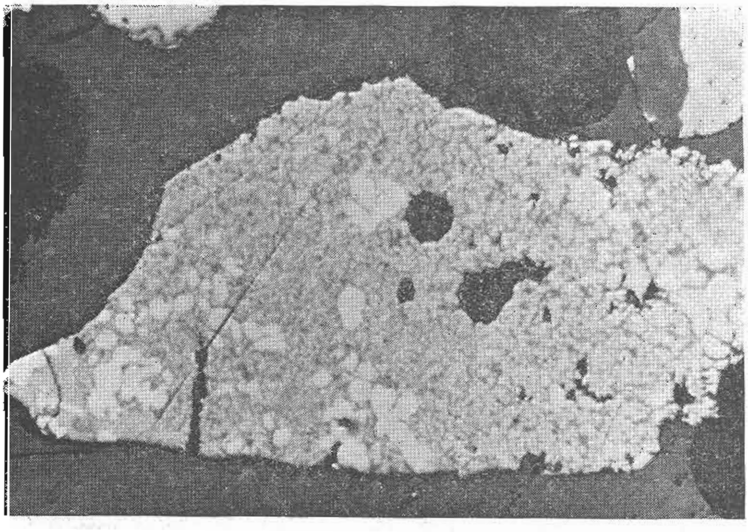

Fig. 48. Simultaneous existence of magnetite skeletal crysrals with myrmekitie intergrowth of magnetite with glass. Polished section 75X.

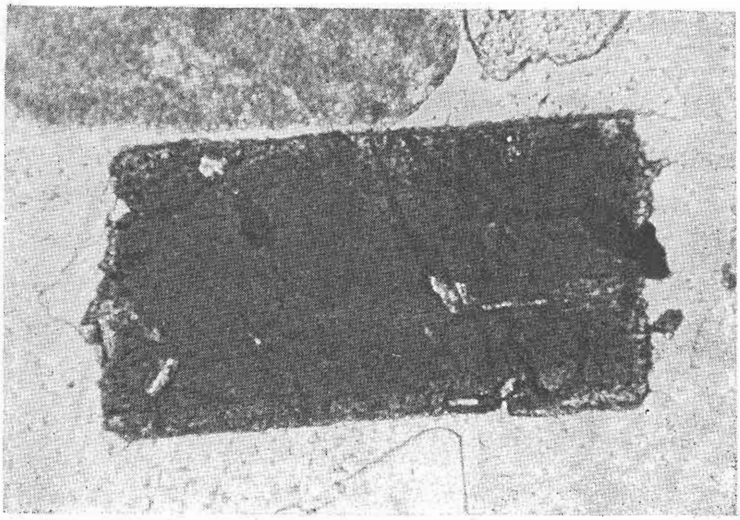

Fig. 49. Orthite euhedral crystal. Thin section 90X.

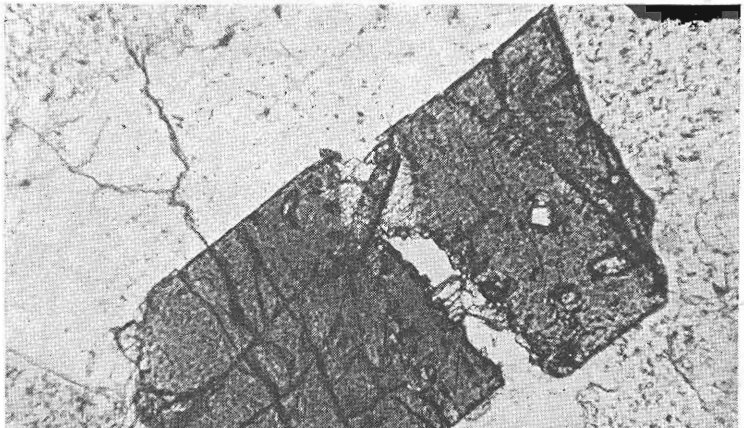

Fig. 50. Orthite crystal shattered and traversed by quartz. Thin section 90X.

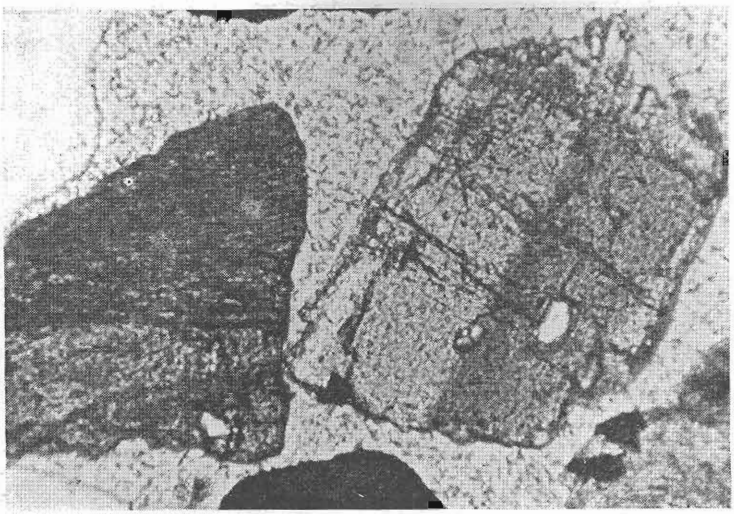

Fig. 51. Orthite twin (crystal). Thin section 90X.

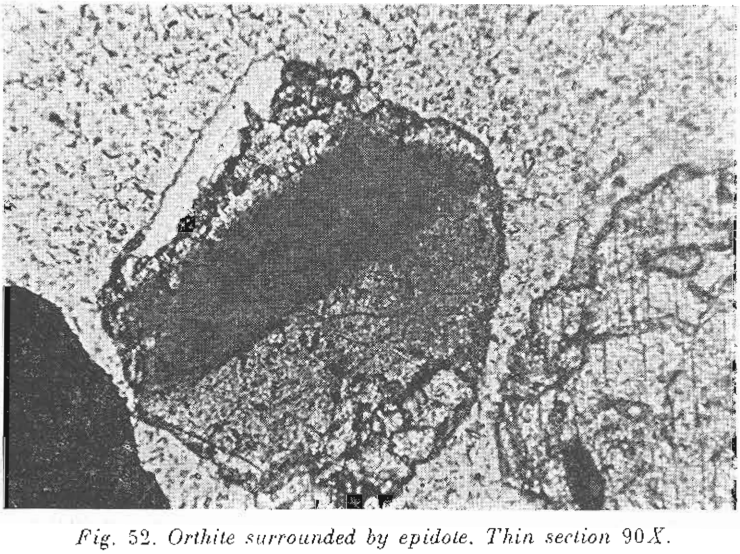

Fig. 52. Orthite surrounded by epidote. Thin section 90X.

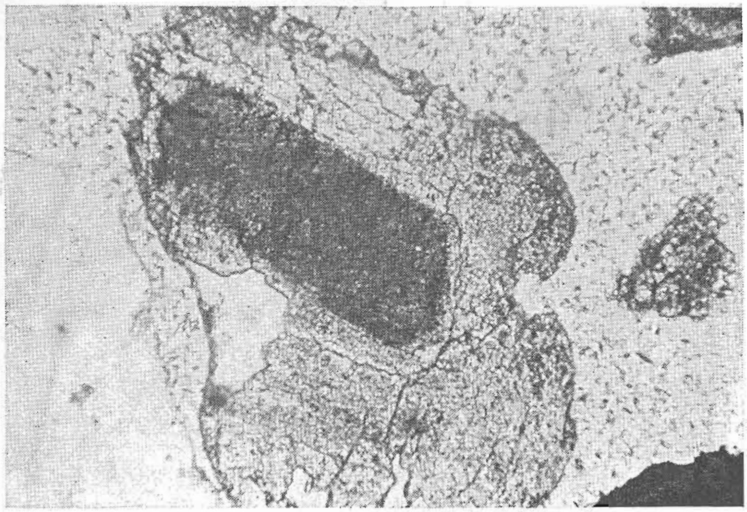

Fig. 53. Orthite surrounded by epidote. Thin section 90X.

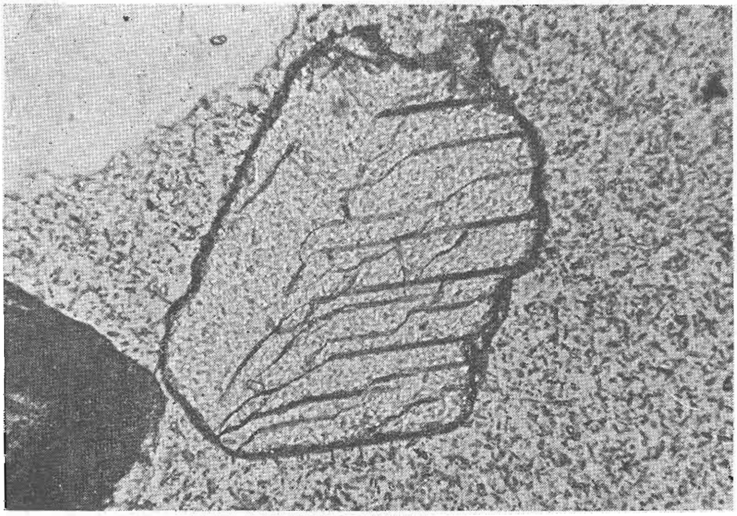

Fig. 54. Epidote euhedral crystal. The cleavage// (001) and twinning (001) are discernible. Thin section 90X.

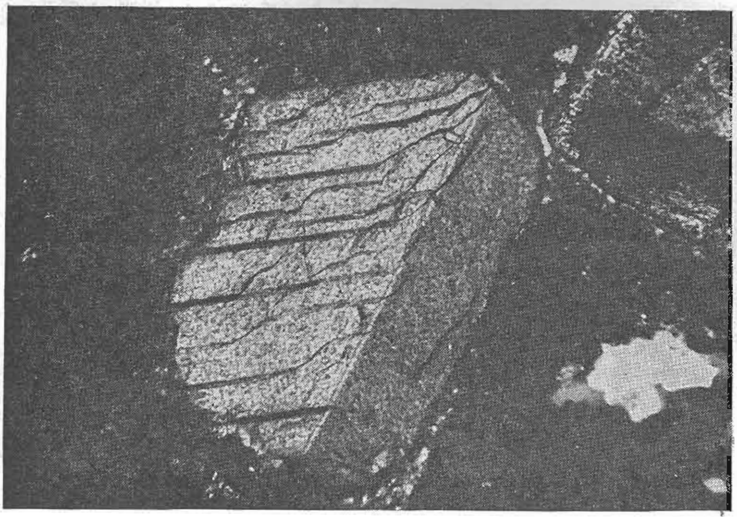

Fig. 55. The same as in fig. 54 under crossed Nicols.

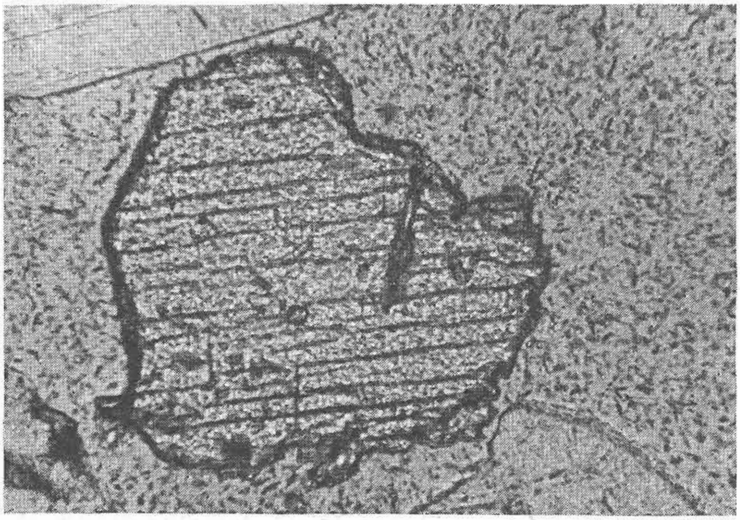

Fig. 56. Epidote hypidiomorphic crystal with clear cleavage //(001). Thin section 90X.

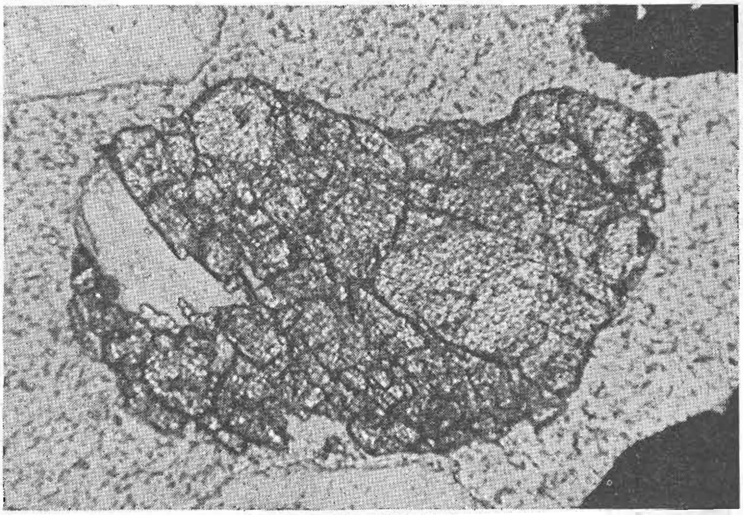

Fig. 57. A grain consisting of aggregates of epidote aneudral crystals. Thin section 90X.

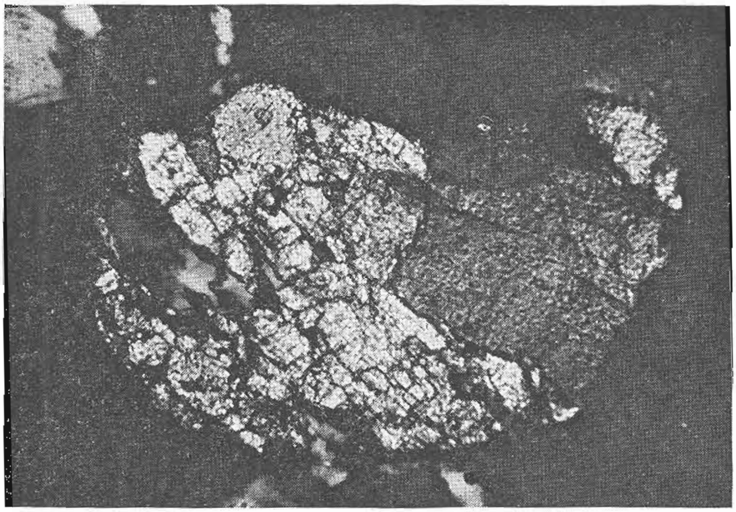

Fig. 58. The some as in fig. 57 under crossed Nicols.

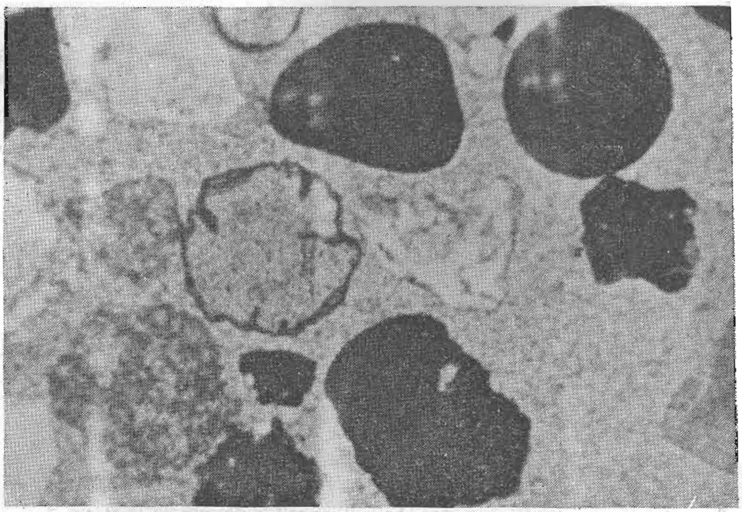

Fig. 59. A general view of the Black Sands in transmitted light. A garnet in the centre. Thin section 30X.

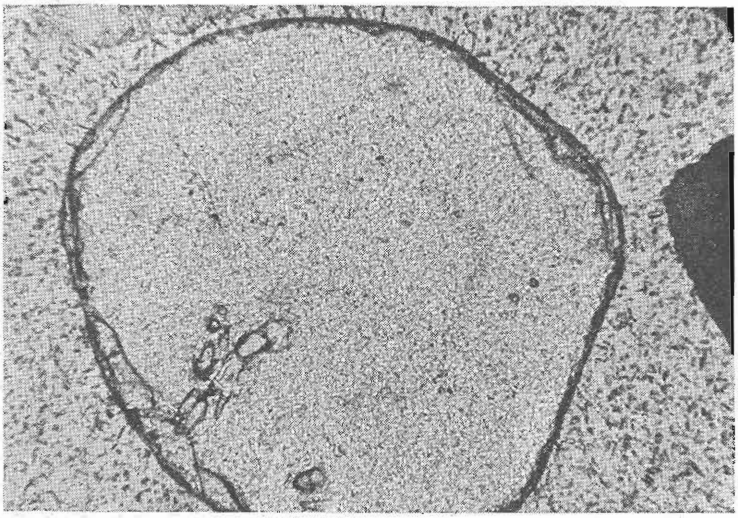

Fig. 60. A garnet of Pyralspit series. Thin section 90X.

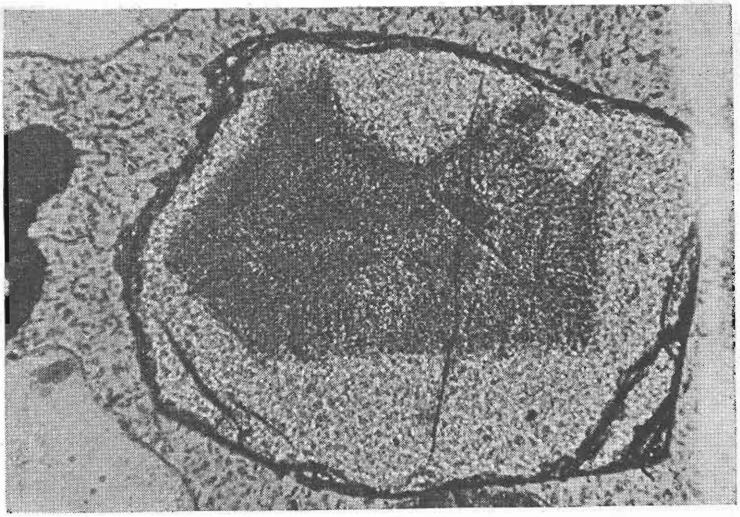

Fig. 61. A garnet of Grandit series. The central part eonsist of melanite. Thin section 90X

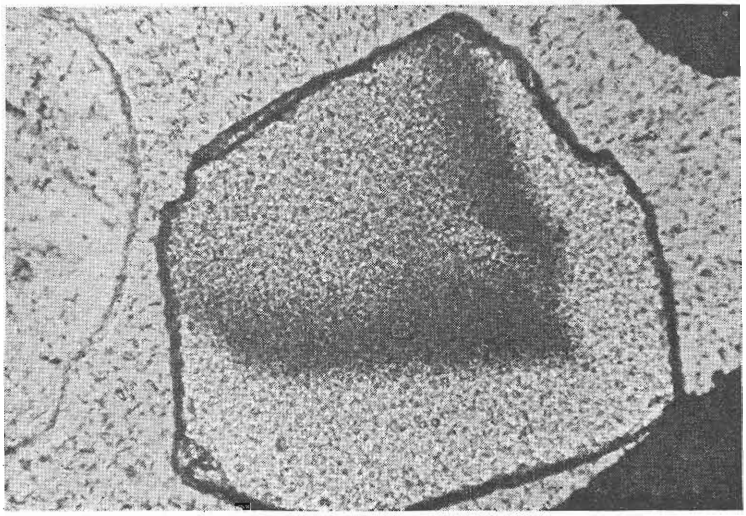

Fig. 62. A garnet of Grandit series. Part of the mineral consists of melanite. The section 90X.

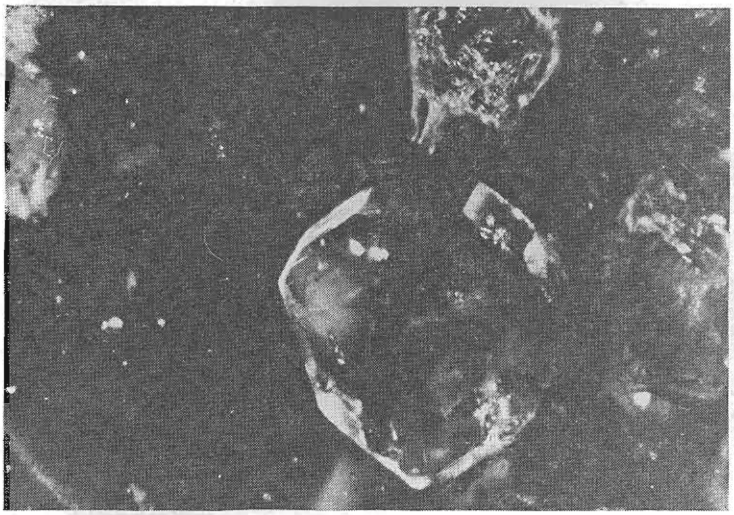

Fig. 63. A garnet under reflected light. Internal reflections arc discernible. Polishde section. Crossed Nicols 35X.

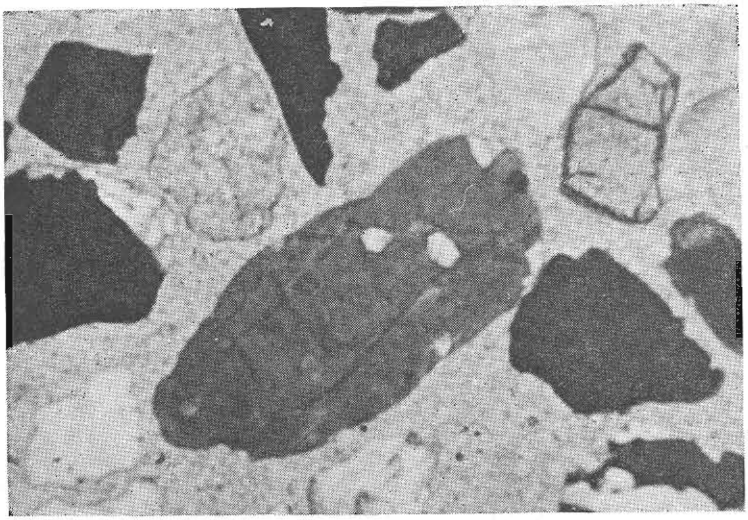

Fig. 64. A hornblende erystal with inclusions of apatite. Thin section 30X.

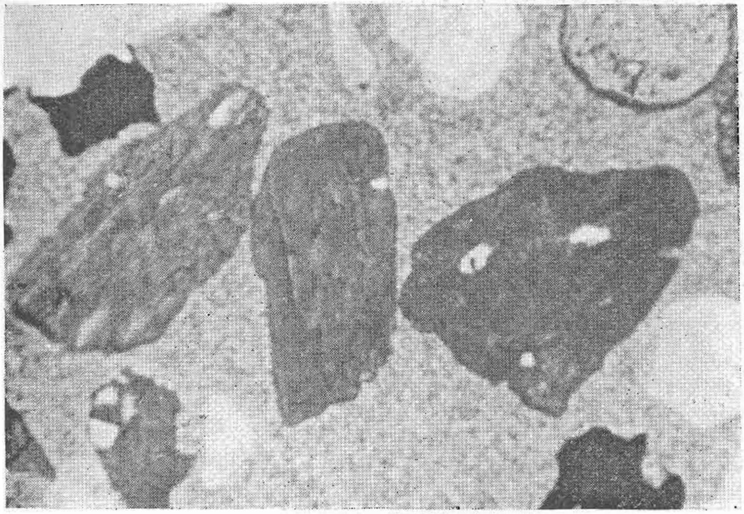

Fig. 65. Three hornblende crystals in different orientations. Thin section 30X.

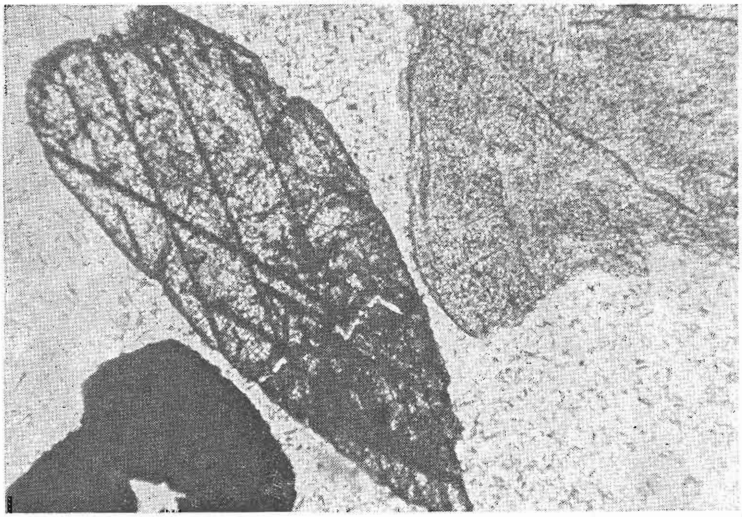

Fig. 66. A sphene euhedral crystal with perfect // (110) cleavage. Thin section 90X.

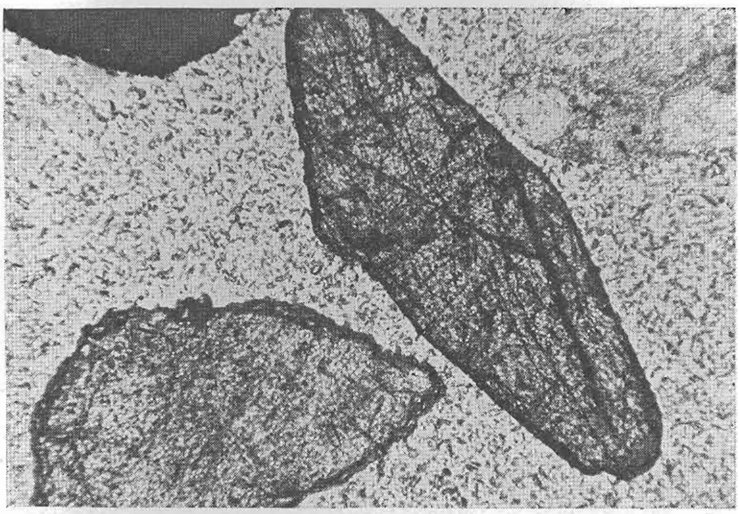

Fig. 67. A sphene crystal with "envelope like" from. Thin seetion 90X.

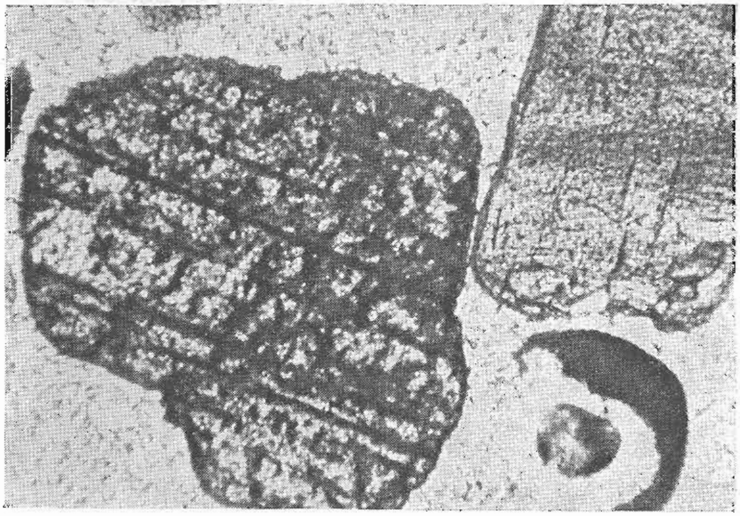

Fig. 68. A sphene hypidiomorphic crystal. The cleavage (110) is visible. Thin section 90X.

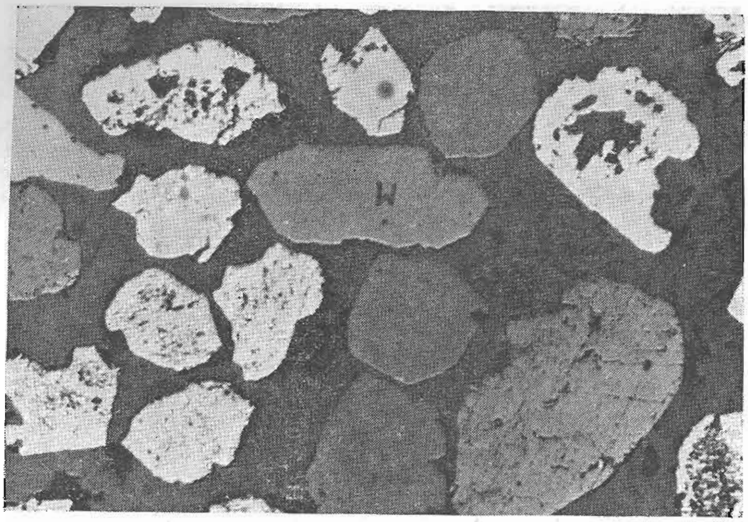

Fig. 69. Monazite (M) between two aproximately round garnet crystals. Polished section 35X.

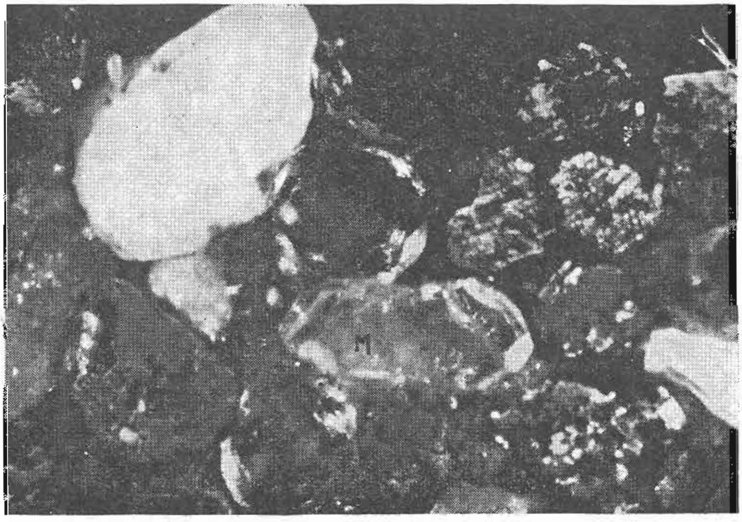

***Fig.** 70. The same as in fig. 68. Under crossed Nicols the characteristic halo is discernible. The white part is calcite.*

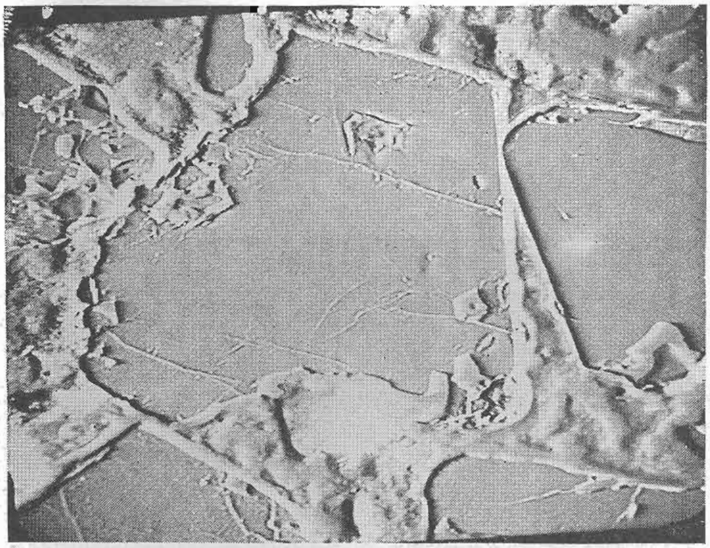

Fig. 71. Absorbed electron image of a magnetite grain. Magnification 200X.

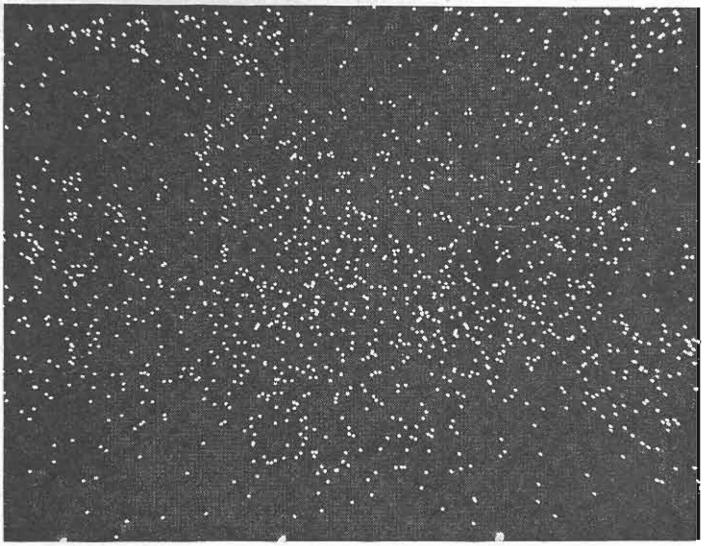

Fig. 72. Mn: Ka X-Ray pulse image. Magnification 200*X. Crystal of* SiO_2.

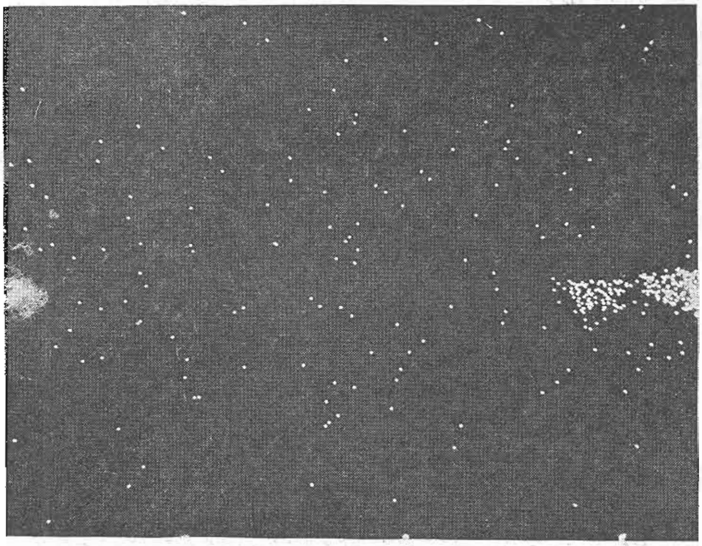

Fig. 73. Ti: Ka X-Ray pulse image. Magnification 200X. Crystal of SiO_2.

REFERENCES

1. Bateman, A., (1950): Economic Mineral Deposits New York 916 p.
2. Chokhrov, F., Zvyagin, B., Ermilowa, L. and Gorshkov, A., (1973): The problem of lepidocrocite.
3. Colombo, V., Faghekazzi, G., Gazzarrini, F., Canzavecchia, G. and Siron, G., (1968): Mechanism of low temperature oxidation of maguetites. Nature 219 p. 1036-1037.
4. Dall'Aglio, M., Gragnani, R. and Locardi, E., (1974): Geochemical factors controlling the formation of the secondary minerals of Uraniun In: Formation of Uranium Ore Deposits. Proceedings of a Symposium. Int. Atom. En. Ag. Vienna 750 p.
5. Duchesne, J., (1973): Microtextures of Fe - Ti oxide minerals in the South - Rugalaud anorthositic complex (Norway). Ann. Soc. geol. Belg. 93 p. 527-544.
6. El-Hinnawi, E., (1964): Mineralogical and geochemical studies of Egyptian (U.A.R.) Black Sands Beitr. Min. Pert. 9 p. 519-532.
7. Fischer, G., (1964): Über das Granitmassiv des Symvolon Gebirges bei Kavala Geol. Rundschan 53 p. 390-392.
8. Friedrich, O., (1966): Microscopic investigation of the iron ore minerals and the more important minerals of the steel alloy metals. In: H. Freund: Applied Ore Microscopy. N. York 607 p.
9. I.F.E.Y., (1954): Geological map of Greece: Athens.
10. Kockel, F. und Walther, H., (1968): Zur geologischen Entwicklung des südlichen serbomakedonischen Massivs (Nordgriechenland). Bulg. Akad. Sc. Bull. Geol. Inst. Ser. Geol. Str. Luth KH XVII p. 133-142.
11. Love, I. and Amstutz, G., (1966): Review of microscopic pyrite from the Devoniau chattanooga shale and Rammelsberg Banderz. Forschr Min. 43 p. 273-304.
12. Mack, E., (1964): Goldvorkommen in griechisch-Makedonien. Erzmetall. Bd XVII p. 9 - 18.
13. Maratos, G., (1972): Geology of Greece Vol. I Athens 189 p. (in Greek).
14. Maucher, A., (1962): Lagerstätten des Urans. Braunschweig. 162 p.
15. Meyrowits, R., (1973): Chemical analysis of rutile. Journ. Res. U.S. Geol. Surv. 1 p. 549-554.
16. Osswald, K., (1938): Geologische Geschichte von griechisch Nord - Macedonien. Athen.
17. Papadakis, A., (1969): The plutonite of Serae - Drama. Diss. Phys. Math. fac. Univ. Thessaloniki. 130 p. (in Greek).
18. Petrascheck, W. E., (1961): Lagerstättenlehre. Wien. 374 p.
19. Ramdohr, P., (1975): Die Erzmineralien und ihre Verwachsungen. Berlin. 1277 p.

20. Rust, G., (1935): Colloidal primary copper ores at Cornwall Mines, Missuri Journ. Geol. 43 p. 398-426.

21. Troeger, E., (1968): Optische Bestimmung der gesteinsbildenden Minerale. Stuttgart 822 p.

22. Uytenbogaardt, W. and Burke, E., (1971): Tables for microscopic identification of ore Minerals. Elsevier. 430 p.

ΠΕΡΙΛΗΨΙΣ

ΑΙ ΜΑΥΡΑΙ ΑΜΜΟΙ ΤΩΝ ΛΟΥΤΡΩΝ ΕΛΕΥΘΕΡΩΝ ΠΛΗΣΙΟΝ ΚΑΒΑΛΑΣ, ΕΛΛΑΣ

Ὑπὸ
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Εἰς τὴν ἀκτὴν τῶν Λουτρῶν Ἐλευθερῶν Καβάλας (Ἑλλὰς) καὶ ἐπὶ ἐκτάσεως τριῶν καὶ πλέον χιλιομέτρων ἐμφανίζονται συγκεντρώσεις βαρέων ὀρυκτῶν ἐντὸς τῶν ἄμμων ὑπὸ μορφὴν Black Sands. Οἱ σχηματισμοὶ αὐτοὶ εἶναι ἰσχυρῶς ραδιενεργοί. Δείγματα ἐξ αὐτῶν τῶν μαύρων ἄμμων ὑπεβλήθησαν εἰς διαχωρισμὸν ἐκ τῶν ἐλαφρῶν ὀρυκτῶν (χαλαζίας, ἄστριοι, ἀσβεστίτης, μαρμαρυγίας) καὶ ἐμελετήθησαν ὀπτικῶς εἰς τὸ μεταλλογραφικὸν μικροσκόπιον (στιλπναὶ τομαὶ) ὡς καὶ εἰς τὸ σύνηθες πολωτικὸν μικροσκόπιον (λεπταὶ τομαί). Συμπληρωματικὴ μελέτη ἔγινεν εἴς τινα ὀρυκτὰ διὰ τῶν ἀκτίνων Χ ὡς καὶ τοῦ μικροαναλυτοῦ. Ἡ μελέτη ἔδειξεν ὅτι ἐκ τῶν ἀδιαφανῶν βαρέων ὀρυκτῶν ἀπαντοῦν ὡς κύρια συστατικὰ τῶν μαύρων ἄμμων μαγνητίτης, γκαιτίτης, λεπιδοκροκίτης καὶ αἱματίτης. Εἰς μικρὰν περιεκτικότητα ἀπαντοῦν ἐπίσης ρουτίλιον, ἰλμενίτης, πυρολουσίτης, ψιλομέλας καὶ σποραδικῶς βολφραμίτης, κασσιτερίτης, οὐρανινίτης καὶ αὐτοφυὴς χρυσός. Ἐπίσης παρατηροῦνται σχηματισμοὶ σιδηροπυρίτου ὑπὸ μορφὴν Framboidal Pyrit καὶ εἰς σημαντικὴν ἀναλογίαν τεχνητὰ προϊόντα (Artifacts). Ταῦτα εἶναι ὑπολείμματα ἐκκαμινεύσεων ἐξ ἀρχαίων ἐκμεταλλεύσεων καὶ ὡς ἐπὶ τὸ πλεῖστον ἀποτελοῦνται ἀπὸ σκελετώδεις κρυστάλλους μαγνητίτου ἀναπτυσσομένους ἐντὸς πυριτικῆς ὑάλου (τεχνιτῆς). Ἐκ τῶν διαφανῶν βαρέων ὀρυκτῶν ἀπαντοῦν ὀρθίτης, ἐπίδοτον, γρανάται, κεροστίλβη (χαστιγξίτης), τιτανίτης καὶ σποραδικῶς ζιρκόνιον καὶ μοναζίτης.

Ἡ λεπτομερὴς ἔρευνα τῶν ὀπτικῶν καὶ λοιπῶν σταθερῶν τῶν ὡς ἄνω ὀρυκτῶν ἐπέτρεψεν τὴν διατύπωσιν ἀπόψεων ἐπὶ τῶν συνθηκῶν γενέσεώς των. Διατυποῦνται ἐπίσης ἀπόψεις καὶ διὰ τὴν προέλευσίν των δηλ. διὰ τὸ ποῖοι ἦσαν οἱ σχηματισμοὶ ἐκ τῶν ὁποίων ἀπεσπάσθησαν τὰ ὀρυκτὰ αὐτὰ καὶ ἐν συνεχεία μετεφέρθησαν εἰς τὰς ἄμμους. Οὕτω ὁ μαγνητίτης ἐσχηματίσθη κατὰ τὸ με-

γαλύτερον μέρος του πνευματολυτικῶς - μετασωματικῶς ἐξ ἐπαφῆς γρανιτικοῦ ὄγκου πρὸς ἀσβεστιτικὸν πέτρωμα. Οἱ κόκκοι γκαιτίτου - λεπιδοκροκίτου οἱ ὁποῖοι ἐμφανίζουν πάντοτε ρυθμικὰς ἐναλλαγὰς μεταξὺ τῶν δύο αὐτῶν ὀρυκτῶν ὑπὸ μορφὴν γελώδους ἱστοῦ, μὲ παρεμβολὴν ἐνίοτε μικρῶν κρυστάλλων πυρολουσίτου, ἐσχηματίσθησαν δευτερογενῶς ἐντὸς σιδηροῦ καλύμματος κοιτάσματος μικτῶν θειούχων (ἢ σιδηροπυρίτου). Ὁ αἱματίτης ἐμφανιζόμενος εἰς λαμέλλας μετὰ ἢ ἄνευ χαλαζίου ἐσχηματίσθη ὑδροθερμικῶς ἐντὸς φλεβῶν συνδεομένων γενετικῶς μετὰ τοῦ γρανίτου τοῦ ὄρους Σύμβολον. Τὰ ὀρυκτὰ βολφραμίτης καὶ κασσιτερίτης ἐσχηματίσθησαν ἐντὸς πηγματιτικῶν - πνευματολυτικῶν φλεβῶν συνδεομένων γενετικῶς ἐπίσης μετὰ τοῦ γρανίτου. Διὰ ὅλους τοὺς ἀνωτέρω σχηματισμοὺς προτείνεται συστηματικὴ μεταλλευτικὴ ἔρευνα τῆς εὐρυτέρας περιοχῆς τῶν μαύρων ἄμμων καὶ κυρίως τῆς πέριξ τῶν ὁρίων τοῦ γρανίτου τοῦ ὄρους Σύμβολον περιοχῆς.

Ὁ σποραδικῶς ἐμφανιζόμενος οὐρανινίτης προέρχεται ἐξ ὑδροθερμικῶν φλεβῶν συνδεομένων γενετικῶς μὲ τὸν γρανίτην. Ἡ πολὺ μικρὰ περιεκτικότης ὑπὸ τὴν ὁποίαν ἐμφανίζεται τὸ ὀρυκτὸν ἐντὸς τῶν μαύρων ἄμμων δὲν ἀποτελεῖ ἔνδειξιν ἐλλείψεως οἰκονομικῶς ἐκμεταλλευσίμων τοιούτων φλεβῶν. Οἱ ἴδιοι συλλογισμοὶ ἐφαρμόζονται καὶ ἐπὶ τοῦ σποραδικῶς ἐντὸς ὑδροθερμικοῦ χαλαζίου ἐμφανιζομένου χρυσοῦ. Ἡ ραδιενέργεια τῶν μαύρων ἄμμων ὀφείλεται πλὴν τοῦ σποραδικῶς καὶ εἴς τινα μόνον δείγματα ἀπαντῶντος οὐρανινίτου εἰς τὰ ὀρυκτὰ τιτανίτην, ρουτίλιον, ζιρκόνιον καὶ μοναζίτην τὰ ὁποῖα περικλείουν ραδιενεργὰ στοιχεῖα. Διατυποῦνται ἀπόψεις καὶ διὰ τὰς συνθήκας γενέσεως καὶ τὴν προέλευσιν τῶν διαφανῶν βαρέων ὀρυκτῶν.