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HYDROTHERMAL ALTERATION AND PORPHYRY COPPER TYPE MINERALIZATION IN THE SUBVOLCANIC ROCKS OF EASTERN CHALKIDIKI (GREECE)

by

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Abstract. *The porphyry copper deposits of eastern Chalkidiki are studied from alteration and ore mineralization of their host rocks point of view. All the hosts are subvolcanic rocks penetrating the metamorphic mass of the Serbomacedonian massif. The host rock of Skouries in the form of a vertical cylinder was initially a syenitic or dioritic porphyry and later converted to a granitic porphyry by silicification and by K-feldsparization in the case of dioritic porphyry. It's greater part has been subjected to an hydrothermal potassic alteration, while certain irregularly distributed parts of it show propylitic alteration in immediate vicinity with potassic. The ore mineralization in the form of stockwork veinlets and disseminations consists of pyrite, chalcopyrite, bornite and magnetite with average copper content 0,7%. Gold also occurs while molybdenum is completly missing. The hosts of the Dilofon-Fisoka-Alatina area are altered quartz porphyries in the form of stock. The greater part of them as well as the surrounding rocks have been subjected to an intense phyllic alteration, while certain irregularly distributed parts (found at greater depth) show propylitic alteration. The ore mineralization in the form of stockwork veinlets and partly disseminations consists of pyrite, chalcopyrite, galena and tetrahedrite with average copper content only 0,056%. Gold also occurs as well as molybdenum in traces. Relying on the above characteristics we classify the porphyry copper deposits of eastern Chalkidiki in two groups. To the first group belongs the Skouries deposit and is of the diorite porphyry copper model. To the second belongs the Dilofon-Fisoka-Alatina deposits of the Lowell and Guilbert porphyry copper model.*

INTRODUCTION

In the north-eastern part of Chalkidiki peninsula and especially in the area which is enclosed by the intelligible line joining the villages Stratonion-Stratoniki-Megali Panajia-Plana-Gomation-Stratonion, subvolcanic rocks occur and with some of them copper mineralization of the porphyry copper type is connected. The number of the designated occurences of subvolcanic rocks is up to now over the 60. They are varying from less than 10 m to more than 1 km in diameter. They appear mainly in the form of stocks, pipes and more seldom dykes, intruding in the metamorphic rocks of the area (gneisses, amphibolites), or penetrating them. All the subvolcanic occurrences are limited in a belt of 5-6 km wide within the above geographically defined area and are extended NE-SW. This area belongs to the recognised by *Kockel* and *Walther* (1965, 1968) Serbomacedonian massif, a prealpidic consolidated block which substantially constitutes the extension in the Greek part of tbe designated by *Arsovski* (1961) and *Dimitrijevic* (1963) with the same name zone in Yugoslavia. The common characteristic feature of all these subvolcanic occurrences, of which the petrologic type is varying from dioritic porphyry, quartz dioritic porphyry to granitic porphyry, is the perceptihle to intense hydrothermal alteration and the lack of any tectonic influence on them.

The exact age of subvolcanic rocks of eastern Chalkidiki is not known because of the lack of radiometric data on them. It is, however, possible to be defined indirectly by a geologic correlation with the known age of the Oligocene (29,6 million years) granodiorite of Stratoni (*Papadakis*, 1971). According to *Nicolaou* (1960) the ore mineralization (of pyrite and B.P.G. sulphide ores) of the known large ore of Madem Lakkos was caused by differentiated magmatic residual (aplite-metalliferous solutions) of the above granodiorite. According to the same investigator (as it is cited by *Gundlach et al* 1971) the aplite of Madem Lakkos is older than the dioritic porphyry which occurs in the area of the deposit. On the contrary *Neubauer* (1957, 1958) expresses opposite aspects i.e., the ore deposit of Madem Lakkos is of subvolcanic origin and that the accompaning aplite is older than the dioritic porpbyry. If we consider *Nicolaou's* aspect right we conclude that the subvolcanic rocks of eastern Chalkidiki are younger than Oligocene.

The cause of discovery, mapping and geochemical investigation for copper of the subvolcanic rocks in the area, was the study of Skouries ore deposit by *Zachos* (1963) within a rock characterized at that time as trachyte. This ore deposit was known in ancient times, as the huge masses of slugs indicate. It is also reported by *Neubauer* (1956); *Zachos*, however, has diagnosed it's economic importance and proposed research for disvovering other deposits in similar rocks in eastern Chalkidiki. It was later understood (*Gundlach et al* 1971) that the Skouries ore deposit belongs to the «porphyry copper» type copper depobiotite (probably partly chloritized) sericite and minor anhydrite. This zone is surrounded by the phyllic zone involving chlorite, sericite and quartz; the argillic zone follows with quartz, chlorite, kaolin and clay minerals and finally the propylitic zone with an assemblage including chlorite, epidote, calcite and quartz as well as small quantities of sericite or other minerals. The copper ore deposit indeed i.e., the area with 0,1-3% copper in grade developed in the form of a hollow cylinder i.e., nearly a pipe at the boundaries of the potassic and phyllic zone. The ore deposit is surrounded by a rich in pyrite zone (often more than 10% FeS_2) wholly enclosed in the phyllic alteration zone. The form of this zone or shell of pyrite is an open below and close above hollow cylinder. Beyond the shell of pyrite and within the propylitic alteration zone appear, except the rare pyrite, minor galena and sphalerite.

Later on the same investigators accepted (*Guilbert* and *Lowell* 1974) that this exemplary model cannot hold for all the porphyry copper deposits. Inclinations from the model may be due as well to differences in the chemism of the wall rock as the host rock, differences in the shape and size of the host as to other reasons. Lowell and Guilbert model has substantially application in calc-alkaline hosts of dioritic to quartz monzonitic composition (*Hollister* 1975). In the cases of hosts of other composition (syenite, diorite, quartz diorite and the corresponding porphyries) the term «island-arc model» was proposed by *Portacio* (1974) for the corresponding ore deposits. *Sutherland Brown* (1974) suggested the term «syenite model» while *Hollister* et al (1974) the term «diorite model». Given that inclinations from Lowell and Guilbert model are also observed in areas of island arcs and on the other hand in areas of Canada, in which *Sutherland Brown* has studied the inclinations, diorites and monzonites predominate, the term «diorite model» seems preferable for the porphyry copper deposits in more basic hosts, with clear differences from the Lowell and Guilbert model. The main differences as regards the alteration zones are that the diorite model has the potassic zone well developed with predominating minerals K-feldspar and biotite and/or chlorite, while phyllic and argillic zone may be entirely absent. They are also poor in molybdenum and certain appreciable quantity of gold. Finally, except pyrite, magnetite usually occurs.

For the certain case of Chalkidiki porphyry copper deposits *Kockel et al* (1975) report that as well these ore deposits as those of the rest Serbomacedonian massif of Greece present only phyllic and propylitic alteration with phyllic zone predominating in the most part. They base sits, which extensively occur in South America (*Lamey* 1966) and somewhere else, and they constitutc today the principal source of metallic copper. The mapping as well as the petrologic and mainly the geochemical research of the subvolcanic rocks and some plutonic rocks of the area has been operated by the institute of geological and mining research at that time (ΙΓΕΥ, later ΕΘΙΓΜΕ today ΙΓΜΕ) in cooperation with the Germany institute of soil research (Hannober W. Germany). Mining research with drillings has followed, in areas with increased geochemical anomaly of copper i.e., in Skouries, Dilofon, Alatina and Fisoka. At Skouries a number of drillings has been carried out by a Japanese company and subsequently by the French company Pechine and in the other areas by the Greek mining company (ΓΕΜΕΕ).

The results untill the year 1975 as well as the theoretical views about the hydrothermal alteration of subvolcanic rocks of the Serbomacedonian massif of Greece, which is connected with the porphyry copper mineralization, are reported by *Kockel et al* (1975). The differences between our observation and these ones which are reported by the above investigators, in combination with the newer aspects about porphyry copper deposits have urged us to study the above ore deposits of Chalkidiki. The topic of our research has been the ore deposit of Skouries and the occurrences of Dilofon, Fisoka, Alatina i.e., the areas of subvolcanic rocks which present mineralization of the porphyry copper type, independently of economic value. For this purpose we have used superficial material which we have collected, as well as drill cores and data of chemical analyses which had been operated by the above companies.

HYDROTHERMAL ALTERATION AND PORPHYRY COPPER MINERALIZATION

The existence of hydrothermal alteration of the host rock and often of the wall rocks of porphyry copper deposits is known long ago *Bateman* (1950). The first systematic study of the phenomenon in 27 of the principal porphyry copper deposits in North and South America was carried out by *Lowell* and *Guilbert* (1970). They came to the conclusion that the local porphyry copper (and molybdenum) deposit is genetically related with a subvolcanic to plutonic rock of posterior geological age in which the ore mineralization has caused four discernible concentric zones of alteration. The alteration zones are called the innermost as potassic with an assemblage including quartz, K-feldspar, this conclusion on the observation of the phyllic zone assemblage (quartz, sericite, hydromica, pyrite, chalcopyrite) and the appearance of the characteristic net of stockwork veinlets, filled with limonite, evidently primarily with pyrite. According to the above investigators the less developed propylitic zone is limited at the peripheral parts of the hosts with an assemblage including quartz, kaolin and/or montmorillonite, chlorite, epidote, carbonates, pyrite, galena and sphalerite. They emphasize characteristically that in no case potassic alteration has been observed.

ALTERATION ZONES AND ORE MINERALIZATION IN SKOURIES DEPOSIT

The Skouries deposit is the only one studied which has economic importance. It is first mentioned by *Neubauer* (1956) as a trachytic lens which has peripherally pyritized and in the centre impregrated by oxidised copper ore, of unknown original composition. *Zachos* (1963) has considered again the host rock as trachyte intensily altered and silicified. He also studies the ore mineralization from data of four drillings, from which two were operated outside the outcrop of the host to recognise any dilatation of it with depth, and two drillings of 76 and 303 metres in depth respectively inside the host. Except the oxidation zone and the enrichmen zone, in the most part excavated by the ancients, he infers that the ore mineralization of chalcopyrite, pyrite, bornite and minor magnetite amounts 0,5% Cu from the depth 100 to 215 m and 1% from the depth 215 to 303 m with relatively high gold content. He characterizes the type of ore mineralization exclusively as stockwork veinlets. *Gundlach et al* (1971) consider the host as a quartz dioritic porphyry in the form of an elliptical upright cylinder 120 by 140 metres in dimensions, with average copper content 0,7‰. As regards the alteration, they eite an intense silicification and a sporadic sericitization of both, decreasing with depth. *Papadakis* (1975), after he had studied the host, came to the conclusion that with it's intense silicification and K-feldsparization it has the composition of a granitic porphyry and this came true by chemical analyses. The primary fresh rock of the subvolcanic intrusion ought to be a syenitic and/or dioritic porphyry.

In order to study the distribution of alteration zones and the type of ore mineralization in the present work, we used superficial material which was collected in regular distances every 10 metres, on two perpendicular axes cut in the centre of the occurrence, as well as drill core samples,which have been taken every 20 m, from two drillings arrived to a depth of 420 and 580 m respectively. From the thin sections we have made, results that the greater part of the rock shows uniform alteration independent of depth and distance from the central axis. Veinlets of quartz have brought K-feldspar either as microcline (Fig. 1) or as orthoclase. They have also brought biotite (Fig. 2, 3). Sometimes secondary biotite appears at the boundaries of secondary K-feldspar (Fig. 4, 5). All the mafic components of the primary fresh (unaltered) rock i.e, augite and hornblende and partly primary biotite have been altered to secondary biotite (Fig. 6, 7). This phenomenon is more intense near the veinlets of quartz (Fig. 7) so that to infer a genetic relation i.e., the carrying of the indispensable solutions for the alteration through the veinlets. Sometimes the plagioclases have been subjected to biotitization either along their cleavage planes, or selectively inside a certain zone of them the central, peripheral or intermediate, a phenomenon described in details in a previous work (*Papadakis* 1975). There is often a dispersed biotitization of the bulk of the host (Fig. 8) with a dispersed ore mineralization. Secondary kaolinization and sericitization of feldspars is also observed in a very limited degree, so that the classification of these samples in the phyllic or argillic alteration zone is not justified. Chloritization of primary biotite sporadically appears. Very characteristic, although rare, is the presence of anhydrite (Fig. 9, 10) which is easily distinguished grace to the oblique after (101) multitwinning of it (Fig. 11). This secondary anhydrite is also connected with quartz veinlets. It is concluded from the above phenomena, that unquestionably the bulk of the host as well as the greater part of its outcrop have subjected potassic alteration, independetly of depth and distance from the central axis. *Gundlach et al* (1970), mentioning the alteration of Chalkidiki subvolcanic rocks exclude the existence of a potassic zone, relying on the absence of anhydrite in the samples which they have studied. In spite of the fact that we have indicated the mineral, as we have mentioned above, we must emphasize that the main characteristic features of the potassic zone are the secondary K-feldsparization and principally the biotitization of the host (*Lowell* and *Guilbert* (1970), *Guilbert* and *Lowell* (1974), *Hollister* (1975). These phenomena are very extensive and perceptive in Skouries deposit at once.

Except the widely spreaded potassic zone, they were observed and isolated samples which showed characteristic features of the propylitic alteration zone. In these samples the mafic minerals have been

Fig. 1. A veinlet of quartz (Q) with microcline (M). Skouries Thin section. Crossed nicols, 41X.

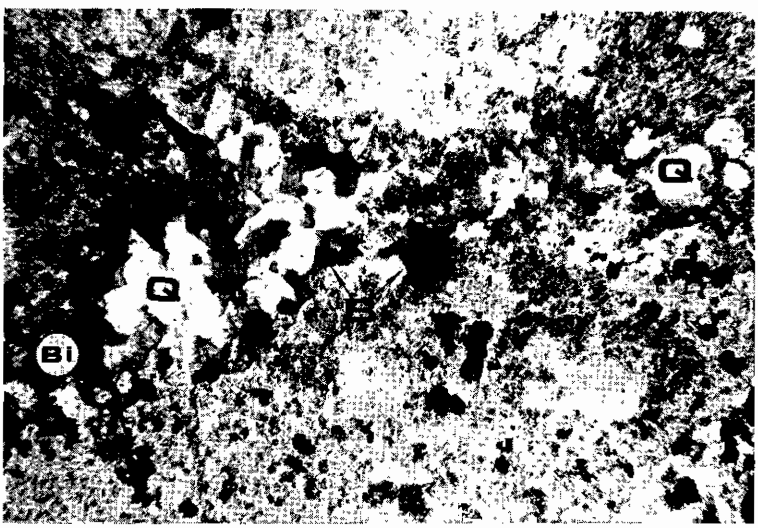

Fig. 2. A veinlet of quartz (Q) and biotite (Bi) crosscutting the host. Skouries. Thin section. One nicol, 41X.

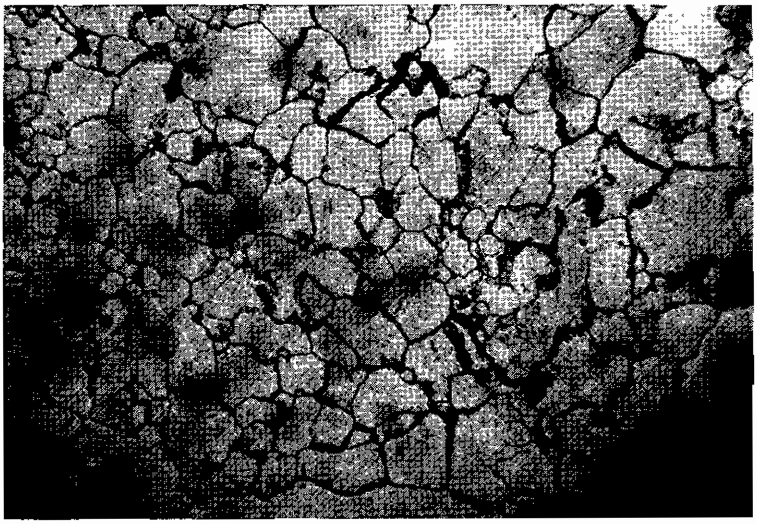

Fig. 3. A quartz veinlet occupying the whole optic field. At the grain boundaries of quartz, biotite is distinguished. Skouries. Thin section. One nicol, 119X.

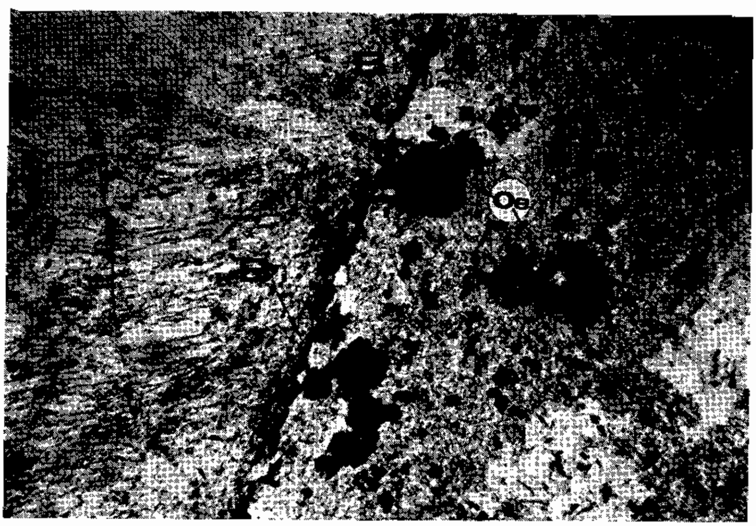

Fig. 4. Biotite (Bi) develops at the boundaries of secondary K-feldspar (left) and host rock. Close to it disseminated ore mineralization (Oe). Skouries. Thin section. One nicol, 41X.

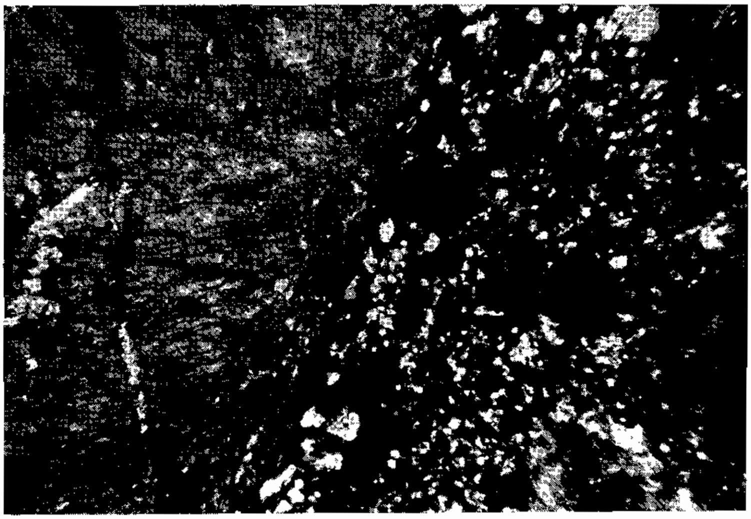

Fig. 5. The same as in fig. 4 under crossed Nicols. A large crystal of secondary K-feldspar and the matrix on the right are distinguished.

Fig. 6. A primary hornblende crystal, with the characteristic shape, which has been converted to an aggregate of biotite crystals and minor quartz in the center. Skouries. Thin section. One nicol, 119X.

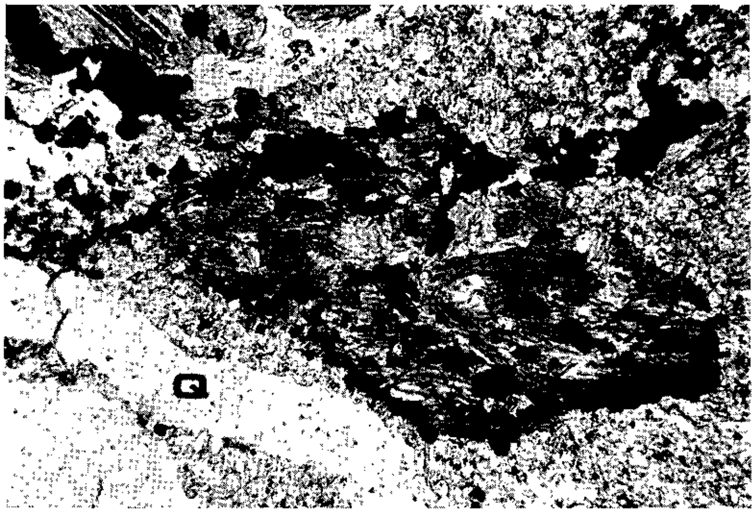

Fig. 7. A primary hornblende crystal, which has been converted to an aggregate of biotite crystals. At the boundaries of the primary hornblende ore mineralization (black). Down on the left a quartz (Q) veinlet is visible. Skouries. Thin section. One nicol, 41X.

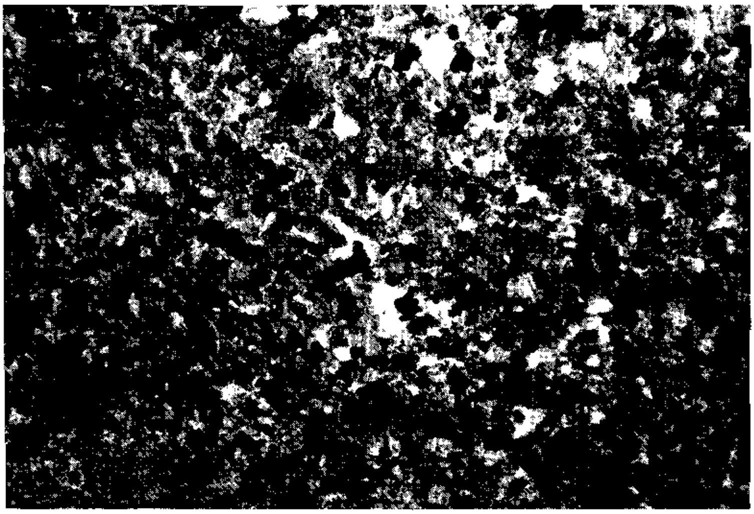

Fig. 8. Disseminated biotitization in the host matrix. Disseminated ore (small black grains) is also distinguished. Skouries. Thin section. One nicol, 41X.

Fig. 9. A primary hornblende crystal which has been converted to a biotite aggregate. In the center of the crystal quartz and anhydrite which only in fig. 11 is clearly distinguished. Skouries. Thin section. One nicol, 41X.

Fig. 10. The same as in fig. 9 but under 119X magnification. Bi=biotite, Q=quartz, Anh=anhydrite (a clear distinction in fig. 11).

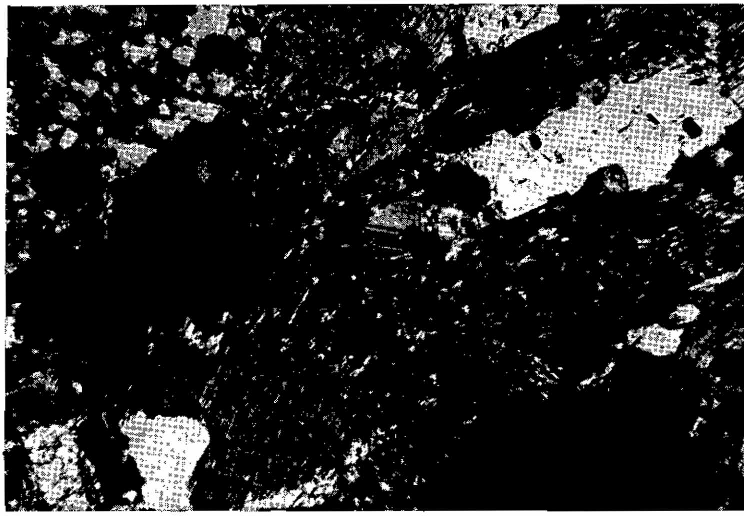

Fig. 11. The same as in fig. 10 under crossed nicols. Anhydrite ***with it is*** *characteristic twinning after (101) is distinguished.*

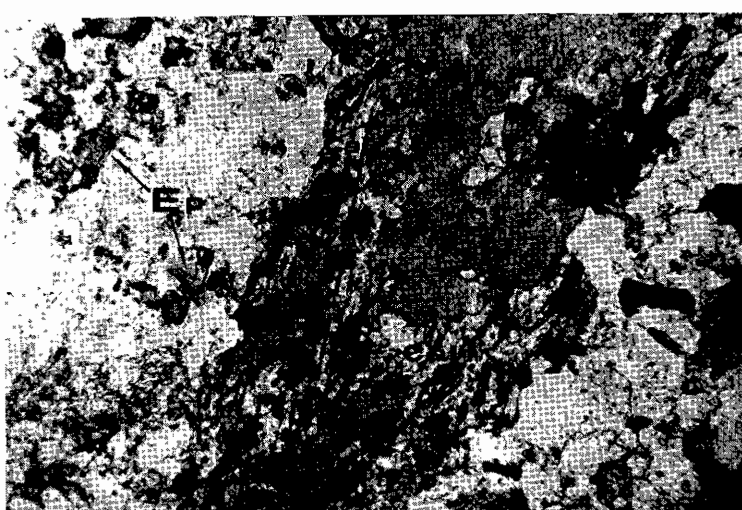

Fig. 12. Propylitic alteration. Cl=chlorite, Cal=calcite, Ep=epidote. Skouries. Thin section. One nicol 119X.

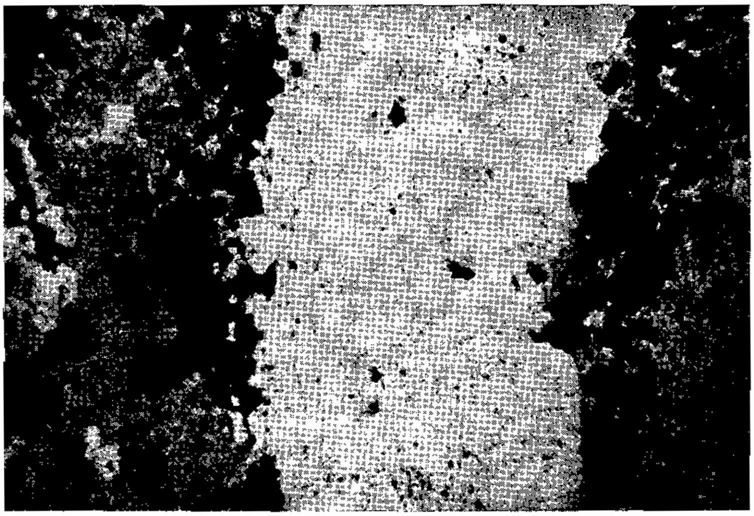

Fig. 13. A quartz veinlet crosscutting the host with also ore deposition (black) at the margins and impregnations in some distance. Skouries. Thin section. One nicol, 41X.

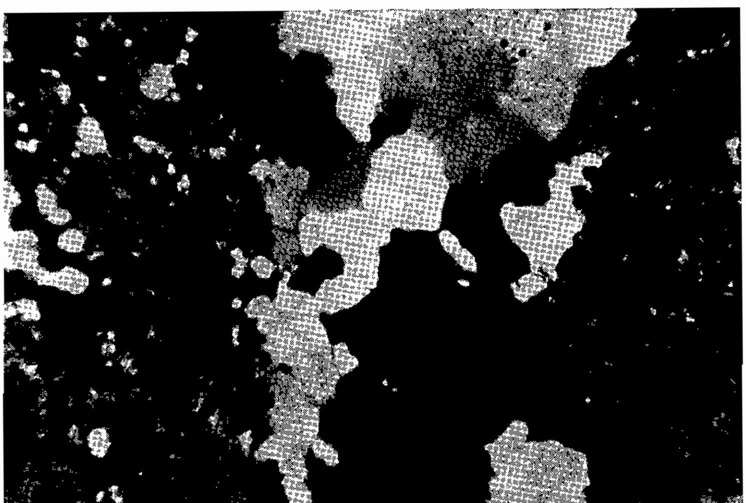

Fig. 14. The same as in fig 13 under crossed nicols.

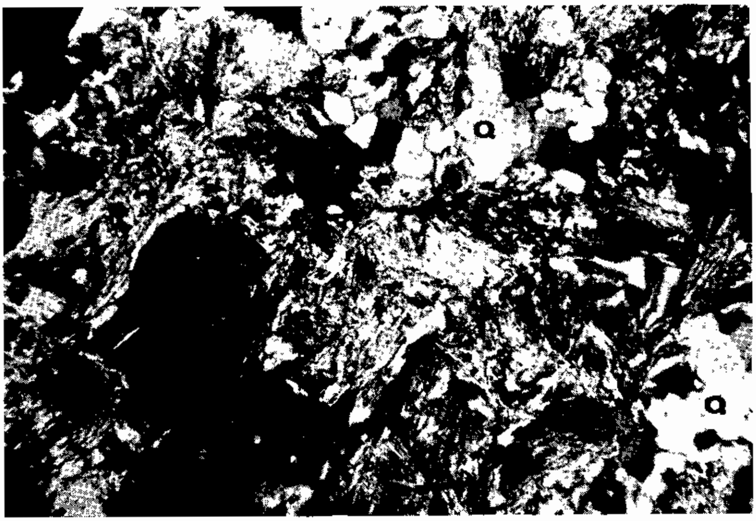

Fig. 15. Phyllic alteraction. Large sericite crystals arranged in a radiated form and quartz (Q). The primary structure is not distinguished. Fisoka. Thin section. Crossed nicols, 41X.

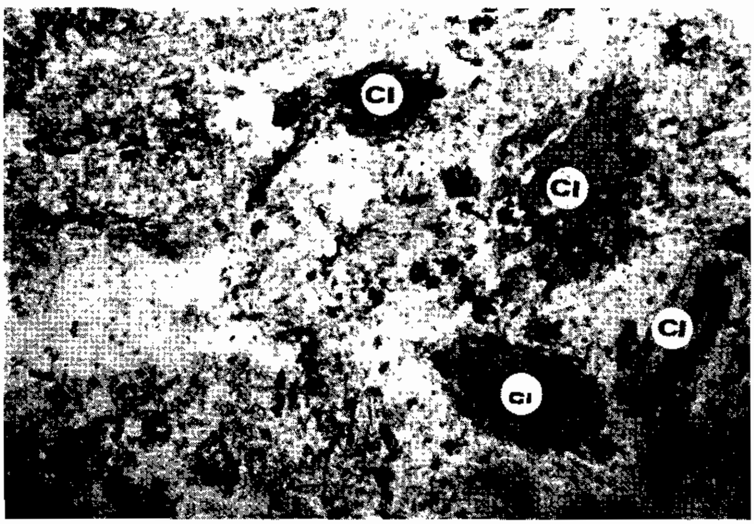

Fig. 16. Phyllic alteration. The mafic minerals are chloritized (Cl) and feldspars with the matrix sericitized. The primary structure of the host is discernible. Fisoka. Thin section. One nicol, 41X.

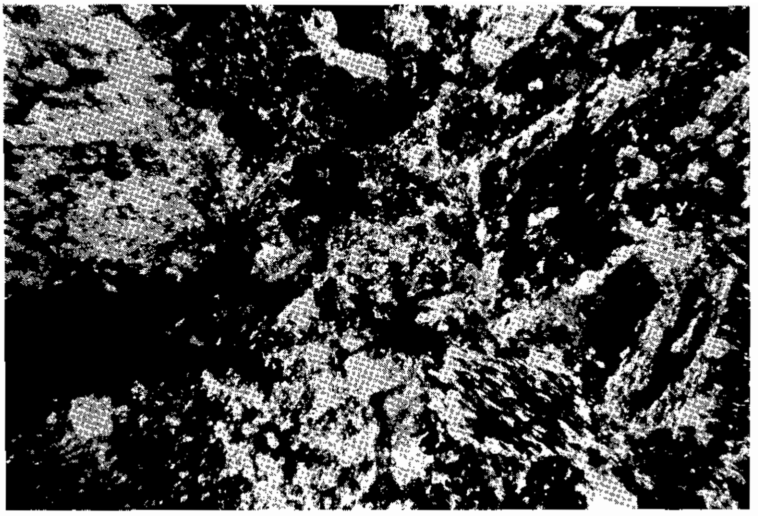

*Fig. 17. The same as in fig. 16 under crossed nicols.
Sericitization is better distinguished.*

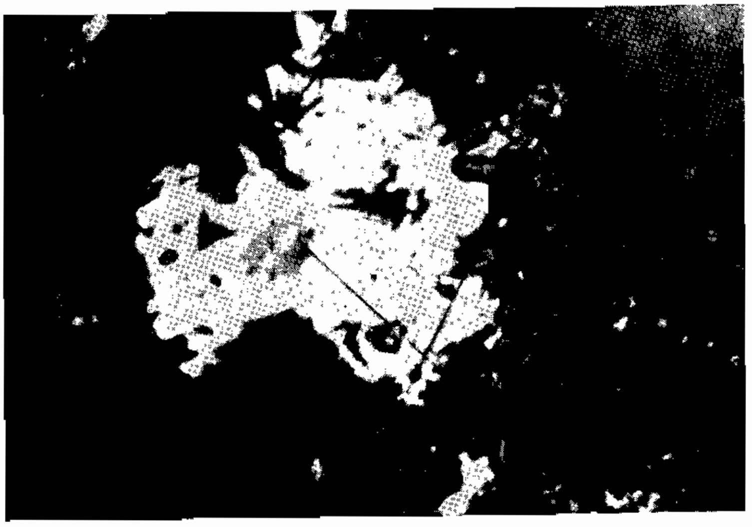

*Fig. 18. A chalcopyrite crystal in the host with phyllic alteration. Fisoka.
Polished section. One nicol 71X.*

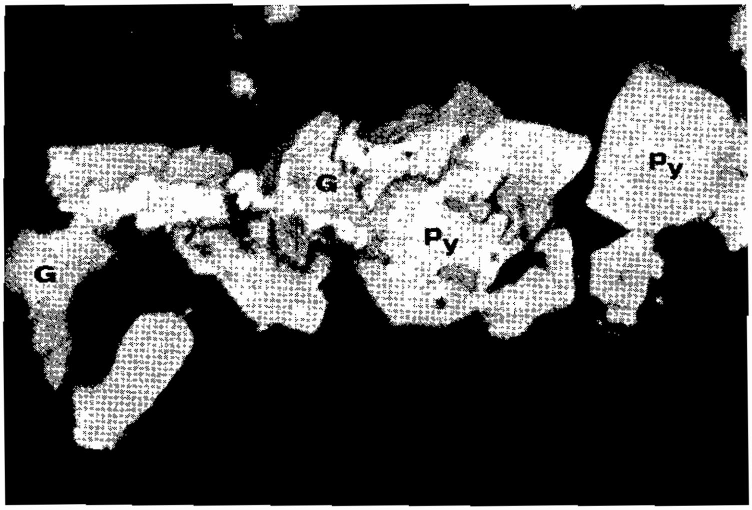

Fig. 19. A veinlet of pyrite (Py) and galena (G) crosscutting the host with phyllic alteration. Fisoka. Polished section. One nicol, 71X.

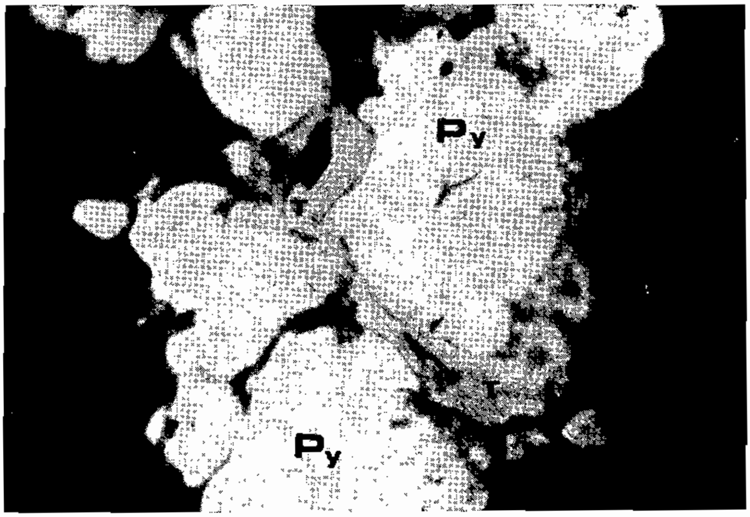

Fig. 20. A veinlet of pyrite (Py) and tetrahedrite (T) in a host with phyllic alteration. Fisoka. Polished section. One nicol, 137X.

Fig. 21. Propylitic alteration Cl= chlorite, Cal=calcite, Ep= epidote. Fisoka. Thin section. One nicol, 41X.

altered to chlorite, epidote and calcite (Fig. 12) while the plagioclases to sericite, epidote and sporadically to calcite. In order to estimate the meaning of the limited alteration of plagioclases to calcite, we must have in mind that these were acid with 18% An content in the primary fresh rock (*Papadakis* 1975). An endeavor to distribute in space the samples, in features of propylitic alteration, showed that there is not a clear and regular propylitic zone surrounding the potassic. So, in the same borehole, under a sample with potassic alteration it is found a sample with propylitic and in continuation the following sample shows potassic alteration again. This can be explained either by accepting that the ore deposit at that point is of less horizontal dimensions, or that there is no regularity in the distribution of propylitic zone which as we have mentioned, appears only in some samples. At any rate, we must emphasize that *Guilbert* and *Lowell* (1974) accept, the porphyry copper deposits of small dimensions show inclinations from the regular distribution of alteration zones. The Skouries deposit in comparison with the known porphyry copper deposits of America, can be characterized as a dwarf from horizontal dimensions view (130 metres average horizontal dimension against 1-2 kilometres of the Americans). We must consequently expect a telescoping and mixing of the appearing alteration zones in a deposit of so small horizontal dimensions.

Another reason for the lack of regularity in the distribution of propylitic zone, is that the ore mineralization and hydrothermal alteration have been caused by solutions, which in Skouries deposit have ascended through the net of stockwork veinlets, because of a preceding fracturing of the host which was not of course necessarily uniform. The result is that the distribution of the ore content does not also show the known regularity after the Lowell and Guilbert model.

As regards the ore mineralization, which outside the oxidation and enrichment zone consists of pyrite, chalcopyrite sometimes bornite and magnetite, it does not appear only in the form of stockwork veinlet fillings, as mentioned by *Zachos* (1963), but it also advances to impregnations in the host (Fig. 4, 8, 13, 14) at any rate in areas near the veinlets. Sometimes it advances till sulphide alteration of hornblende (Fig. 7). Finally magnetite usually appears disseminated in the host rock and probably consists its primary magnetite. An endeavor to distribute also the ore mineralization in zones or shells of chalcopyrite and surrounding pyrite, according to the Lowell and Guilbert model, showed that there is not such a regularity. This has been mentioned and explained in the preceding paragraph. The only one regularity we have observed is the relation of ore mineralization with the phenomenon of secondary biotitization. The rich in biotite areas (or/and later chloritized or discolored by the action of solutions) are also rich in ore. This is in accordance with *Schwartz* (1947), *Stringham* (1953), *Lowell* (1968), *Nielsen* (1968), *Macnamara* (1968), *Bryner* (1969), *Rose* (1970) and *Moore* and *Lanphere* (1971) observations. As it resulfs from the chemical analyses it is characteristic for the deposit the increased gold content (3-5 gr/ton) and the lack of molybdenum even in traces.

ALTERATION ZONES AND ORE MINERALIZATION IN DILOFON - FISOKA - ALATINA AREA

The ore mineralization in this area was unknown before and was discovered after the geochemical research which had been operated by ΙΓΕΥ in cooperation with the Germany institute of soil. *Gundlach et al* (1974) characterise the hosts as altered quartz dioritic porphyries in the form of stock with also occurrence of volcanic Brekzies at Dilofon. According to the above investigators the phyllic alteration prevails. The followed three drillings, from which two have been made at the centre of geochemical anomalies and the other peripherally of them, prooved a sulphide mineralization mainly in the form of veinlets but also in disseminated form. The ore consists of pyrite with minor chalcopyrite and chalcocite, while peripherally galena and sphalerite predominate. The total copper content is of the order of 0,1% with considerable gold content (*Kockel et al* 1975).

For the study of hydrothermal alteration of the hosts and ore mineralization in the area we used drill cores which had been taken every 10m, from three drillings 145, 170 and 300 m in depth respectively, as well as the data of the chemical analyses of the samples. The study of the thin sections showed that the number one borehole, 145 m in depth at Dilofon, had been totally operated in the adjacent metamorphic rock, while the other two in Fisoka area had bored the altered host. From the microscopic study of thin sections results that the host as well as the adjacent rock present intense hydrothermal alteration. In many samples of the host the alteration is so intense that neither the primary mineralogical composition of the fresh rock nor its structure is distinguished (fig. 15). In samples with relatively mild alteration the characteristic structure of subvolcanic porphyries is distinguished (fig. 16, 17). The complete alteration of feldspars in all samples of the rock makes the definition of the rock type difficult. We can, however, state with a great probability, that the hosts of the ore deposits of Dilofon-Fisoka-Alatina area belong to the quartz dioritic porphyry type. This is in agreement with *Gundlach et al* (1971) observations.

The greater number of the studied thin sections of the altered rock as well as the adjacent rock show a constant and uniform mineralogical composition. It consists of a large quantity of sericite either in small or large radiated foliated crystals in the form of a gland (fig. 15) quartz, chlorite (fig. 16, 17), muscovite or discolored biotite, and veinlets or impregnations of pyrite with minor chalcopyrite (fig. 18). At the marginal parts of the occurrences the ore changes to veinlets of pyrite and galena (fig 19) and tetrahedrite (fig. 20). Such a mineralogical composition shows that the bulk of the hosts as well as the adjacent rock have been subjected to a phyllic alteration.

A small number of samples, at the lower part of number three drilling and at a depth of 250-300 m, shows inclinations from the above. Here, chlorite epidote and calcite (fig. 21) predominate while sericite appears in considerably smaller quantities. The lower part of the investigated by drillings Fisoka host, has been consequently subjected to propylitic alteration. Given that all the Chalkidiki subvolcanic rocks, without exception, appear tectonically unaffected, it is excluded that this lower part has formerly constituted the superior part of the host rock as it happens at Kalamazoo (*Lowell* and *Guilbert* 1970). The question is this «which of the following quoted explanations must be consider right?» «Is it about a diminishing of the dimensions (narrowing) of the subvolcanic rock at that point or an irregular distribution of zones as we accepted for Skouries deposit, or besides a dyke and not a stock wbich terminates below after the propylitic alteration zone?» In none of these questions we can answer with certainty. But given that the mining research by drilling continues we hope to find in the future more elements about the shape and the dimensions of the host and mainly if there is or no a potassic zone under the phyllic. The fact is that from the up to now data in the Dilofon-Fisoka-Alatina area they are observed only phyllic and propylitic alteration zones with the first predominating.

From the data of chemical analyses which have heen made at the laboratory of ETBA, results the following average content of the unenriched ore:

Cu=558p.p.m or 0,056%Pb=559p.p.m or 0,056%Zn=228p.p. m or0,023%
Fe=3,60% and Mo=3p.p.m

From these metals, except Mo in traces, on one hand copper and lead have been observed in the polished sections as chalcopyrite and galena respectively, while the greater part of iron must be attributed to the sufficiently spreaded pyrite. Given that, we have indicated sphalerite in none polished section, it results that the small quantity of zinc must slip in the observed tetrahedrite. The copper content of 0,056% is very low and considerably far from the stated by *Kockel et al* for the district limit of 0,1%. It is probable the operated drillings bored only a peripheral part of a larger deposit, lying at depth, because only phyllic and partly propylitic alteration is observed as well as a considerable pyrite content, or it is about a very poor porphyry copper deposit.

CONCLUSIONS

The porphyry copper deposits of Eastern Chalkidiki belong to two discernible categories from alteration and ore mineralization of their hosts, point of view. The category of Skouries and the category of the group Dilofon-Fisoka-Alatina. The principal characteristics of each category on which we depent to classify them in models of porphyry copper deposits after *Hollister* (1975) are the following:

Skouries

1) Primary fresh (unaltered) rock a syenitic or dioritic porphyry.

2) Existence of a very extensive potassic alteration zone

3) Complete lack of phyllic and argillic zone

4) Immediate vicinity of propylitic and potassic zone (although there is not regularity in the distribution of propylitic)

5) Appreciable gold content

6) Complete absence of molybdenum

7) Existence of bornite in the ore

8) Existence of magnetite in the ore

All the eight above mentioned properties constitute the more significant characteristics of the diorite model porphyry copper deposit after *Hollister*. The only exception appears in the irregular distribution of propylitic zone which we explained before. Consequently we classify the Skouries deposit undoubtly in the diorite model.

Dilofon-Fisoka-Alatina

1) Primary fresh rock a quartz dioritic porphyry

2) Existence of a very extensive phyllic alteration zone

3) Complete lack of potassic and argillic zone (unless the potassic develops deeper)

4) Appreciable gold content

5) Existence of molybdenum in traces

6) Bornite is missing from the ore

7) Magnetite is missing from the ore

The six from the above mentioned seven properties (except number 4), constitute the more significant characteristics of the Lowell and Guilbert model porphyry copper deposit after *Hollister*. The discovery by chance of potassic zone at a greater depth does not change the characteristics because the potassic zone is not necessarily absent from the Lowell and Guilbert model. Consequently we classify the deposit of the group Dilofon-Fisoka-Alatina in the Lowell and Guilbert model.

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ΠΕΡΙΛΗΨΙΣ

ΥΔΡΟΘΕΡΜΙΚΗ ΕΞΑΛΛΟΙΩΣΙΣ ΚΑΙ ΜΕΤΑΛΛΟΦΟΡΙΑ ΤΥΠΟΥ ΠΟΡΦΥΡΙΤΙΚΩΝ ΧΑΛΚΩΝ, ΕΙΣ ΤΑ ΥΠΟΗΦΑΙΣΤΙΑΚΑ ΠΕΤΡΩΜΑΤΑ ΤΗΣ Α. ΧΑΛΚΙΔΙΚΗΣ (ΕΛΛΑΣ)

ΥΠΟ

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Μελετῶνται τὰ κοιτάσματα πορφυριτικῶν χαλκῶν τῆς 'Ανατολικῆς Χαλκιδικῆς ἀπὸ ἀπόψεως ὑδροθερμικῆς ἐξαλλοιώσεως τῶν μητρικῶν τῶν πετρωμάτων καὶ μεταλλοφορίας. Ἅπαντα τὰ μητρικὰ πετρώματα εἶναι ὑποηφαιστῖται διαπερῶντες τὴν μεταμορφωμένην μάζαν τῆς Σερβομακεδονικῆς ζώνης. Τὸ μητρικὸν πέτρωμα τῶν Σκουριῶν, μὲ μορφὴν κατακορύφου κυλίνδρου, ἦτο ἀρχικῶς συηνιτικὸς ἢ διοριτικὸς πορφύρης μετατραπεὶς ἀργότερον, λόγω πυριτιώσεως (καὶ καλιοαστριώσεως εἰς τὴν περίπτωσιν διοριτικοῦ πορφύρου) εἰς γρανιτικὸν πορφύρην. Τὸ μεγαλύτερον τμῆμα του ἔχει ὑποστῆ ποτασσικὴν ὑδροθερμικὴν ἐξαλλοίωσιν, ἐνῶ ὡρισμένα τμήματά του, ἀνωμάλως κατανεμημένα ἐμφανίζουν προπυλιτικὴν ἐξαλλοίωσιν εἰς ἄμεσον γειτονίαν πρὸς τὴν ποτασσικήν. Ἡ μεταλλοφορία ὑπὸ μορφὴν stockwerk φλεβιδίων καὶ διάσπαρτον τοιαύτην ἀποτελεῖται ἀπὸ σιδηροπυρίτην, χαλκοπυρίτην, βορνίτην καὶ μαγνητίτην μὲ μέσην σύστασιν 0,7% Cu. 'Απαντᾶται καὶ χρυσὸς 3-5 gr/t ἐνῶ τὸ μολυβδαίνιον ἀπουσιάζει παντελῶς. Τὰ μητρικὰ πετρώματα τῆς περιοχῆς Δίλοφον-Φισώκα-'Αλατίνα ὑπὸ μορφὴν stock εἶναι ἐξαλλοιωμένοι χαλαζιακοδιοριτικοὶ πορφῦραι. Τὸ μεγαλύτερον τμῆμα των ὡς καὶ τὰ περιβάλλοντα πετρώματα ἔχουν ὑποστῆ ἔντονον φυλλιτικὴν ἐξαλλοίωσιν, ἐνῶ ὡρισμένα τμήματα ἀνωμάλως κατανεμημένα (βαθύτερον εὑρισκόμενα) ἐμφανίζουν προπυλιτικὴν ἐξαλλοίωσιν. Ἡ μεταλλοφορία ὑπὸ μορφὴν stockwerk φλεβιδίων καὶ ἐν μέρει διάσπαρτος ἀποτελεῖται ἀπὸ σιδηροπυρίτην, χαλκοπυρίτην, γαληνίτην καὶ τετραεδρίτην μὲ μέσην σύστασιν μόνον 0,056% Cu. 'Απαντᾶται καὶ χρυσὸς ὡς καὶ ἴχνη μολυβδαινίου. Βάσει τῶν ἀνωτέρω χαρακτηριστικῶν κατατάσσομεν τὰ κοιτάσματα πορφυριτικῶν χαλκῶν τῆς Α. Χαλκιδικῆς εἰς δύο ὁμάδας. Εἰς τὴν πρώτην περιλαμβάνεται τὸ κοίτασμα τῶν Σκουριῶν καὶ ἀνήκει εἰς τὸ διοριτικὸν πρότυπον πορφυριτικῶν χαλκῶν. Εἰς τὴν δευτέραν ὁμάδα περιλαμβάνονται τὰ κοιτάσματα Δίλοφον - Φυσώκα - 'Αλατίνα τὰ ὁποῖα ἀνήκουν εἰς τὸ πρότυπον *Lowell* and *Guilbert* πορφυριτικῶν χαλκῶν.