OPHIOLITE AND RELATED COPPER DEPOSITS OF THE ERGANİ MINING DISTRICT, SOUTHEASTERN TURKEY

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1. INTRODUCTION

The Ergani mine, Southeastern Turkey, is well-known for its cupriferous pyrite ore deposits associated with ophiolite, but the reserve is on the decrease recently. Following the proposal of Mineral Research and Exploration Institute of Turkey (M.T.A.), the present author engaged in the geological work during two years since 1971 as a project manager of «Regional Research for the Subsurface Copper Deposits in the Ergani Mining District». The area of 200 km^2, mostly occupied by alpine ophiolite including several copper deposits, Kısabekir, Mızırtepe, Anayatak, Weiss and Hacan, has been a target for this investigation.

This mining district is situated near Maden town, about midway between Diyarbakır and Elazığ (Fig. 1). This area is connected by a railroad constructed in 1935 and a good hard surfaced highway. Daily flight is also available from Ankara to Diyarbakır.

The Anayatak deposft was one of the centers of the most ancient copper mining. According to some authors the Anayatak deposit has been known since 2000 B.C. The modern era of copper production at Ergani mine began in 1939 when Etibank, a state mining organization, started exploiting the ore. From this date onwards until 1968, 6.1 million metric tons of massive sulphide ores with the average grade 6.5 % Cu, were mined from the Anayatak and some other deposits in the vicinity. Recently around 10,000 metric tons of refined copper (99 % Cu) have been produced annually.

Pilz (1917) and Behrend (1925) studied the geology of the area and they made valuable petrographic descriptions of various rocks in the Ergani mining district. Based on their investigations, Romieux (1941) and Wijkerslooth (1944) concluded that the Anayatak deposit is of «mesothermal chlorite copper type». Sirel (1949) proposed that the Anayatak deposit may be of a syngenetic sedimentary origin. His work was based on the microscopic investigation. Borchert (1957) explained the genesis of the Anayatak deposit as a volcanic exhalative origin, while Helke (1964) considered that the main part of the copper deposit was formed by ascending hydrothermal solution and some special ore minerals such as malachite and azurite were finally formed as supergene alteration. Çağatay (1968) confirmed the Helke's (1964) view based on the discovery of chromite in massive sulphide ores from the Weiss open pit, and Griffits *et al.* (1972) advanced the theory that the sulphide ore in the Anayatak was caused by replacement.

The Ergani ophiolite associated with the deposits was studied petrographically as well as chemically by the present author in order to find the way for the exploration of the copper ore deposits. Thus the result obtained will be reported, then the copper mineralization will be described in this paper.

2. GEOLOGIC SETTING

Anatolian peninsula is geotectonically divided into four units, i. e., they are Pontids, Anatolids, Taurids and Border folds from the north (Ketin 1966). According to Ketin (1966) it is believed that the erogenic evolution of Anatolia proceeded from the north to the south. The first effective erogenic movements began in the northern ranges, then passed to the Central Anatolia, afterwards to the Taurids belt and finally to the southeastern Border folds region.

The Ergani mining district, Southeastern Anatolia, belongs to the Taurids ophiolite belt wich have been believed to be formed during the Alpine orogeny. Permian limestone is thrust over this ophiolite formation in northeastern side of this area, and the formation, in turn, is thrust over the Border folds consisting of Neogene Tertiary sedimentary rocks. Thus two nappes showing imbricated structures are formed.

This area is composed principally of thick Upper Cretaceous mudstone intercalated with thin layers of sedimentary rocks such as sandstone, chert and limestone. In this formation, pillow-lava and a kind of green rocks composed mainly of pyroclastic materials predominate. Thin chert layers or thin ferruginous quartz layers associated with bedded manganiferous hematite deposits occur in the pillow lava or along the boundary between pillow lava and mudstone.

Ophiolite complex consisting of basic-ultrabasic rocks is observed in this Upper Cretaceous formation. This is generally composed of serpentinite, saussurite gabbro and diabase displaying a consistent sequence from bottom to top. The diabase mass is composed of repeatedly intruded sheets, thus it is called «sheeted diabase» in this paper. As shown on geological map (Fig. 1), the ophiolite complex occurs in a narrow belt running to E-W trend in the eastern part of the mapped area. The width of the complex is about 1.5 km, and its length is 11 km. On the other hand, in the western part of the mapped area, the ophiolite complex lacking serpentinite forms a stock which has 1 km of diameter on the surface. It is notable that the Upper Cretaceous formation including pillow lava is found not only at the top of the complex but beneath the complex. This field evidence seems to be very important to consider the modes of emplacement of ophiolite complex.

The ultrabasic rocks are completely serpentinized. The serpentinites may be classified into two rock facies: i.e., massive serpentinite believed to be changed from peridotite or harzburgite and foliated one. The foliated serpentinite generally occurs as marginal facies of the massive one, and occasionally occurs as separated small outcrops. These small serpentinite masses are regarded to be dislocated rock bodies from the massive one. In both facies of the ultrabasic rocks, blocky rodingite occurs frequently.

As to gabbro,' massive saussurite gabbro and schistose one are distinguished. The latter is found around the massive one. Both of them consist of altered pyroxene associated with green hornblende and partially sericitized plagicclase.

Sheeted diabase having the thickness of around 100 m generally covers the saussurite gabbro. A contact relation between the sheeted diabase and gabbro is illustrated in Figure 2. Chilled marginal facies found within the sheeted diabase mass suggests that the diabase mass was formed by multiple intrusions. The rocks are composed essentially of clinopyroxene and sericitized plagioclase. Typical ophitic texture is observed in either coarse-grained facies or fine-grained facies. Irregular shaped intrusions of gabbro into sheeted diabase are occasinonally observed along the boundary between gabbro and diabase (Fig. 2). This suggests that the gabbro was fluidal after the consolidation of diabase.

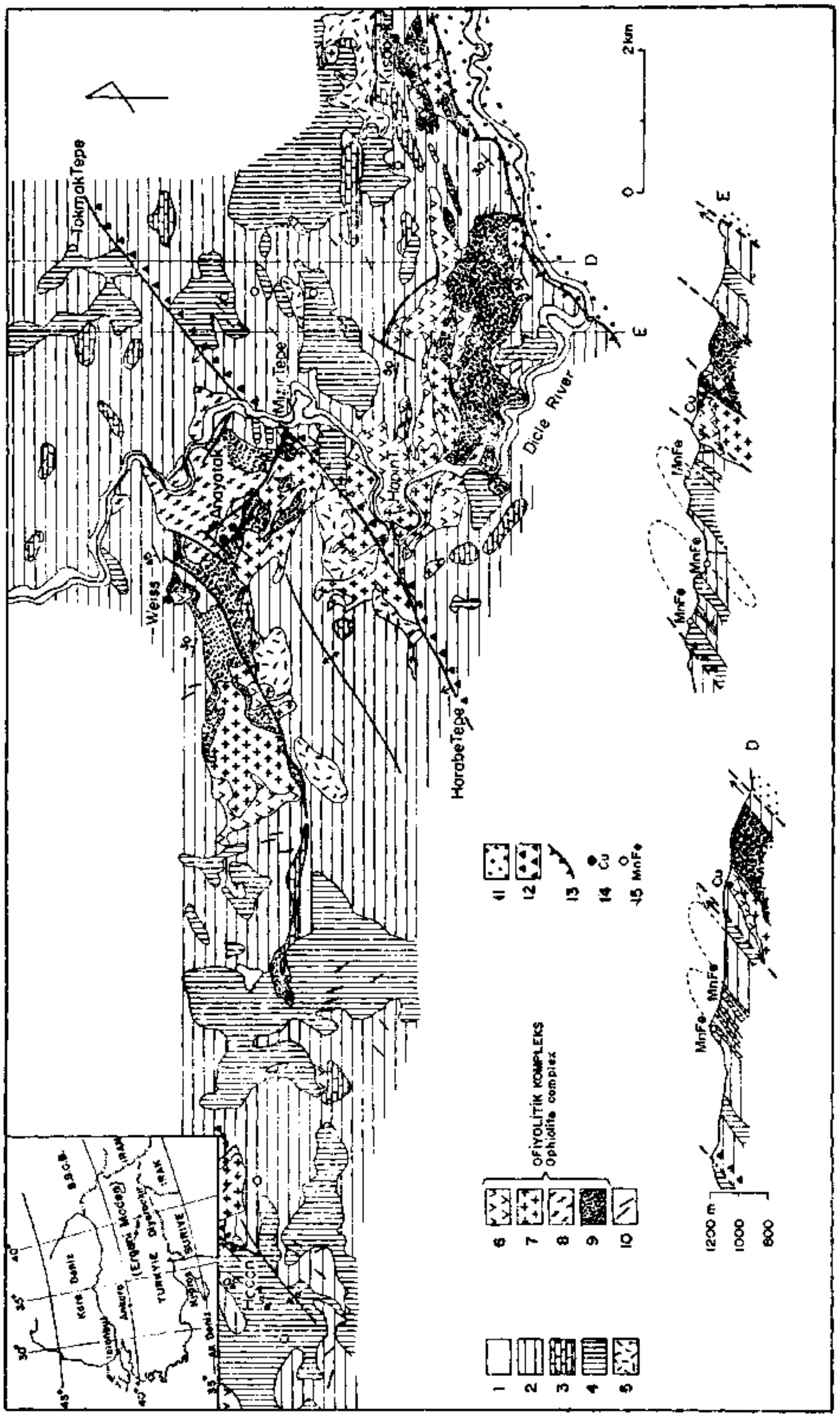

Fig. 1 - Geological map of the Ergani mining district, Southeastern Turkey (Takeo Bamba *et al.*).

1 - Alluvium; 2 - Mudstone; 3 - Limestone; 4 - Pillow lava; 5 - Diabase tuff; 6 - Sheeted diabase; 7 - Saussurite gabbro; 8 - Schistose gabbro; 9 - Serpentinite; 10 - Diabase dyke; 11 - Mylonite; 12 - Breccia; 13 - Thrust; 14 - Copper ore deposit; 15 - Manganiferous hematite ore deposit.

Another type of diabase is observed anywhere in the mapped area. This occurs as small-scale dykes. The diabase dykes show difference from the sheeted diabase not only in the modes of occurrence but in the petrographical properties and chemistry. Thus this kind of diabase is called «diabase dyke» in this paper to distinguish from the sheeted diabase.

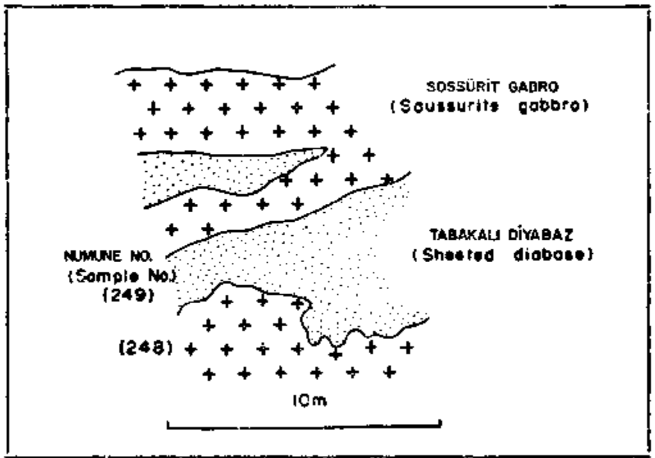

Fig. 2 - Contact between sheeted diabase and saussurite gabbro in Hopin Tepe near the Ergani mine.

Moores and Vine (1971) described «sheeted diabase» of the Troodos massif, Cyprus. It may be required to compare two sheeted diabases from Ergani massif, Turkey, and from Troodos massif, Cyprus, in order to avoid confusion. Moores and Vine (1971) reported that the Troodos massif, Cyprus, consists of a pseudostratiform mass of harzburgite, dunite, pyroxenite, gabbro, quartz-diorite, diabase and pillow lava arranged in a dome-like manner, and the diabase forms a remarkable dyke swarm or «sheeted diabase». Regarding the formation process of diabase dyke swarm, a short note is quoted from Moores and Vine (1971): «Apparently the process has been that one dyke is intruded and has its margins chilled against the wall rock. The next dyke then intrudes up the middle of the previous one, and in turn forms chilled margins, then the next one repeats and so on.»

In the Ergani mining district, internal structure of the sheeted diabase represented by complex chilled margin is parallel to contact surface between rock units; mudstone covers the sheeted diabase concordantly and the elongation of the sheeted diabase overlies gabbro nearly concordantly, though the contact surface between the sheeted diabase and the underlying gabbro is irregular in details.

Setting aside the difference of modes of occurrence, the sheeted diabase of Ergani massif, Turkey, may correlate to the early phase of the diabase dyke swarm in Troodos massif, Cyprus, and the diabase dyke in Ergani mining district may be correlated to the later phase of the diabase dyke swarm in Troodos massif, Cyprus.

3. GEOLOGIC STRUCTURE

Mudstone of the Ergani ophiolite belt in the mapped area shows NEE-SWW strike and 20-30°N dip, then it looks that the formation forms apparently homoclinal structure, but the manganiferous hematite deposits occurring between pillow lava and mudstone indicate that the geological structure of this area is remarkably complicated as illustrated in geological profiles (Fig. 1). The structure can be confirmed from the symmetrical distribution of green rock layers consisting mainly of diabase tuff. Imbricated structures are observable in southwestern part of Anayatak and Hacan areas (Fig. 1). It is notable that the ophiolite complex frequently occurs along the anticlinal axis.

Fault system and fracture system running to N-S or NW are nearly perpendicular to the above-noted folding structure. There is no doubt that the faults are younger than the folds due to the field evidence. It is considered that this younger tectonic movement yielded numerous diabase dykes mentioned above.

The remarkable thrust which divided the Upper Cretaceous formation (ophiolite suite) and Neogene Tertiary system is observed in the southeastern corner of the mapped area. As shown in geological map (Fig. 1), the thrust is characterized by presence of mylonite and crushed materials. There are two other parallel fracture zones running in a NE-SW direction. One of them is represented by a breccia zone running from Tokmak Tepe to Harabe Tepe, and the other found in the central part of mapped area is a shear zone characterized by presence of foliated serpentinite. These are considered to be formed related to the formation of main thrusts.

4. PILLOW LAVA, OPHIOLITE COMPLEX AND DIABASE DYKE

Owing to the progress of geological investigations, it has been identified that many alpine ophiolites display a pseudostratiform sequence of ultramafics, gabbro, diabase, pillow lava and deep-sea sediments, in ascending order (e.g., Coleman, 1971; Moores & Vine, 1971). In Europe to Middle East region, this type of association and sequence of ophiolite rocks have been well recognized.

In the Ergani mining district, though the ophiolite complex displays a consistent sequence, Upper Cretaceous formation including pillow lava occurs beneath as well as above the complex, as illusrated in Figure 1. From the modes of occurrence of the rocks it seems to the present author that pillow lava is a product of initial magmatism in geosynclinal phase, and ophiolite complex or basic-ultrabasic igneous complex is synkinematic, and diabase dykes are post-kinematic.

Various rock facies of the ophiolite from the Ergani mining district are illustrated in Photos 1 and 2. The chemical analyses of some selected rocks were made. The results are given in Table 1. From the available chemical data of pillow lava, sheeted diabase and diabase dyke it may be concluded that all of the analyzed rocks belong to alkali basalt type, as far as it is justified that the rocks did not suffer any significant metasomatism during alteration.

Tablo - 1

Chemical compositions of diabase dyke, sheeted diabase and pillow lava from the Ergani mining district, Eastern Turkey

	(1)	*(2)*	*(3)*
SiO_2	53.15	51.37	48.80
TiO_2	1.17	0.32	1.79
Al_2O_3	16.11	15.28	13.85
Fe_2O_3	3.10	1.66	5.12
FeO	7.90	7.55	8.08
MnO	0.21	0.24	0.33
MgO	4.46	9.68	7.47
CaO	3.70	4.91	5.89
Na_2O	3.85	3.32	3.37
K_2O	3.24	1.67	0.63
P_2O_5	0.30	0.04	0.20
$H_2O(+)$	3.49	3.44	3.99
$H_2O(-)$	0.26	0.38	0.34
Total :	99.94	99.86	99.86

(1) Pillow lava near the Ergani mine.
(2) Sheeted diabase from Anayatak, Ergani mine.
(3) Diabase dyke from Hacan mine.
(Analyst: Research Institute for Mineral and Coal, Tokyo.)

Table - 2

Norms of pillow lava, sheeted diabase and diabase dyke from the Ergani mining district, Eastern Turkey

	(1)	(2)	(3)
Q	3.63	0.01	1.36
or	13.24	9.87	3.72
ab	32.58	28.09	28.52
an	16.57	21.86	20.82
c	1.29	—	—
wo	—	0.93	3.00
en	11.11	13.72	18.60
fs	10.41	7.03	8.26
fo	—	7.28	—
fa	—	4.14	—
mt	4.49	2.41	7.42
il	2.22	0.61	3.40
hm	—	—	—
ap	0.66	0.09	0.44

(1) Pillow lava near the Ergani mine.
(2) Sheeted diabase from Anayatak.
(3) Diabase dyke from Hacan mine.

The analyzed diabase dyke is somewhat poor in SiO_2, Al_2O_3 and rich in $FeO+Fe_2O_3$ and CaO compared with pillow lava and sheeted diabase. The analyzed pillow lava is characterized by higher alkali content, and the sheeted diabase is intermediate in contents of SiO_2, Al_2O_3, $FeO+Fe_2O_3$, CaO and K_2O among these three. These rocks were plotted on Kuno's alkali-alumina-silica diagram (Fig. 3). All the rocks are plotted within the alkali basalt field but the diabase dyke is plotted near the boundary between tholeiite and alkali basalt fields.

Norms of these three kinds of rocks were calculated from the chemical compositions, as given in Table 2. The normative feldspars were plotted on a normative albite-anorthite-orthoclase diagram. All of the three rocks were plotted on a spilite field indicated by Yoder (1967), as shown in Figure 4.

In the pillow lava a felsic rock composed mainly of numerous gray - white varioles consisting of acicular albite and small amount of quartz is observable. This rock may be called keratophyre. Thus, it may be concluded that volcanics in the mapped area belong to «spilite-keratophyre suite».

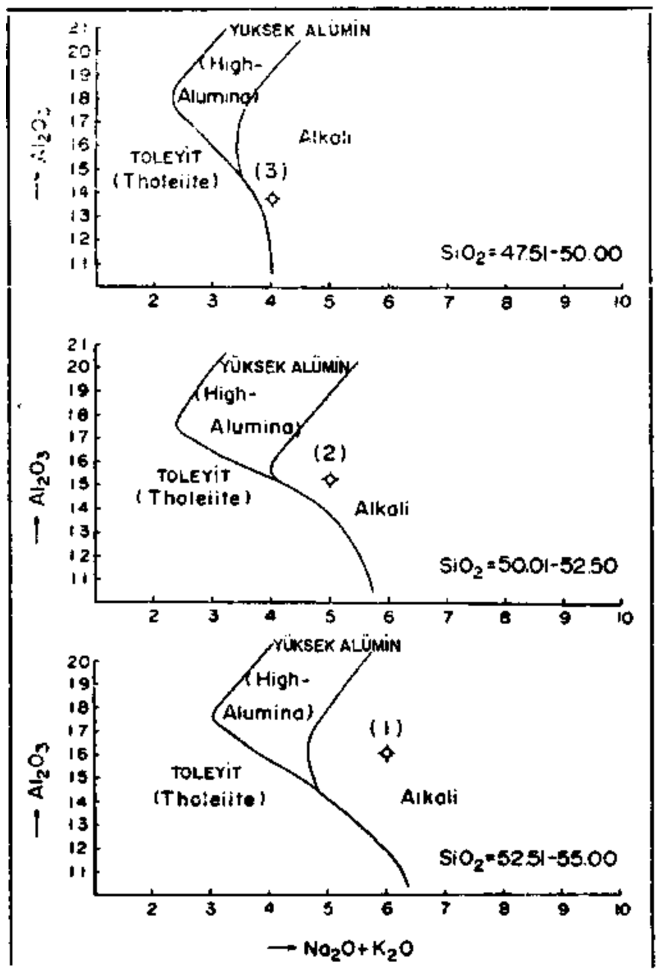

Fig. 3 - Kuno (1960)'s diagram showing Al_2O_3-total alkalis-SiO_2 relation of the three basalt types, and the situations of the three kinds of rock from the Ergani mining district.
1 - Pillow lava near the Ergani mine; 2 - Sheeted diabase from Anayatak; 3 - Diabase dyke from Hacan area.

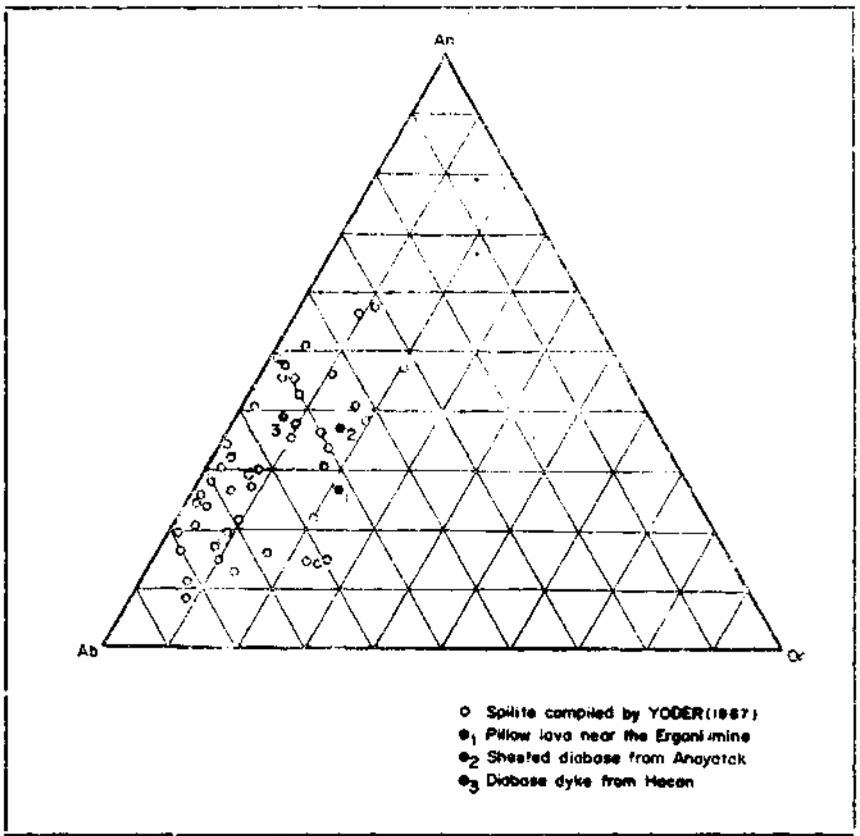

Fig. 4 - Normative feldspar of spilites compiled by Yoder (1967) and normative feldspars of pillow lava, sheeted diabase and diabase dyke from the Ergani mining district.

5. MODES OF EMPLACEMENT OF THE OPHIOLITE

Many alpine ophiolite massifs are known in Greece, Cyprus and Turkey along the so-called Mediterranean Tethyan belt. These massifs are believed to be formed during Jurassic to late Cretaceous period.

Moores and Vine (1971) compared the structure of the Vourinos ophiolite, northern Greece, with that of the Troodos ophiolite massif, Cyprus, and interpreted the difeference based on the aspects of sea-floor spreading. They came to the following conclusion: «On Troodos foliations of dunite and harzburgite are vertical, whereas in Vourinos they were originally horizontal away from the divergent and complexly domed center. This difference implies that mantle laying on slow-spreading ridges tends to be vertical and becomes horizontal on fast-spreading ridges. Under this interpretation, the divergent structure present in the Vourinos Complex implies that it represents a piece of the actual crest of the former mid-Tethyan ridge.»

On the other hand, Sawamura (1971) supported the Ketin's (1966) idea that the Russian plateau had spread towards Arabian plateau in Paleozoic to Mesozoic period. The following is quoted from Sawamura (1971): «The geologic episodes of the Anatolian peninsula indicate that the relative positions of Russian and Arabian plateaus standing against Turkey from both sides have been kept steadfastly since Paleozoic until present time, and the successive tectonic movements forming Anatolia orginated from the Russian plateau side, because there have been found many geologic features related to the Russian plateau type basement. Therefore, it is difficult to consider that the ophiolite suite of Anatolia is a fragment of oceanic crust derived from the former Tethyan ridge.»

The present author has recognized the ophiolite formation consisting of Upper Cretaceous sediments and contemporaneous pillow lava beneath the serpantinite, a basal member of the ophiolite complex, in the Ergani mining district. This fact suggests that the eruption of pillow lava is initial in a serial magmatism related to the formation of ophiolite suite, and afterwards the ophiolite complex or basic-ultrabasic igneous complex intruded the Upper Cretaceous sediments along the folding axis, then the diabase dykes followed as final intrusives.

It is concluded that the Ergani ophiolite was originated in the geosynclinal basin of Cretaceous age laid at the southern front ofthe former Anatolids, central massif of Anatolian peninsula in present time. This ophiolite suite was heaved up together with basic-ultrabasic intrusives at the south side of Anatolids through the alpine orogenic movement during late Cretaceous to early Tertiary period. Then the ophiolite suite was emplaced at the present loci by thrust movement compressed from the north in late Miocene to Pliocene period.

6. COPPER DEPOSITS AND ORES

Most of the cupriferous pyrite deposits concerned are found within the ophiolite complex (Fig. 1). There are several open-pits exploiting the copper ores. They are Kısabekir, Mızırtepe, Anayatak, Weiss, and Hacan from the east to the west. The deposits are classified into the following three types: a) Bedded type (Weiss), b) Massive replacement type (Anayatak, Hacan, Mızırtepe), c) Fissure filling type (Kısabekir).

6.1. Bedded type copper deposit (Weiss)

As illustrated in Figure 5, the main ore body occurs between sedimentary rock and chloritized green rock. The hanging wall is composed ofthick mudstone intercalated with lenticular limestone and thin layers of green rock. The footwall consists of remarkably uralitized or chloritized green rock, in which low-grade disseminated sulphide ores and small-scale lenticular massive sulphide ores are found. The main ore body, 10 m thick and about 50 m long, is concordant with the overlying mudstone.

Pyrite and chalcopyrite are main constituent minerals of the sulphide ore. Small amount of pyrrhotite, sphalerite is generally associated.

Microscopically, framboidal pyrite or colloform pyrite in chalcopyrite base, probably a product of low-temperature mineralization, is obsen ed in the ores from the top of the massive ore body (Photo 3-1, 2), whereas exsolution intergrowth consisting of chalcopyrite and sphalerite, conceivably a higher-temperature product (Photo 3-3) is found in the ores from the bottom of the same ore body. The disseminated ores in the underlying chloritized green rock are also characterized by the presence of the exsolution intergrowth. Besides, pyrrhotite and magnetite are common in the disseminated ore.

It is notable that chromite crystals are contained in massive sulphide ore. The chromite is round but occasionally idiomorphic as illustrated m Photo 3. Color in thin section is reddish brown and the grain size of individual crystal is around 0.1 mm. Secondary electron and characteristic X-ray images for the chromite are given in Photo 4.

Though the footwall is remarkably altered by chloritization, the microscopic fabric suggests that the original rock belongs to the sheeted diabase. Thus, the deposit lies just at the boundary between ophiolite complex and the overlying sediments.

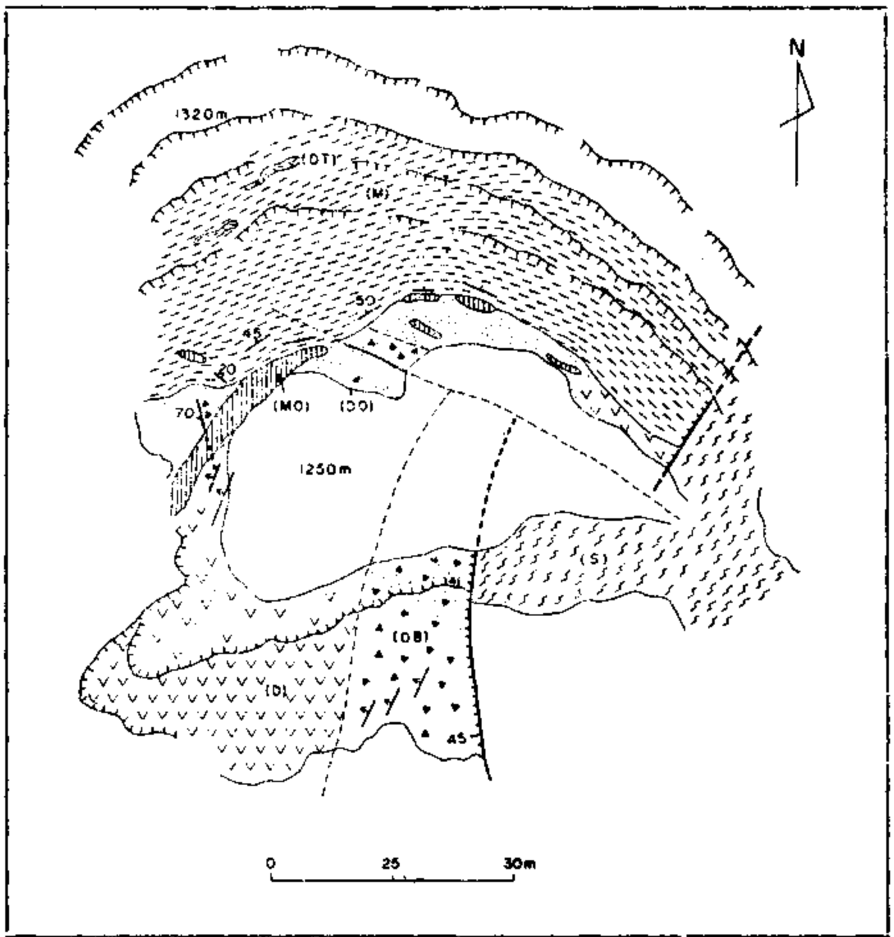

Fig. 5 - Geological sketch showing the positions of the cupriferous pyrite ores in the Weiss open-pit (Takeo Bamba).
(DT) - Diabase tuff; (M) - Mudstone; (D) - Diabase; (DB) - Diabase breccia; (MO) - Massive ore; (DO) - Disseminated ore; (S) - Serpentinite.

It looks that the modes of occurrence of the ores indicate apparently their exhalative sedimentary origin. It seems, however, to the present author that the presence of chromite in the ores strongly suggests their epigenetic origin.

6.2 Massive replacement type copper deposit (Anayatak)

The view of Anayatak looking to the north is given in Photo 5. Geology of Anayatak, Ergani mine, is mainly composed of serpentinite, chloritized sheeted diabase and calcareous mudstone. They show a systematic distribution from the south as illustrated in Figure 6. Gabbro grades to sheeted diabase at the northwestern corner of the open-pit. Diabase breccia, a kind of tectonite, occurs between serpentinite and sheeted diabase.

In Anayatak, three notable fault systems are distinguished. The first (fault I) appears as diabase breccia running in NW trend. The second (fault II) is perpendicular to the former. This is found in the western side of the open-pit showing NE trend, and the third (fault III) develops between the sheeted diabase and the overlying calcareous sedimentary rocks. The time relation between these faults is believed that the fault I is the oldest and fault III is the youngest.

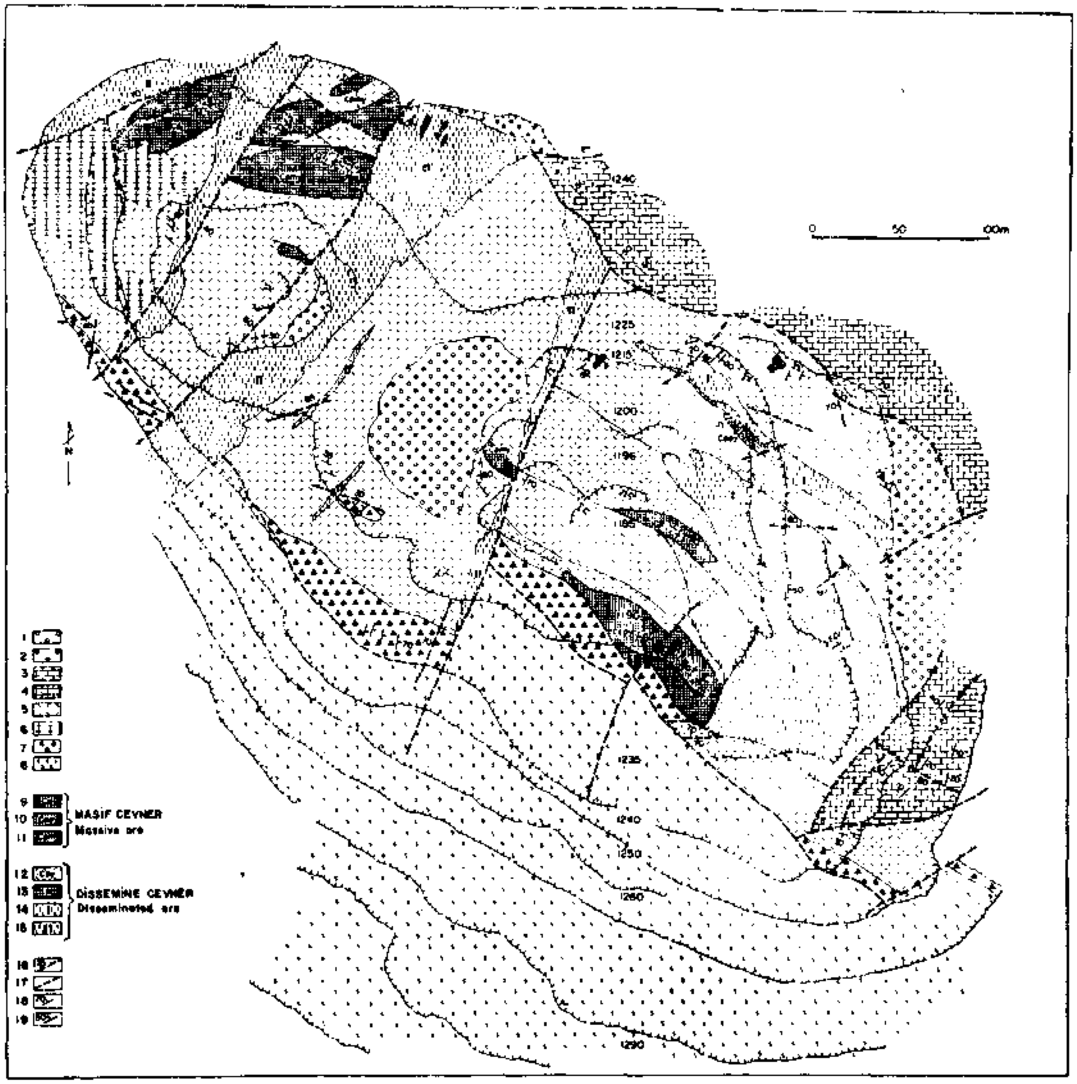

Fig. 6 - Geological map of the Anayatak, Ergani mine (Takeo Bamba, Asil Tin, Hanefi Polat).
1 - Dump area; 2 - Limonite; 3 - Calcareous mudstone; 4 - Calcareous sandstone; 5 - Chloritized diabase; 6 - Chloritized gabbro; 7 - Diabase breccia; 8 - Serpentinite; 9 - Chlorite-chalcopyrite ore; 10 - Chalcopyrite-pyrite-pyrrhotite ore; 11 - Pyrrhotite-magnetite-chalcopyrite ore; 12 - Chlorite-chalcopyrite-pyrrhotite ore; 13 - Pyrite ore; 14 - Quartz-sericite-pyrite (I); 15 - Quartz-sericite-pyrite (II); 16 - Fault; 17 - Estimated fault; 18 - Dip and strike; 19 - Joint.

Several massive cupriferous sulphide ore bodies are found in the open-pit of Anayatak. Two kinds of ores called «yellow-colored ore» and «black-colored ore» are distinguished. The yellow-colored ore, mainly composed of pyrite and chalcopyrite, generally occurs in the sheeted diabase. On the other hand, the black-colored ore, characterized by the presence of a large amount of magnetite, occurs near the boundary between gabbro and sheeted diabase in the western part of the open-pit.

The biggest ore mass is 100 m wide and 30 m thick on surface, but the extent for the subsurface level is uncertain. Strictly speaking, each ore mass is composed of numerous unit ore bodies as illustrated in Figure 7.

Disseminated sulphide ore is found around the compact ore mass. Change between compact ore and disseminated one is principally gradual, but sometimes the boundary is very distinct.

Geological profile of Anayatak (Fig. 7) was made based on the available Kovenko's (1944) data illustrating the previous surface of the open-pit and the results newly obtained by the present author.

Widely distributed diabase playing a role of host rock shows typical ophitia texture and is mainly composed of chloritized clinopyroxene and albitized plagioclase. In addition, a considerable amount of ilmenite is scattered.

Altered rocks characterized by the mineral assemblage of quartz-sericite-pyrite occur in Anayatak. Two kinds of quartz-sericite-pyrite rocks, I and II, are distinguished due to their modes of occurrence and petrographic properties. As shown in Figure 6, type (I) surrounding the massive sulphide ores in the southeastern part of the open-pit is characterized by the abundant sericite and scantiness of quartz, whereas type (II) along the fault II is rich in quartz. The quartz-sericite-pyrite (I) is considerad to have been formed as the result of wall rock alteration related to the copper mineralization, because this facies runs in NW trend and is always accompanied by disseminated copper sulphide ores. The type (II) seems not to be related to the wall rock alteration.

Descriptions of the yellow-colored and black-colored ores from the Anayatak are given below.

1. *Cupriferous pyrite ore (yellow-colored ore).* — In general, yellow-colored ore is compact and consists mainly of pyrite and chalcopyrite. Pyrrhotite, mackinawite, cubanite, sphalerite are accessory minerals.

Pyrite shows generally cataclastic structure, and the cracks are usually filled with chalcopyrite as shown in Photo 6. Mackinawite and cubanite associated with chalcopyrite are rarely found. Though the mackinawite resembles very much to the valleriite under ore-microscope, the chromographic contact print method for this mineral detected Ni enough to determine it as mackinawite. The textural relationship between the three minerals is illustrated in photomicrographs (3) of Photo 6. It seems that pyrite was formed earlier than chalcopyrite. Sphalerite seems also to belong to the later phase. The mineral occurs frequently as tiny grains in chalcopyrite suggesting possible exsolution intergrowth. Pyrrhotite showing worm-like form is commonly accompanied by chalcopyrite.

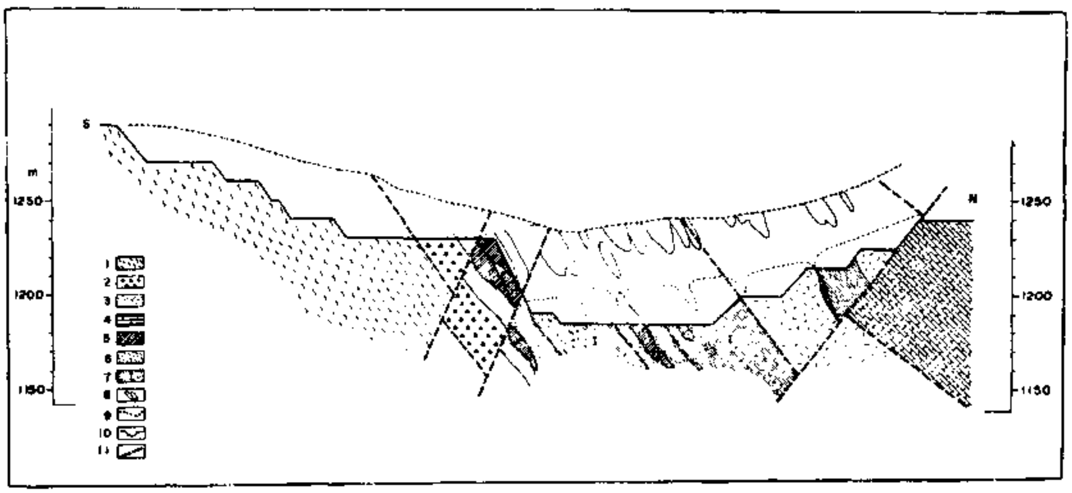

Fig. 7 - Geological profile showing the present and previous positions of ores in the Anayatak, Ergani mine (Takeo Bamba, Asil Tin).

1 - Serpentinite; 2 - Diabase breccia; 3 - Chloritized diabase; 4 - Calcareous mudstone; 5 - Massive ore; 6 - Disseminated ore; 7 - Quartz-sericite-pyrite (I); 8 - Ore units in previous position; 9 - Previous surface; 10 - Present surface; 11 - Fault.

2. *Cupriferous magnetite ore (black-colored ore).* — Black-colored ore is characterized by the presence of a considerable amount of magnetite and chlorite. Discrete magnetite grains are observed in chloritized diabase or in the chloritized gabbro. The distribution of magnetite in the chloritized rock is uneven and the mineral is abundant in some parts of the rock.

Sulphide ore consisting mainly of chalcopyrite and pyrite occurs as network veins and/or as numerous small spots in the magnetite ore.

There are two kinds of magnetite: one is cubic and the other is wedge-shaped in the crystal form. The latter is considered to be changed from hematite, because wedge-shaped hematite is occasionally observed as a relic in the ores. Thus the two kinds of magnetite are called magnetite (I) and magnetite (II), respectively. Magnetite (I) is generally cut by sulphide ore veins mentioned above, whereas magnetite (II) shows its own shape against the sulphide minerals as illustrated in Photo 6-4.

Cubanite-mackinawite-chalcopyrite assemblage has been realized in the sulphide ores. Cubanite accompanied by chalcopyrite shows typical lamellar structure regarded to be originated by exsolution.

6.3 Fissure-filling type copper deposit (Kısabekir)

Kısabekir mine is situated 10 km east of Anayatak. Though the mine has been closed already, rest of ores is found in the open-pit. Cupriferous pyrite ore veins are observed as illustrated in Figure 8. Ore vein swarm occurs in foliated serpentinite associated with pyroxenite along the shear zone running in NE trend.

The ore is compact and is microscopically characterized by the presence of framboidal pyrite and colloform pyrite. Photomicrographs of the ores are shown in Photo 7. At the top of the ore veins, supergene alteration of the ores represented by malachite and occasionally azurite is observed.

In the neighboring area of this open-pit, numerous outcrops of small-scale copper ore veins composed mainly of supergene minerals are known in the sheeted diabase.

It is believed from the modes of occurrence and the characteristics of the ores that the ore deposit of this mine belongs to fissure filling type. The presence of framboidal pyrite and colloform texture indicates that the ores were formed in lower temperature condition compared with the other copper deposits of the Ergani mining district.

7. OPHIOLITE AND RELATED COPPER MINERALIZATION

As briefly outlined above, the copper ore deposits of the Ergani mining district are classified into three types: (a) bedded type, (b) massive type, and (c) fissure filling type. The geological positions of the individual ore deposits are summarized in Figure 9.

Almost all the copper deposits occur in the restricted rock facies of the ophiolite complex, especially in the sheeted diabase occurring near the diabase dykes. Thus it may be considered that these copper deposits were originated from the same mineralization related to the activities of diabasic rocks.

A series of diabasic rocks in the Ergani mining district represented by pillow lava, sheeted diabase and diabase dyke was studied petrograpftically as well as chemically and it has been shown that there is a series of magmatism showing the possible gradational change from alkali basalt type towards tholeiitic.

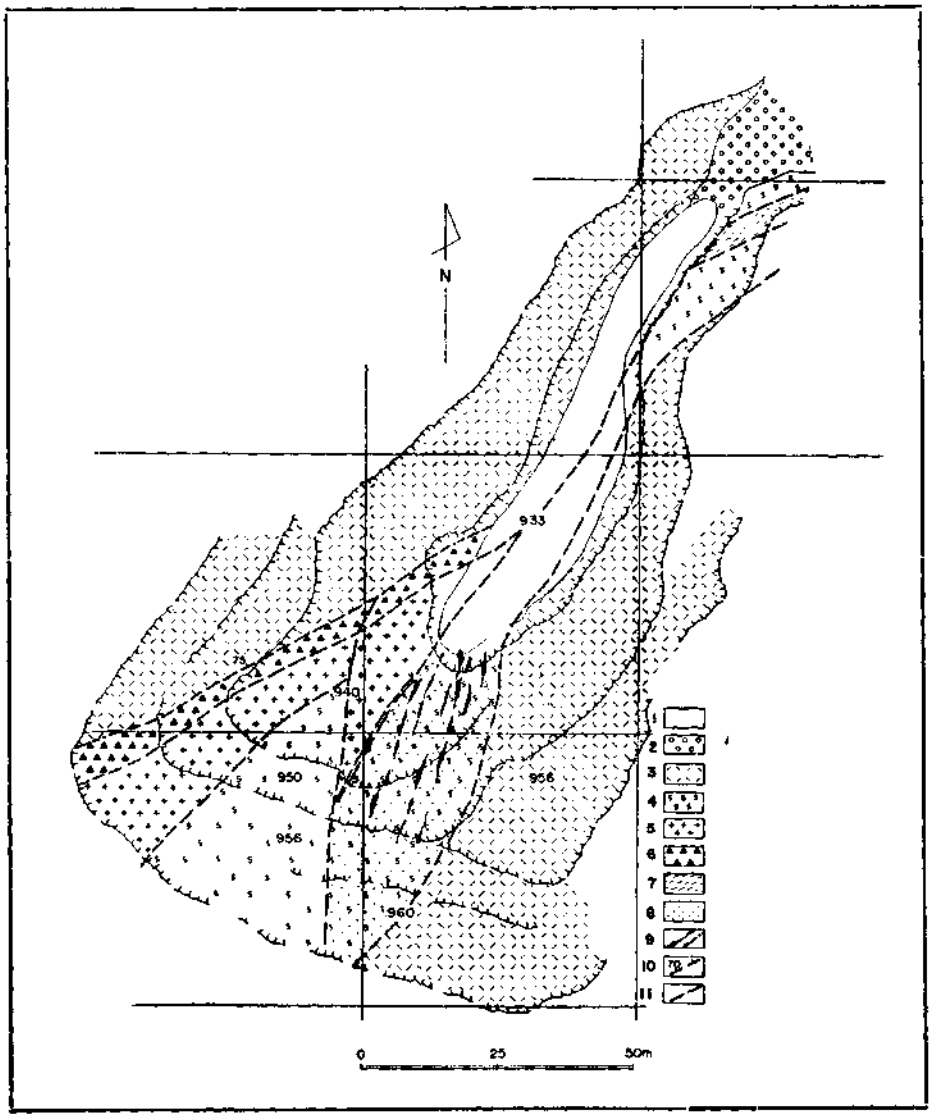

Fig. 8 - Geological sketch of the Kısabekir open-pit (Takeo Bamba).
1 - Pond; 2 - Dump area; 3 - Diabasic tuff; 4 - Serpentinite; 5 - Pyroxenite; 6 - Serpentinite breccia; 7 - Silicified serpentinite; 8 - Chloritized facies; 9 - Chalcopyrite-pyrite ore; 10 - Fault; 11 - Estimated fault.

The available geological data indicate that pillow lava erupted initially in geosynclinal phase and yielded some bedded type manganiferous hematite deposits belonging to exhalative sedimentary origin. Afterwards, in late-kinematic to post-kinematic phase, the sheeted diabase occupying the top of the ophiolite comphex was chloritized and partially mineralized by the hydrothermal solution.

The author's view concerning the modes of formation of the copper deposits in this district is summarized as follows: Fault system running with NW trend played a role of channelways for the ascending ore solution. Thus massive replacement type copper deposit of Anayatak and bedded type copper deposit of the Weiss mine were formed. Afterwards, the fracture system showing NE trend promoted upwards migration of residual ore solution and fissure filling type copper veins were formed in the Kısabekir mine and the neighboring area. During the ore-forming process, the solution might have caught the chromite crystals from pre-existed serpentinite in deep niveau.

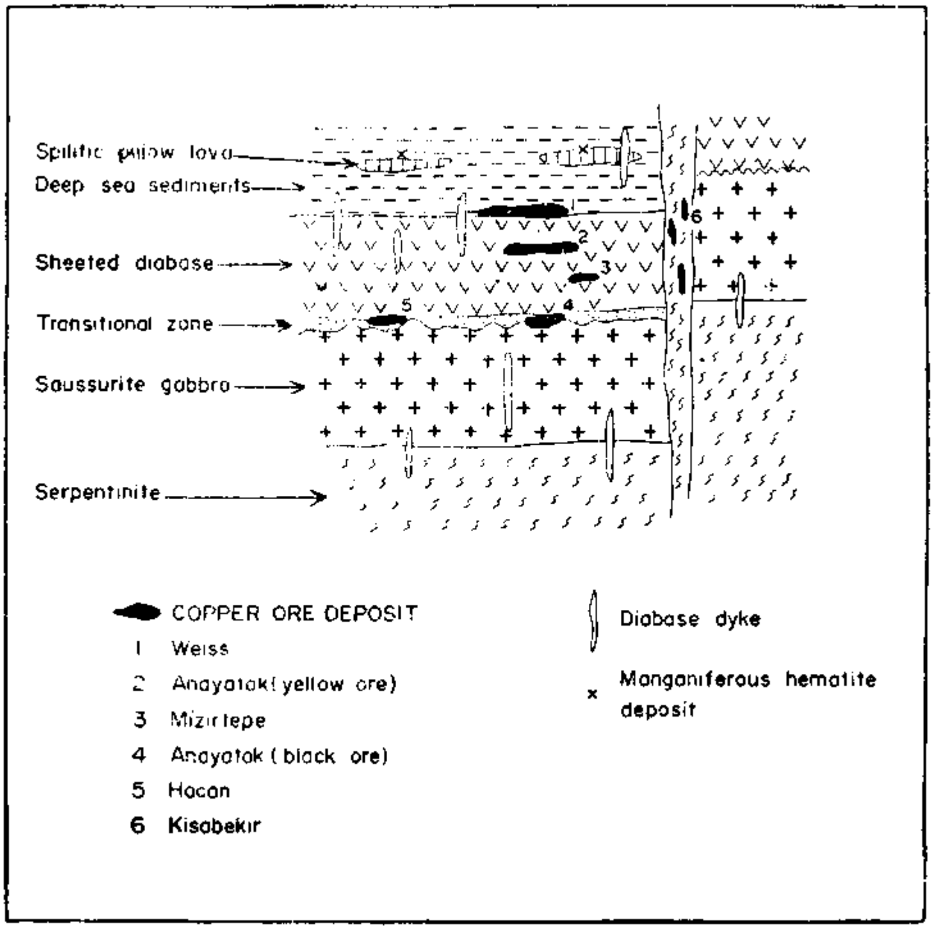

Fig. 9 - Schematic profile and the geological positions of manganiferous hematite deposits and copper deposits of the Ergani mining district, Southeastern (Turkey T. Bamba, 1972).

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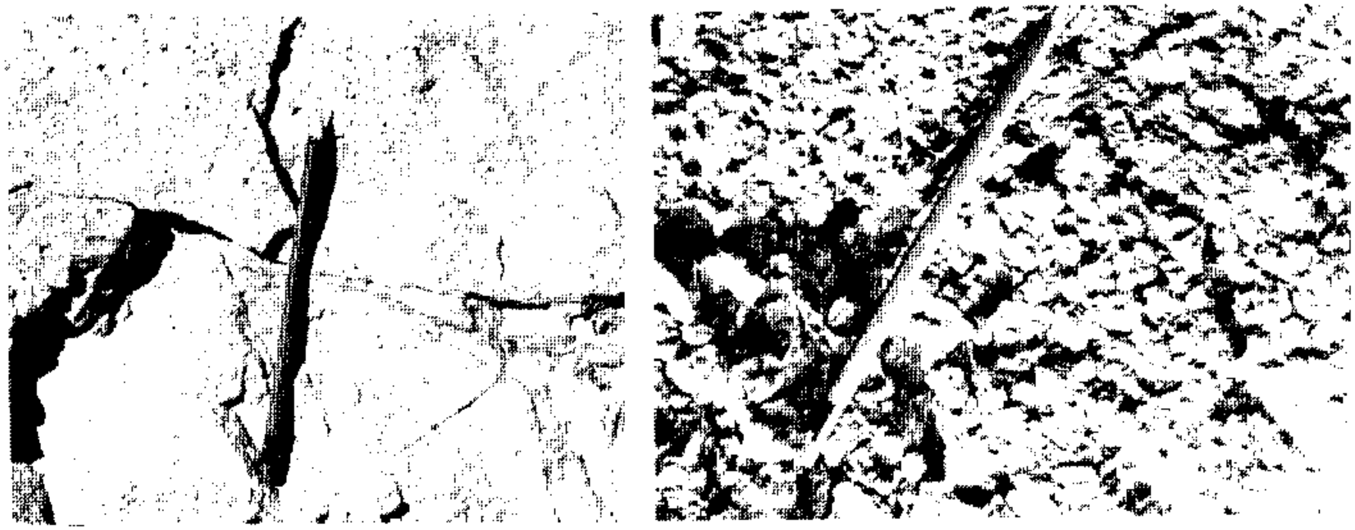

Photo 1 - Occurrence of pillow lava and keratophyre in Hacan area, western part of mapped area.

(1) Contact between unit pillows of spilite. Outer shell consisting of thin glassy facies is observable. Rock property of spilite is porous and color is heterogeneous by presence of chloritized facies.

(2) Keratophyre showing amygdaloidal structure. Numerous amygdules are mainly composed of acicular albite and small amount of quartz.

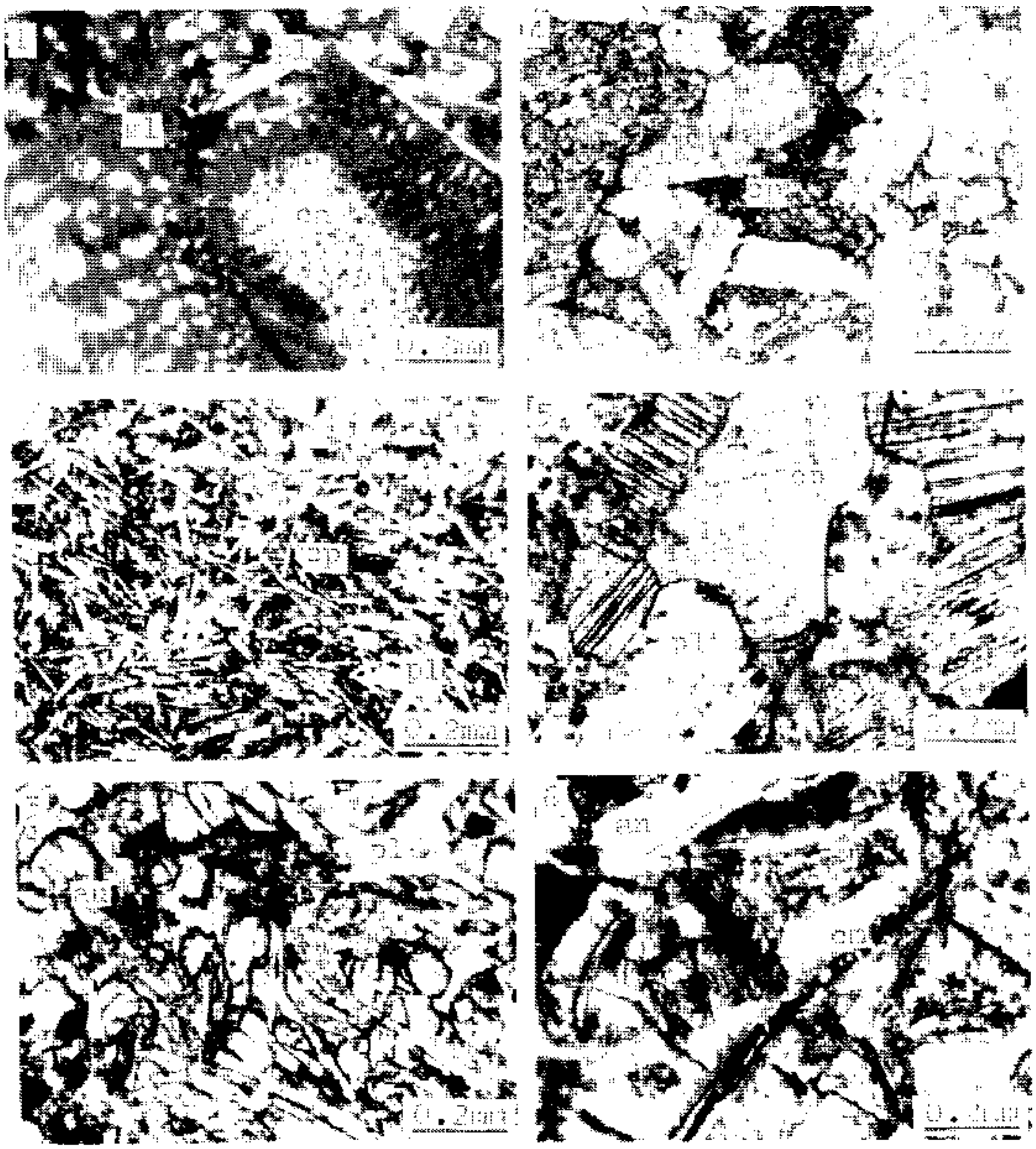

Photo 2 - Microphotographs of thin sections of pillow lava, sheeted diabase, saussurite gabbro, serpantinite and diabase dyke from the Ergani mining district.

(1) Pillow lava (outer shell) from Tigris (Dicle) River near the Ergani mine. Glassy facies: pl - plagioclase; gl - glass; ca - calcite (open nicol).
(2) Pillow lava (core) from Tigris River near the Ergani mine. Variolite facies: pl - albite; cp - clinopyroxene (open nicol).
(3) Diabase dyke from Hacan area, western part of the mapped area. pl - plagioclase; au - titaniferous augite (open nicol).
(4) Sheeted diabase from eastern part of the mapped area. pl - plagioclase; cp - clinopyroxene (open nicol).
(5) Saussurite gabbro from the Ergani mine. pl - sericitized plagioclase; cp - clinopyroxene (open nicol).
(6) Serpentinite from the Ergani mine. an - antigorite; cm - chromite (crossed nicols).

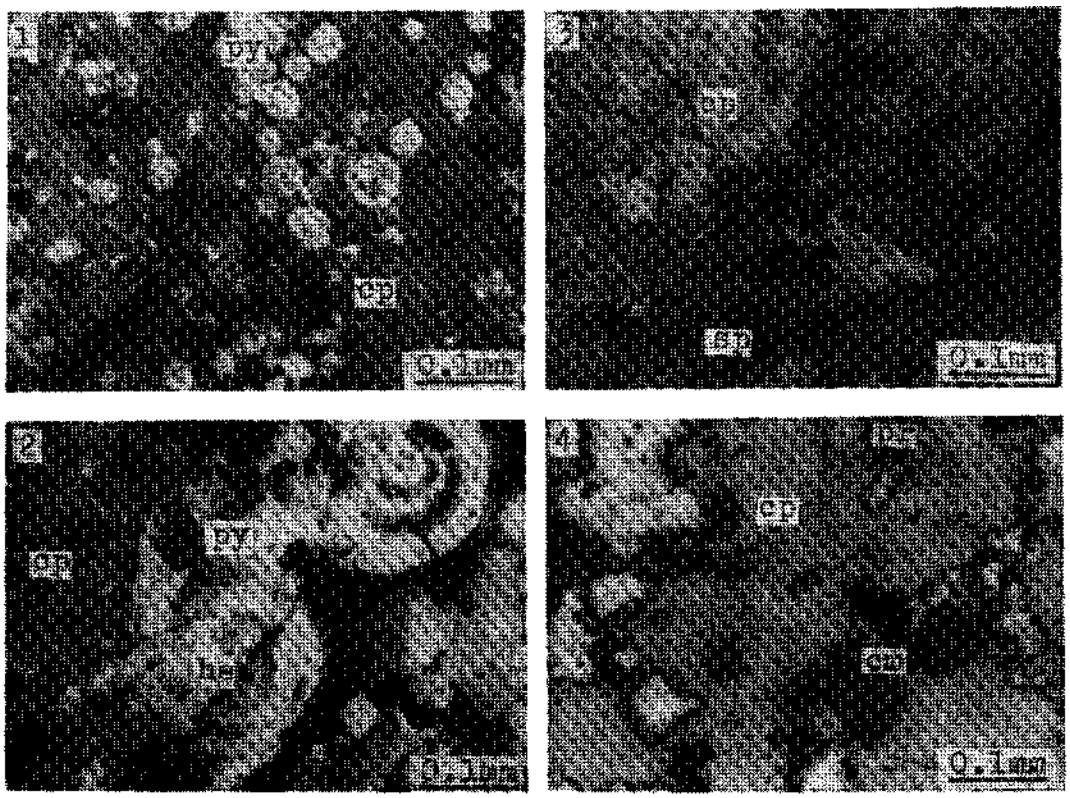

Photo 3 - Micrographs of polished sections of bedded type copper ores from the Weiss open-pit.

(1) Massive cupriferous pyrite ore from the top of the main ore body. py - framboidal pyrite; cp - chalcopyrite.

(2) Massive cupriferous pyrite ore from the top of the main ore body. py - colloform pyrite; he - hematite; cp - chalcopyrite.

(3) Massive 'copper zinc ore showing possible exsolution texture. cp - chalcopyrite; sp - sphalerite.

(4) Massive copper pyrrhotite ore from the bottom of the main ore body. cm - chromite; cp - chalcopyrite; pr - pyrrhotite.

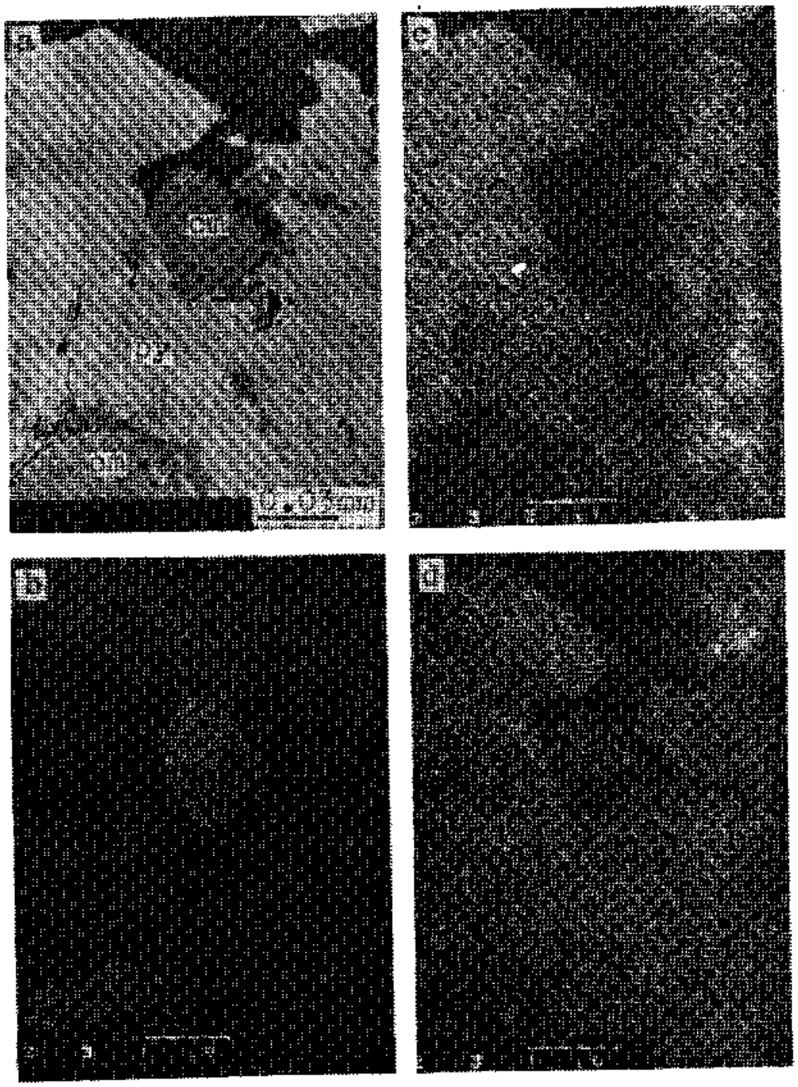

Photo 4 - (a) Secondary electron image of polished section of ore from the Weiss open-pit. cm - chromite; py - pyrite.
(b) ditto characteristic X-ray image (Cr K).
(c) ditto (S K).
(d) ditto (Fe K).

Photo 5 - View of open-pit of the Anayatak, Ergani mine, looking to the north. Buildings opposite are refinery and residential quarters.

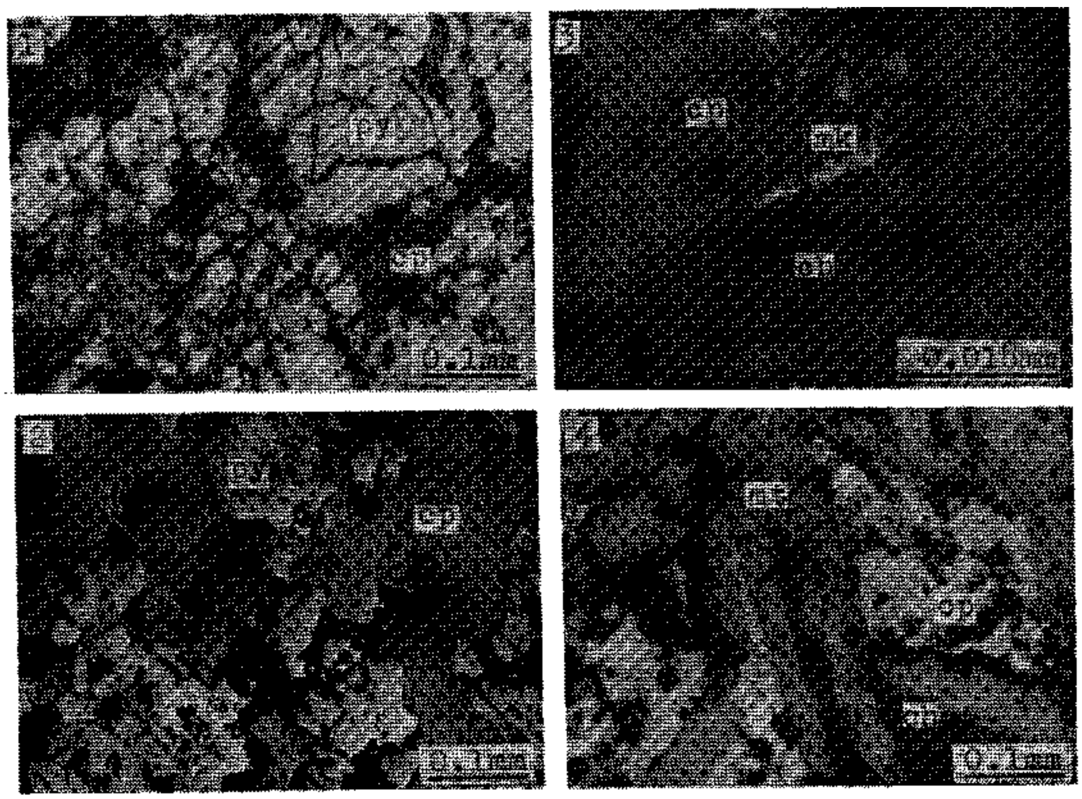

Photo 6 - Micrographs of polished sections of replacement type copper ores from the Anayatak, Ergani mine.

(1) Massive cupriferous pyrite ore (yellow-colored ore). py - pyrite showing cataclastic structure; cp - chalcopyrite.

(2) Typical yellow ore. The fragments of pyrite are considered as a variety of cataclastic pyrite. py - pyrite; cp - chalcopyrite.

(3) Disseminated copper sulphide ore. cp - chalcopyrite; cb - cubanite; mk - mackinawite, oil immersion, crossed nicols.

(4) Massive chalcopyrite-magnetite ore (black-colored ore). mt - magnetite (II); cp - chalcopyrite; ch- chlorite.

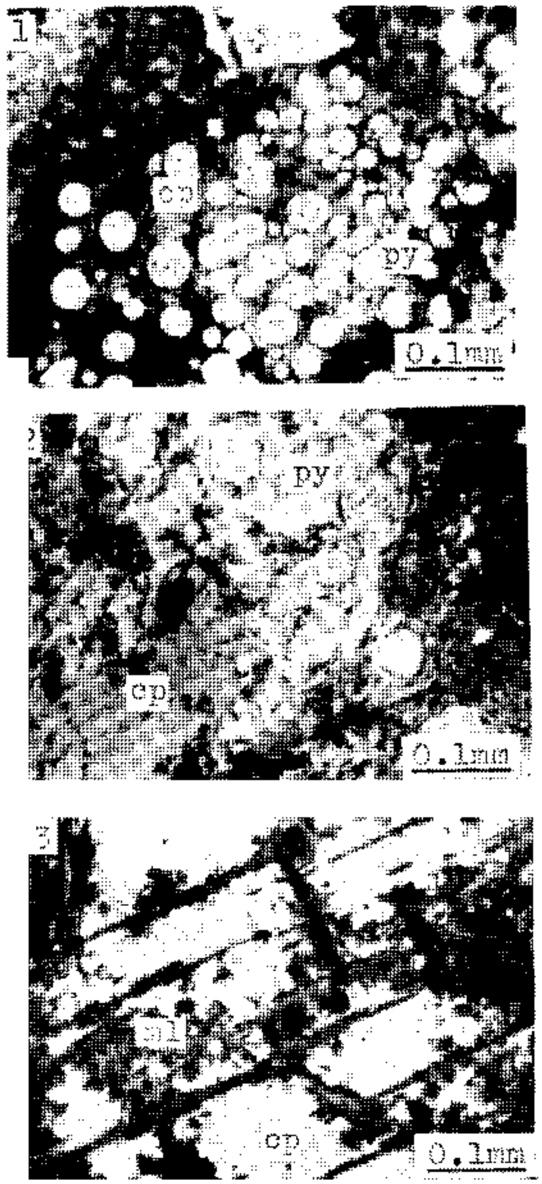

Photo 7 - Micrographs of polished sections of fissure-filling type copper ores from the Kısabekir open-pit and Mergen Tepe.

(1) Chalcopyrite-pyrite ore. cp - chalcopyrite; py - framboidal pyrite.

(2) ditto, cp - chalcopyrite; py - colloform pyrite.

(3) Supergene copper ore from Mergen Tepe. cp - chalcopyrite; ml - malachite, crossed nicols.