Mineral Res. Expl. Bull., 117, 29-40, 1995

GEOLOGICAL CHARACTERISTICS OF THE AŞIKÖY-TOYKONDU (Küre-Kastamonu) MASSIVE SULFIDE DEPOSITS

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ABSTRACT.- Massive sulfide deposits of Küre occur in a basaltic sequence, the uppermost unit of the Kure ophiolite. This unit is massive at the bottom and passes into the pillow lavas and hyaloclastites towards the top. Geochermcal analyses indicate an origin of oceanic ridge basalt. The basalts are overlain by a detritic sedimantary sequence represented essentially by shales at the base and shale-sand stone alternations at the upper levels Beneath the shale, the ore is generally massive and has a high grade, and towards the tower levels of the basalts it becomes stockworked and disseminated Structurally, the Aşıköy ore deposit has a form of ridge with a general direction of N45 W The average grade of the ore is 1 96 % Cu and 35 % S. Main ore minerals are chalcopyrite and pyrite. Cobalt minerals like linneite, bravoite and native gold minerals are also present. Ore mineralization is mainly thought to be the result of submanne volcanism and hydrothermal processes occurred during the Lias It probably developed near a spreading axis of a narrow and short-lived back-arc marginal basin and remobilized later due to granitic intrusions of Dogger age.

INTRODUCTION

Aşıköy-Toykondu massive sulfide deposits are situated in the western part of the Küre district of the Kastamonu province (Fig.1.) The orebody is extracted at present by open pit methods. The preparations for underground mining are in progress.

Early detailed geological investigations of Küre mining area was carried out by Kovenko for the MTA General Directorate. He prepared a geological map of the Küre area with a scale of 1:5000 and discovered the Aşıköy-Toykondu deposits from the gossan (Kovenko,1944).

In 1966, a Cento team aiming to tram geologists in geological mapping techniques under the management of MTA, made a general geological map of the Küre district with a scale of 1:5000 and a detailed geological map of the Aşıköy pit with a scale of 1:1000. They however misinterpreted the repetition of the basalt-shale alternation related to the thrusting ascribing incorrectly to two horizons. They proposed that the ore mineralization was formed by the hydrothermal solutions flowing along the old faults much after deposition of the shale and the intrusion of the grafiites.

Güner (1980) remapped the Küre area with a scale of 1:10 000. His major and trace element analyses revealed that, the basalts had an oceanifc ridge basalt character. The relative ages of different units determined from his paleo-magnetic data, are very questionable. His suggestion that the shale-sandstone unit is older than the basalts and peridotites are younger than the dacite dykes contradicts the field observations made in this study. It is clearly observed that the shale sandstone unit covers the basalts and the dacite dykes cut all the ophiolitic units.

Demirbaş (1984) calculated by the cross-section method, that the proven+probable reserves of Aşıköy is 15.24 million tons with an average grade of 1.69 % Cu and 36.73 % S.

MTA with an objective to discover new ore deposits and enlarge the known ones prepared a geological map of an area of 850 km^2 with a scale of 1:25 000 and prospected an area of 100 km? between 1976-1978. As a part of this project, the area including Aşıköy, Toykondu, Bakibaba and Kızılsu ore deposits was also mapped with a scale of 1:5000 and 1: 2000, and the Aşıköy pit with a scale of 1: 1000 (Pehlivanoğlu, 1985).

In another study conducted by the cooperation of Etibank with the Japan international Cooperation Agency (JICA) and Metal Mining Agency (MMAJ), a semi-detailled geological and detailed geophysical prospection of the Aşıköy, Toykondu, Bakibaba and Kızılsu mine districts were carried out (JICA and MMAJ, 1992).

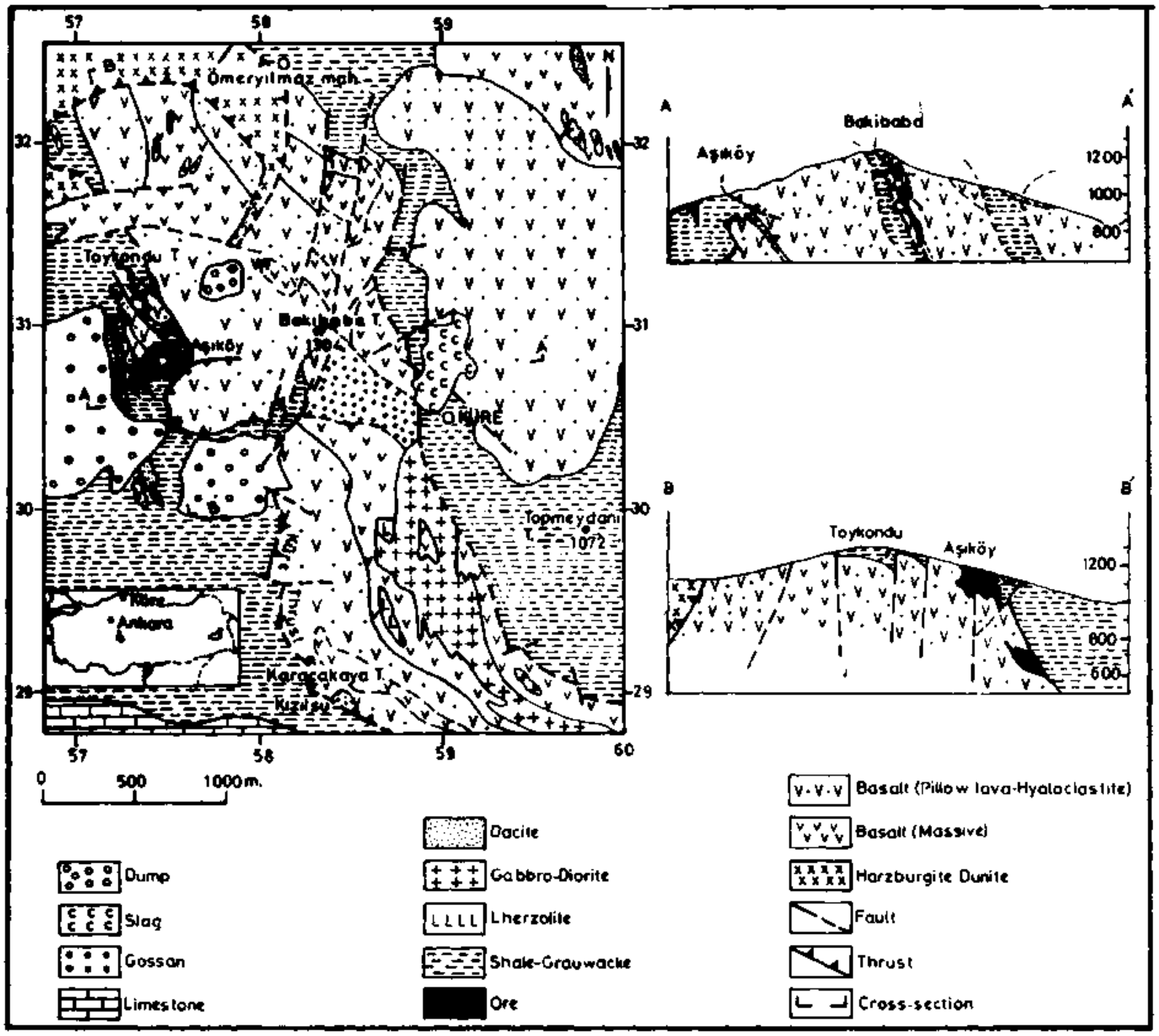

Fig. 1- Geological map and cross-sections of Küre area. Based on Pehlivanoğlu (1985), JICA and MMAJ (1992) with the exception of the mine areas of Aşıköy, Toykondu and Bakibaba.

Recently, Ustaömer and Robertson (1994) studied the petrological characters of the different lithological units of the Küre area and by evaluating their chemical compositions concluded that the ophiolite of Küre represents the slices of a marginal back-arc basin.

This paper is prepared from the results of the detailed geological study of the Aşıköy, Toykondu and Bakibaba ore deposits within the Aşıköy underground mining project signed between Etibank and Teknomad in 1986.

The objective of the work was to determine the geological characteristics of the ore deposits and to calculate the proven reserves. To update the geological data with the progress of the mining operation the detailed surface geological maps of the Aşıköy, Toykondu and Bakibaba areas and underground geological maps of Bakibaba underground mine and Eti gallery were prepared with a scale of 1:1000 (Teknomad, 1988). The logs of the 164 drills from surface and 69 drills from drifts obtained by Etibank in the Aşıköy, Toykondu and Bakibaba areas between 1965-1986 were classified and standardized. The cores of some important drill-holes was re-examined.

Based on the geological maps and drill-hole data, 70 vertical geological cross-sections with 20 m interval and 43 horizontal geological cross-sections with 12 m intervals were prepared for the Aşıköy deposit. Similarly for the Bakibaba deposit 24 vertical and 23 horizontal geological cross-sections and for the Toykondu deposit 20 vertical geological cross-sections were drawn with a scale of 1:1000.

The proven reserves were estimated from the vertical geological cross-sections. The ore tonnages of each grade and structure type were separately calculated for each horizontal slice of the deposit with 12 m of thickness. The results of all the data are summarised in this paper so as to present the general characteristics of Aşıköy-Toykondu massive sulfide deposits.

GEOLOGY OF THE SURROUNDING ROCKS

Küre massive sulfide deposits are situated within the basalts forming the upper unit of the Küre ophiolite (Teknomad, 1988). The Küre ophiolite is formed by harzburgite and dunite tectonite, intrusive gabbro-diorite and Iherzolite, basaltic volcanics and detritic sedimentary rocks. The primary successions of the different ophiolitic units generally dissappeared as a result of strong tectonic activity. The harzburgites forming the lower unit in a normal ophiolitic massive occur on the volcanic and sedimentary unit as tectonic slices. The basalts are generally overthrusted onto their cover, the shale sandstone unit (Fig.1).

The basalts, enclosing rocks, are represented by massive lavas at the bottom and pillow lavas and hyaloclastites at the upper levels. The ore lies essentially in the hyaloclastites. The pillow lavas have ellipsoidal form of which long axis varies between 5-10 cm and 2-3. m Their intertices are filled generally by calcite, argiles and chloritised volcanic glass. They have some separation planes having onion skin form parallel to their external surfaces and millimethc radial tension cracks filled by ore minerals.

Hyaloclastites, are formed by angular elements of basaltic lavas millimetrc to decimetric in size. They are cemented generally by basaltic glass. Some pieces of red jasper can also be seen. The rock has greenish color and is cut by the veins of various thickness, filled by calcite, quartz and ore minerals.

The microscopic examination indicate that the basalts are formed principally by microlites of albitised, sensitised and epidotised piagiodase and by ouralitised and chloritised interstitial augites. Some skeletal augites can also be observed.

The major and trace element analyses of the basalts show that they have oceanic ridge basalt character (Güner. 1980; JICA and MMAJ, 1992; Ustaömer and Robertson, 1994). Basaltic unit is cut by diabasic dykes having centimetric chilled margins and a general strike of NW-SE. Their thickness varies between 20 cm and 10m. They crop out generally in the eastern part of the Aşıköy open pit. They have ophitic texture and are formed essentially by albitised piagiodase and ouralitised augite. Some chlorite, sericite, quartz, magnetite, pyrite, chalcopyrite and ilmenite can be seen. Ustaömer and Robertson (1994) pointed out the existence of some sheeted dykes at the eastern flank of the Bakibaba pit. The lower levels of the basalts are also cut by gabbroic and Iherzolitic intrusive rocks. The gabbros crop out in dyke and batholitic form at the south of Küre. In thin section they represent granular texture and constituted essentially by labrador, augite and hornblende. Some minerals such as olivine, sphene, magnetite are also observed.

The Iherzolites are found as two small intrusions at south of Küre. The first one is enveloped by gabbros and has a triangle form with hectometric dimension. Its contacts are covered. The second intrusion is observed further south than the first one in the basalts. It is in ellips form striking N37W, with 400 m length and 75-100 m thickness. Near the contacts it is brecciated and, some traces of high temperature metamorphism are observed along a zone of about one meter thickness from the contact within the basalts. In thin section the Iherzolites are fresh and have poikilitik texture. Subeuhedral and rounded olivines are included in large pyroxenes. The principal mineralogical constituents of the rock are, olivine ($_{82-88}$), augite, ofthopyroxene (En$_{82-87}$), brown titanian-magnesio-hastingsitic hornblende and kaersutite garnet, rare piagiodase and phlogopite. The secondary formation of the hornblende, garnet and some phlogopite from the pyroxenes and olivines is interpreted as the metasomatisme of the peridotite by an alcaline and hydrous melt. The Iherzolites represent probably the partially melted and uplifted upper mantle and metasomatised later at depth. The origin of the metasomatising melt is questionable. But neverthless it may be related to a subducted slab (Çakır and Genç, 1995).

The basalts are covered by a detritic sedimentary unit represented by shale at the bottom and shale-sandstone alternations towards the top. Shale is dark grey or black in color and characterised by the much less strength relative to the basalts. It is foliated in the fault zones parallel to the fault planes. It is often folded. Along the fold axis the recrystallization of the quartz makes this part harder. It is formed principally by illite, quartz, chlorite and muscovite. The other minerals, such as pyrite, chalcopyrite, chromite, hematite and ilmenite are rarely observed (Güner, 1980). In the Aşıköy open pit, at the basal parts of the sedimentary unit, near the contacts with the basalts, some blocks of basalts are found. On the drill hole cores the basalt-shale alternations are often seen. Pehlivanoğlu (1985), investigating a much wider area, pointed out the existence of the basaltic lava layers in the lower levels of the shale. In the Elekdağ ordered ophiolite, situated at the south- east of Küre and thought to be a continuation of the Küre massif, the basalts lies in alternation with similar sedimentary rocks towards the top (Tüysüz, 1985). This finding is important because it shows that the upper parts of the basalts and lower parts of the shale are formed at the same time and in the same geological environment. The shale-sandstone unit named Akgöl (Ketin and Gümüş, 1962) or Börümce formation (Yılmaz, 1979) lies conformably on the Kayabaşı Upper-Triassic platform limestones at the south of Abana (Önder et al., 1987) and covered unconformably by conglomerates and limestones of Dogger-Malm age at south of Küre (Pehlivanoğlu, 1985). The fossils found in this formation are generally indicative of Lias (Kovenko, 1944, Ketin, 1962) or Upper Trias-Lias (Aydın et al., 1986) in age. The pollens of Upper Carboniferous-Lower Permian age found in this formation (Kutluk and Bozdoğan, 1981) are supposed to be transported from the continent because of the considerable age difference between them and conformable geological situation of this unit on Upper-Triassic limestones. Its general detritic character and the occurrence of some elements of metamorphic rocks in the sandstpne unit (Pehlivanoğlu, 1985) show that the shale-sandstone formation was formed in a basin near a continental margin. From these data, it may be suggested that the volcanic and sedimentary unit representing the upper unit of the Küre ophiolite was formed in an oceanic ridge environment not far from the continental margin in Lias and obducted on the continent in Dogger. In this scheme, it seems that the Küre ophiolite represents the fragments of a narrow and short-lived oceanic lithosphere. For this reason without obtaining systematic geochronological data, the interpretation of Küre ophiolite as a fragments of the Paleo-tethyan oceanic lithosphere (Şengör et al., 1980; Tüysüz, 1985) must be taken with precaution.

The volcanic and sedimentary unit, surrounding rocks of the Küre massive sulfide deposits, are cut by the dacitic and rhyodacitic dykes (Fig.2). In the Aşıköy and Toykondu areas they have a general direction of NW-SE. Their length varies between 150-500 m and thickness between 10-60 m. They contain some blocks of shale which are baked at the contact zones. They are composed of corroded semieuhedral quartz, sericitised plagioclase and chloritised biotite. It is supposed that the dacites and rhyodacites are the dyke form prolongation of the granites and granodiorites cropping out northwest of Küre. Yılmaz and Boztuğ (1986) give a Dogger age for the granitoides of the Daday-Devrekani area having similar geological characteristics and interpret them as the products of northward subduction of the Paleo-Tethyan oceanic lithosphere.

In this case, the oceanisation giving birth to the Küre ophiolite may be interpreted as the result of the same subduction process and that the Küre massif represents the fragments of a back-arc marginal basin. The reaching to the same conclusion from the major and trace elements analyses of different units of Küre area (Ustaömer and Robertson, 1994) fortifies this hypothesis.

STRUCTURAL GEOLOGY

The volcanic and sedimentary unit represented by basalts at the bottom and shale-sandstone at the top is divided into two tectonic units by the Küre thrust (Fig.1). The basalts thrust onto their own cover, i.e. shale-sandstone unit,

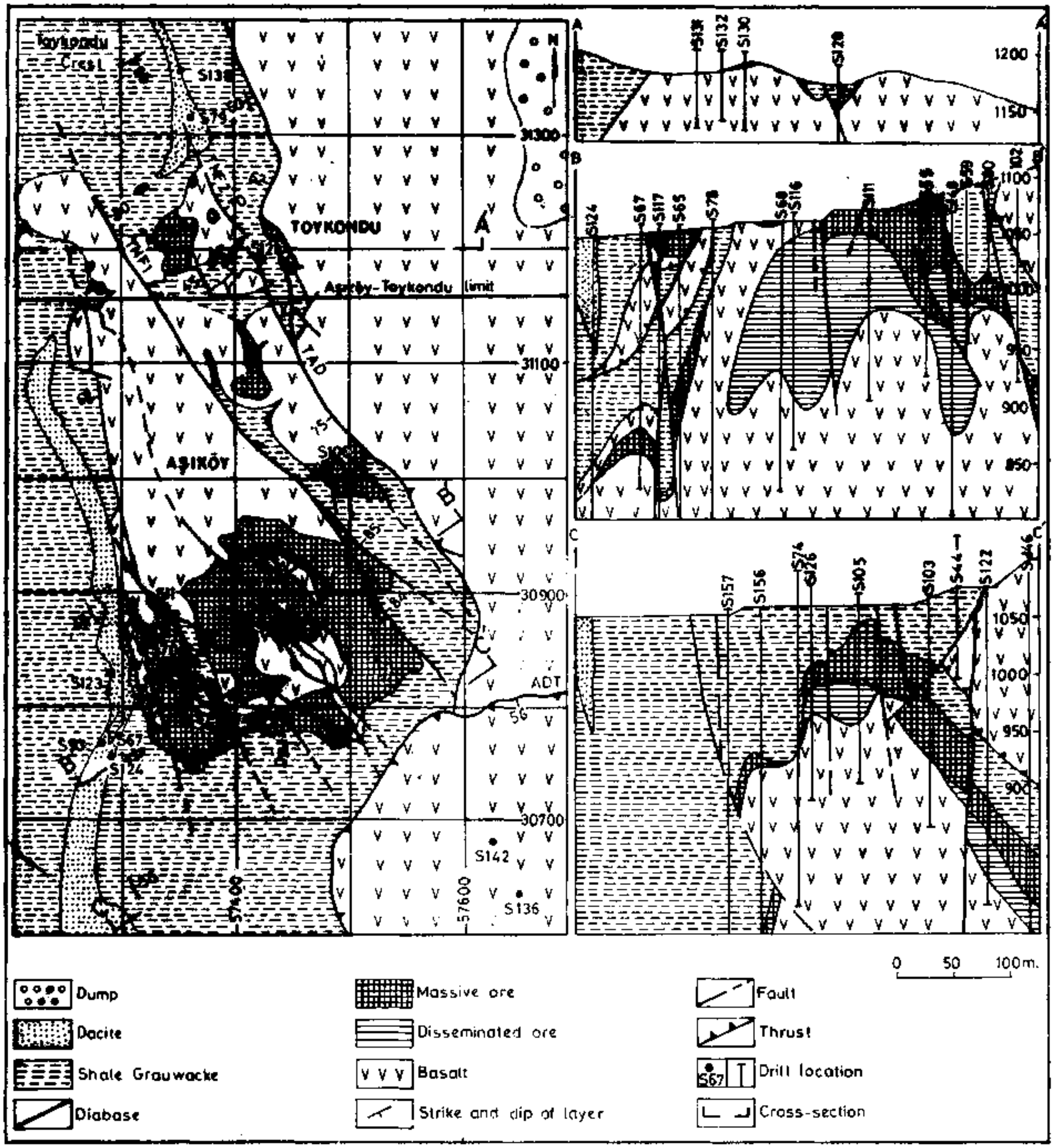

Fig. 2- Geological map and cross-sections of Aşıköy-Toykondu massive sulfide deposits.

along the Aşıköy and Kızılsu line. The western part of the upper slice has generally been eroded. However it is important to observe in places that the shale shows long continuation through the basalts. The shale on the Bakibaba crest having 40 m of thickness can be followed at least 375 m along the dip, with a degree of 65. On the surface and in Bakibaba drift the observation of some non-faulted contacts between the basalt and shale give the impression that this situation could be the result of the initial structural setting. The lower tectonic unit is bordered by TAD fault in the east of the Aşıköy area (Fig.2). This fault begins south of Toykondu pit as a strike slip fault and turns into the reverse strike-slip fault towards the southeast. In Toykondu area its general strike and dip is N30W/73 SW and the lineation measured on the upper mirror is N13W/24SE. It is followed 850 m. In the southeast end, the TAD fault disappeares under the ADT fault. The latter with a brecciated zone of approximately of 15 m thickness is a reverse fault with a sinistral oblique slip. Its strike and dip measured at the intersection zone with TAD fault is N76W/56SW and the lineation is N83E/24SW.

The lower tectonic unit including the Aşıköy ore deposit has a ridge form with a general direction of N45W. It is generally fractured by normal faults usually parallel to the axial plane. The Aşıköy massive appears to have been rotated around a NE-SW oriented axis. The elevated northwest part has been eroded and the lower levels of the basalts crops out. The southeastern part formed by basalt, ore and shale plunges under the basalts of the upper tectonic unit. The general direction and dip of the NE flank of the Aşıköy ridge is N4W/60NE, and that of the SW flank is N87E/62SE (Fig.3). The upper tectonic unit is also fractured by reverse and strike slip faults oriented generally NE-SW direction-Trie latter is important because of their roles of principal guidance for the mineralization in the Bakibaba area.

- It is interesting to point out that various structural elements observed in the volcanic and sedimentary unit of the Aşıköy massive are parallel to each other and show a general direction of NW-SE. Especially the parallel orientation of diabase dykes, gabbroic and lherzolitic intrusions to the Aşıköy ridge axis give the impression that this ridge form represents a primary structure formed in an oceanic environment. Consequently the contradictory situation of the normal faults being parallel to the ridge axis and creating a horst graben system becomes explainable. Bailey et al. (1967) suggests that these faults were formed before the mineralization and created the channels for the mineralising solutions.

In the Aşıköy and Toykondu areas the parallel orientation of the dacitic dykes to the primary structures give the impression that these rocks were injected into the fractures formed during the extensive phase of the Küre ophiolite and represents the product of the same mechanism.

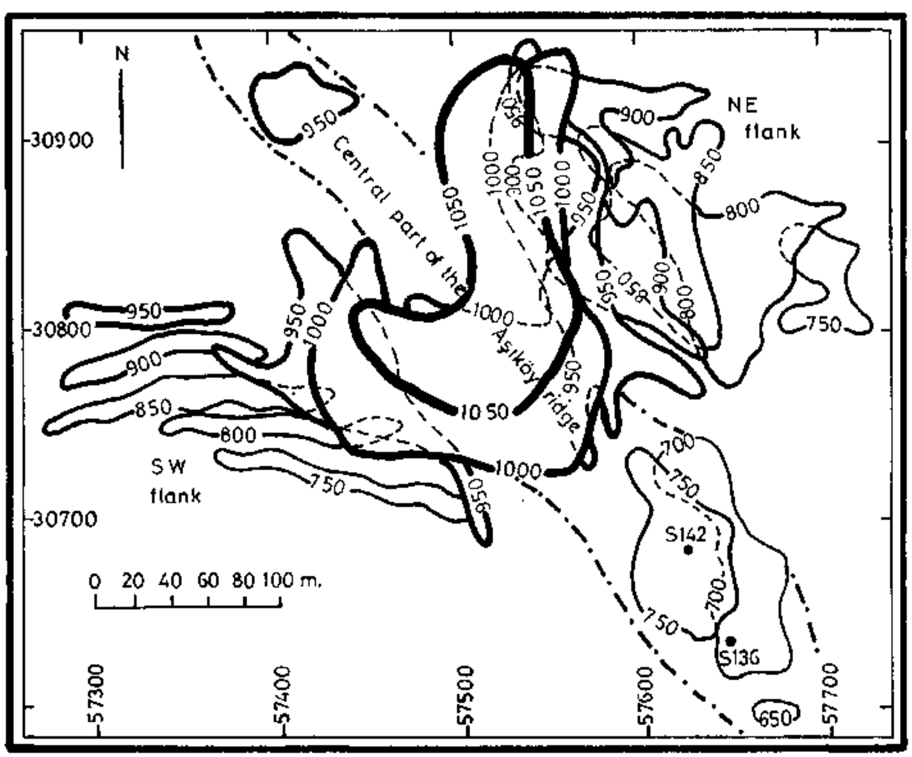

Fig. 3- Isohypse map of Aşıköy massive sulfide deposit.

GEOLOGY OF THE ORE DEPOSITS

The ore deposits in Aşıköy and Toykondu are-as occur:

1- As lenses of different dimensions in the upper levels of the basalts. Right under the shale, the ore has a massive structure and the axial planes of the lenses are parallel to the basalt-shale contact plane. Towards the lower levels, it becomes partially stockworked and disseminated.

2- As the discontinous and non-determined shaped mass at the top of the secondary anticline between basalt and shale. The structure of the ore has the same properties. The ore deposits at the south of Toykondu are the characteristic examples of this type.

The Aşıköy ore deposit is the most important mineralization of Küre. It forms the upper parts of the Aşıköy ridge of which the axis has a general direction of N45W and dip of 38-60 SE (Fig.2). In the southwest it plunges with a dip of 55 degrees. The northwest flank, the most important part of the deposit, continues under the shales and the basalts of the upper tectonic unit. The southwest flanc lies under a thick shale unit.

The central part of the Aşıköy deposit is bounded by a shale observed along the SII, S70, S78 at the Southwest (Fig. 2). The ore block at the west of this shale is interpreted as a thin slice because of the presence of two levels of ore and basalt along the drill of S65, S67, and S117. The two orebodies, i.e. the one drilled by S106 and the other situated 100 m away from the former, form discontinuous mass of a thickness of maximum 25 m at the roof of the secondary anticlines.

An important orebody which does not crop out is discovered by the drill holes of S136 and S142. It shows that the main mineralization of Aşıköy follows the ridge axis along N45W/55SE and forms thick ore lenses in places.

The Toykondu ore deposit is situated at the northwest of the Aşıköy open pit (Fig.2). The orebodies between the faults TNF1 and TNF2 occupy the roof of the secondary anticline. Their* axial orientation is N85E/62SW and they have an average thickness of 5 m.

The orebody at the east of S128 forms a lense having 50 m of length, 10 m of width and 5 m of thickness. The direction and dip of its axial plane is N25W/65SW. The drill-holes S79, S128 and S138 indicated that its thickness reaches 13 m between the depths of 50 m-75 m.

In the upper levels of the basalts at the west of the TNF1 fault small orebodies could be seen in places. This mineralization zone has a N-S general direction and a dip of 50-70 to the west. The cutting of some ore levels by the drill-holes of S93, S123 and S124 shows that this zone continues at least 360 m towards the south and forms massif ore lenses in places.

MINERALOGY

The ore deposits of Toykondu and Aşıköy have very similar mineralogical characteristics. The principal ore minerals are chalcopyrite and pyrite. Some marcasite, sphalerite, covelline and neodigenite are also observed. The rare minerals are bravoite, linneite, tetrahedrite, goethite, hematite, chromite, rutile, anatase, chalcosine, tenorite, magnetite, pyrrhotite, bornite and native gold. The gangue is represented by calcite, siderite and quartz. The microscopical characteristics of the main ore minerals were described in detail by Çağatay et al., (1980), Güner (1980) and Pehlivanoğlu (1985). They may be summarised as follows:

Pyrite constitutes the major party of the ore. It is idiomorphe and generally smaller than 1 mm in size. Some melnicovite having colloforme structure can also be seen. The cracks of the idiomorphic pyrite are filled by chalcopyrite, melnicovite and gangue minerals, showing that it is the mineral formed first. It is replaced by chalcopyrite along the cleavages and its borders are corroded. Economically, chalcopyrite is the most important mineral. It is generally interstitial between the pyrites and fills the cracxs of the pyrites. Along its cleavages and cracks it is replaced by neodigenite and covelline (Çağatay et al., 1980; Güner, 1980; Pehlivanoğlu, 1985).

Bravoites and pyrites form some zoned structures having a thickness of 5-30 microns.

Linneite is the most important cobalt mineral observed in the Küre massive sulfide deposits. It occurs as idiomorphic and semi-idiomorphic minerals smaller than 200 micron in chalcopyrite and chalcopyrite rich sections.

Native gold occurs as very fine grains smaller than 30 micron generally along the contacts between chalcopyrite. idiomorphe pyrite, bornit and along the cracks in these minerals.

RESERVES AND GRADE VARIATIONS

The proven reserves of the Aşıköy and Toykondu deposits were calculated by the prism method from the cross-sections perpendicular to the direction of the Aşıköy ridge at intervals of 20 m. The ore tonnages and grades variations of different structural units of the deposit for each mine levels were determined separately. The ore is classified into six types according to their Cu and S grades. The grade ranges for open pit and underground mine are presented on Table 1.

Table 1- Classification of ore types in the Aşıköy and Toykondu Deposits.

Ore type	Symbol	Open pit mine Grade(g) Cu%	S%	Underground mine Grade(g) Cu%	S%
Massive high grade	MH	g≥2	g≥34	g≥3	g≥34
Massive medium grade	MM	1≤g<2	g≥34	1.5≤g<3	g≥34
Massive low grade	ML	0≤g<1	g≥34	0≤g<1.5	g≥34
Disseminated high grade	DH	g≥2	g<34	g≥3	g<34
Disseminated medium grade	DM	1≤g<2	g<34	1.5≤g<3	g<34
Disseminated low grade	DI.	0.5≤g<1	g<34	0 5≤g<1.5	g<34

The density of different type of ore is approximated from the relationship obtained from grade-density measurements. The results are presented on Tables 2,3 and 4 separately for the different parts.of the deposit, types of ore and mining levels.

The Aşıköy ore deposit is planned to be extracted by open pit method till it reaches 936 m level and by underground method between 936 m and 756 m. The present lowest level in the open pit is 1140. m. The preparation for underground mining is in progress.

It can be seen from the tables that the northeast flanc represents the most important reserves of the Aşıköy ore deposit in terms of quantity and grade.

In the Toykondu area the grade is high, but the reserve is very low. The maximum depth of the ore is 90 m. It is to be extracted by open pit method.

The Küre massive sulfide deposits also contain gold and cobalt. Çağatay et al. (1980) estimated that the average grades of cobalt and gold of Küre deposit are 0,3 % and 2,48 g/t respectively. In Toykondu area, the average grades of cobalt and gold calculated from 12 m of massive ore cores obtained in 1993, were 0,016 % and 1,55 g/t respectively. Although these grades appears to be low in the massive ore, it is expected that the grades of the gold in the desulphurated alteration zones will be as high as it can be, to be considered as a gold deposit.

DISCUSSION ON MINERALIZATION

Aşıköy-Toykondu massive sulfide deposits are interpreted as being formed during a submarine volcanism in Lias and subsequent hydrothermal process. All the deposits occurs at the upper levels of the basalts. However in the lower parts of the shale covering the basalts some thin levels of pyrite can be seen. Especially the occurrence of some breccia formed by angular pieces of pyrite and cemented by shale and pyrite (Kamitani and Çamaşırcıoğlu, 1976) shows that the mineralization continued during the sedimentation of the first levels of the shale.

In the south of Toykondu pit, it is observed that the pillow lavas forming the upper levels of the basalts are entirely replaced by the ore. This proves that the mineralization taking place after the volcanism includes a replacement process.

Table 2- Proven Reserves of the Aşıköy Open Pit Mine (surface-936 m).

Part of Deposit	*Ore Type*	*Average Cu%*	*Grade S%*	*Density*	*Reserve (tonne)*
Northeast Flank	MH	3,79	44,30	4,5	119001
	MM	1,61	40,93	4,4	674080
	ML	0,71	43,08	4,3	469904
	DH	2,69	29,24	3,7	28415
	DM	1,76	26,42	3,6	44928
	DL	0,66	17,01	3,3	452534
	Total	2,23	35,33		2859874
Central Part	MH	2,94	45,72	4,5	346869
	MM	1,30	44,45	4,3	985043
	ML	0,17	40,31	4,1	574615
	DL	0,86	20,15	3,2	797620
	Total	1,14	36,56		2704147
Southwest Part	MH	2,67	41,74	4,4	360800
	MM	0,76	45,89	4,5	157500
	DH	2,48	27,05	3,7	2620
	DL	0,81	26,05	3,5	948500
	Total	1,26	32,03		1469420
Grand Total		1,61	35,11		7033441

Table 3- Proven Reserves of the Aşıköy Underground Mine (936m-756 m).

Part of Deposit	*Ore Type*	*Average Cu%*	*Grade S%*	*Density*	*Reserve (tonne)*
Northeast Flank	MH	6,29	44,22	4,6	857440
	MM	1,94	44,17	4,4	254144
	ML	0,65	43,20	4,3	536124
	DH	3,69	27,48	3,8	234992
	DM	1,66	19,11	3,4	6664
	DL	0,75	13,18	3,1	447659
	Total	3,18	36,27		2337023
Central Part	DL	0,89	21,28	3,2	129138
	Total	0,89	21,28	3,2	129138
Southeast Flank	MH	3,35	42,72	4,5	26100
	MM	2,38	42,81	4,3	283628
	ML	0,88	40,02	4,2	122808
	DH	3,15	28,08	3,8	44785
	DL	0,60	17,72	3,3	250272
	Total	1,60	32,80		727593
Grand Total		2,73	34,88		3193754

Table 4- Proven Reserves of the Toykondu Open Pit Mine

Part of Deposit	*Ore Type*	*Average Cu%*	*Grade S%*	*Density*	*Reserve (tonne)*
North Part	MH	6,04	42,83	4,5	101700
	ML	0,32	39,17	4,2	28560
	DL	0,55	23,87	3,5	10780
	Total	4,47	40,64		141040
South Part	MH	2,59	35,76	4,3	17974
	MM	1,84	45,60	4,4	16940
	Total	2,26	40,53		34914
Grand Total		4,03	40,62		175954

The orebody does not contain any high temperature minerals. Some high temperature minerals such as magnetite, ilmenite and chromite rarely observed in the basalts are believed to be contemporaneous with these rocks. The minerals such as melnicovite, chalcopyhte and gangue form colloform structure indicating a low temperature formation. From these data it may be suggested that the mineralization comprised of hydrothermal and sedimentary process. Thereby the Aşıköy and Toykondu deposits can be considered analogues to that at the modern oceanic spreading centres. An especially well observed example lies along the axial ridge of the Galapagos spreading center in the East Pacific rise (Corlis et al., 1979; Haymon and Kastner, 1981).

As it is cited from Koski (1983), "This mineralization results from large scale circulation of seawater through basaltic basement along the fracture zones near the technically active axis of spreading. The high geothermal gradient above 1 to 2 km-deep magma chambers emplaced below the ridge axis drives the convective circulation cell. Cold oxidizing sea-water penetrating the crust becomes heated and evolves into a highly reduced somewhat acidic hydrothermal solvent during interaction with basaltic wall-rock. Depending on the temperature and water/rock ratio, this fluid is capable of leaching and transporting the ore metals. Dissolved sea-water sulphate is reduced to sulfide. Consequently metal sulfides are precipitated along channelways and replaced the wall-rock from ascending fluid. Vigorous fluid flow results in venting of reduced fluid at the sea-floor/sea-water interface and deposition of ore minerals."

In Küre deposits following data indicating the remobilization of ore posterior to the principal mineralization is observed:

1 - In Toykondu area some of the orebodies occur along the axis of the secondary anticlines oblique to the primary structures. They were probably formed during or after the obduction of the Küre ophiolite.

2- The ore right under the shale is generally massive and Cu rich, and becomes stockworked and disseminated downwards.

3- In Bakibaba area the mineralization also occurs as discontinuous veins in the fracture zones.

4- The cracks of idiomorphic pyrites, the first mineral in paragenesis, are filled by chalcopyrite.

The results obtained by Pehlivanoğlu (1985) indicate that some of the sulfide mineralizations is associated with the granitic intrusions of Dogger age. It appears that the granitic intrusions increases the temperature of the environment and causes the remobilization of some mobile elements. They consequently formed the secondary mineralization by precipitation and replacement mainly under the shale which did not allow the mineralising solutions to penetrate.

CONCLUSIONS

The Küre massive sulfide deposits constitute a typical-example for a mineralization in ophiolitic volcanic rocks. They probably occurred near the spreading axis of a narrow and short-lived back-arc marginal basin at Lias and obducted on continent at Dogger.

Aşıköy ore deposit occurs at the upper levels of the Aşıköy ridge. As proven reserves, it contains 10,2 millions tons of ore with average grade of 1,96 % Cu and 35 % S.

Toykondu deposit is smaller with 176 000 tons of proven reserves and average grade 4% Cu and 40,6 %S.

Küre massive sulfide deposits also contain cobalt and gold. Their grade distribution within the deposit is not well known because of insufficient number of assays obtained from drill cores. Therefore it will be very useful to investigate especially gold distribution in Küre area by assaying the old core samples and the samples taken sistematically from the atmospheric alteration zones.

ACKNOWLEDGEMENTS

This paper is based on the study carried out as a part of the project signed between Teknomad and Etibank. I would like to thank the management of Etibank Küre Mine, Project Implementation and Mineral Research Departments of Etibank for their support for the project. I also thank Hacı Karakuş, geologist, who collaborated with me on the field and office, Assoc. Prof. Taylan Lünel and his team who started the project and obtained the first resulsts.

Manuscript received May 9,1994

REFERENCES

Aydın, M.; Şahintürk, O.; Serdar, H.S.; Özçelik, Y.; Akarsu, İ.; Üngör, A.; Çokuğraş., R. and Kasar, S., 1986, Ballıdağ-Çangaldağı (Kastamonu) arasındaki bölgenin jeolojisi. Geol. Bull of Turkey, 29, 1-16.

Bailey, E.H.; Barnes, J.W. and Kupfer, D.H., 1967, Geology and ore deposits of the Küre District, Kastamonu Province, Turkey: Shields, L.L. (Ed.) CENTO summer training program in geological mapping techniques Küre, Turkey, part II, CENTO, 17-75, Ankara.

Corliss, J.B.; Dymond, J.; Gordon, L.I.; Edmond, J.M.; vanHerzen, P.P.; Ballard, R.D.; Green, K.; Williams, D.; Bambridge, A.; Crane, K. and vanAndel, T.H., 1979, Submarine thermal springs on the Galapagos Rift: Science, 203, 1073-1082.

Çağatay, A.; Pehlivanoğlu, H. and Altun, Y., 1980, Küre piritli bakır yataklarının kobalt-altın mineralleri ve yatakların bu metaller açısından ekonomik değeri: MTA Bull., 93/94, 110-117, Ankara, Turkey.

Çakır, Ü. and Genç, Y., 1995, Küre ofiyolitinde flogopitl and granatli lerzolit intruzyonlan: 30th. Ann. Sym. of the Geol. Dept. at KTÜ, Abstracts, 23, Trabzon.

Demirbaş, T.T., 1984, Aşıköy rezerv hesabı raporu: Etibank Rep., Maden Arama Dairesi Başkanlığı (unpublished), Ankara.

Güner, M., 1980, Küre civarının masif sülfid yatakları ve jeolojisi, Pontidler (Kuzey Türkiye): MTA Bull., 93/94, 65-109, Ankara, Turkey.

Haymon, R.M. and Kastner, M., 1981, Hot spring deposits on the East Pacific Rise at 21°N: preliminary description of mineralogy and genesis: Earth Plan. Sci. Let, 53, 363-381.

J.I.C.A. and M.M.A.J., 1992, The Republic of Turkey report on the mineral exploration of Küre area: Etibank Rep., Etibank Genel Müdürlüğü (unpublished), Ankara.

Kamitani, M. and Çamasırcıoğlu, A., 1976, Kastamonu-Küre'nin batı kısımlarındaki cevherleşme ve jeolojisi: MTA Rep., 1335 (unpublished), Ankara.

Ketin, I. 1962, 1:500 000 ölçekli jeolojik harita ve izahnamesi (Sinop): MTA Yayl., Ankara, Turkey.

——— and Gümüş, Ö., 1962, Sinop, Ayancık ve güneyinde, III. bölgeye dahil sahaların jeolojisi hakkında rapor: TPAO Rep. No. 288 (unpublished), Ankara, Turkey.

Kovenko, V., 1944, Küre'deki eski bakır yatağı ile yeni keşfedilen Aşıköy yatağının ve Karadeniz Orta ve Doğu kesimleri sahil bölgesinin metallojenisi: MTA Bull., 2/32, 180-211, Ankara.

Kutluk, H. and Bozdoğan, N., 1981, IV. Bölge Üst Paleozoyik-Alt Mesozoyik çökelleri palinoloji ön raporu: TPAO Rep., 1545 (unpublished), Ankara, Turkey.

Önder, F.; Boztuğ, D. and Yılmaz, O., 1987, Batı Pontidlerdeki Göynükdağı-Kastamonu yöresi Alt Mesozoik kayaçlarında yeni paleontolojik (Konodont) bulgular: Melih Tokay Geol. Symp., 87, Abstracts, 127-128, Ankara.

Pehlivanoğlu, H., 1985, Kastamonu-Küre piritli bakır yatakları (Bakibaba-Aşıköy) ve çevresinin jeoloji raporu: MTA Rep., 1744: (unpublished), Ankara, Turkey.

Şengör, A.M.C.; Yılmaz, Y. and Ketin, İ., 1980, Remnants of a pre-Late Jurassic ocean in northern Turkey: Fragments of Permian-Triassic Paleo-Tethys?. Geol. Soc. Am. Bull. Part 1, v. 91, 599-609.

Teknomad, 1986, Etibank-Küre masif sulfid yatakları (Aşıköy-Toykondu-Bakibaba) Jeoloji ve rezerv-kalite raporu: Etibank Rep. (unpublished), Ankara, Turkey.

______, 1988, Aşıköy-Toykondu-Bakibaba masif sülfid yatakları cevherleşmenin oluşum modeli ve arama progamı raporu: Etibank Rep. (unpublished), Ankara, Turkey.

______, 1991, Etibank-Küre Aşıköy yeraltı işletme projesi, cevher yatağı modellemesi ve rezerv hesapları revizyonu raporu: Etibank Rep. (unpublished), Ankara.

Tüysüz, O., 1986, Kuzey Anadolu'da iki farklı ofiyolit topluluğu: Eski ve Yeni Tetisin artıkları: Doğa Tr. Müh. and Çev., 10, 2, 172-179.

Ustaömer, T. and Robertson, A.H.F., 1994, Late Palaeozoic marginal basin and subduction-accretion: The Palaeotethyan Küre Complex, Central Pontides, northern Turkey: Jour. Geo. Soc., 151, 291-305, London.

Yılmaz, O., 1979, Daday-Devrekani masifi kuzeydoğu kesimi metamortik petrolojisi: Docentlik Tezi, Hacettepe Üniversitesi, Jeo. Müh. B61.176 p. Ankara.

Yılmaz, *O. and Boztuğ, D., 1986, Kastamonu granitoid belt of northern Turkey: First arc plutonism product related to the subduction of the paleo-Tethys. Geology, 14, 179-183.