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THE GEOLOGY, GEOCHEMISTRY AND GENETICAL FEATURES OF THE ORMANBAŞI HILL (SİNCİK, ADIYAMAN) COPPER MINERALIZATION

Nail YILDIRIM*, Semiha İLHAN**, Esra YILDIRIM*** and Cahit DÖNMEZ****

ABSTRACT.- The study area covers Ormanbaşı Hill of Adıyaman–Sincik County and its vicinity. Regional geological locations of Cu mineralizations that lie between the Southeastern Anatolian Foothill Belt and Taurus Orogenic Belt are conformable with thrust planes approximately extending in E-W directions. Cu mineralizations are observed in the form of lenses and layers within mudstone, diabase, spilite and claystone - shales of the Koçali complex. The primary genetic relations of these formations have completely been disappeared but have only been traced along thrust planes that are conformable with general tectonic lineaments. The ore structure is generally massive but is stockwork and disseminated in some zones. The ore bearing layer with pyrite towards deeper parts is observed, while the mineralization is observed in the form of iron ore cap (gossan) at surface. Ore paragenesis consists of pyrite, marcasite, chalcopyrite, sphalerite, bornite, chalcosine - covelline and native copper. All samples belonging to ore mineralizations plot on Cyprus type volcanogenic massive sulfide (VMS) area in Cu – Pb - Zn and Au - (Cu + Pb + Zn) - Ag ternary diagrams. All samples in Pb, Cu, Ag, Au and Zn spider diagrams which were normalized to primary mantle show a trend similar to VMS deposits. Besides, analyses carried out in massive pyrites indicated that these had Ni/Co ratio higher than 1% and less Ni content. Therefore; it was detected that hydrothermal processes had been affective in ore mineralizations. S^{32}/S^{34} ratios were obtained as 6.9 and 7.6 in sulfur isotope analyses performed by using pyrite and chalcopyrite samples. These values are both compatible with sulfur ratios in hydrothermal solutions related to volcanism and show a similar composition with that of Cyprus type VMS deposits on the world.

Keywords: Adıyaman, Sincik, Koçali complex, Cyprus type, VMS, Copper

INTRODUCTION

PURPOSE OF THE STUDY

The study area is located between the Southeastern Anatolian Fold Belt and Tauride Orogenic Belt and possesses a significant potential in terms of base and precious metals. Especially; the Adıyaman territory forms a rich sub region in terms of Cu mineralization. Numerous Cu anomalies were detected during prospective and geochemical studies which had been performed by MTA along the Southeast Anatolian Thrust Belt around the region (Cengiz, 1991). One of them is the Ormanbaşı Hill mineralization which is located at the southeast of Sincik, Adıyaman (Gültekin, 2004; Yıldırım 2011). The aim of this study is to define the mineralization model and contribute to the detection of similar mineralizations within the same belt zone by this method.

GEOGRAPHICAL LOCATION

The study area is located at Ormanbaşı Hill site within the boundary of Zeynelaslan settlement which is 20 km southeast of Sincik County of Adıyaman City and is 78 km away from Adıyaman city (Figure 1).

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* Maden Tetkik ve Arama Orta Anadolu IV. Bölge Müdürlüğü, 44100 Malatya

** Çukurova Üniversitesi, Mühendislik ve Mimarlık Fakültesi, Jeoloji Mühendisliği Bölümü, 01330 Balcalı/Adana

*** Fırat Üniversitesi, Mühendislik Fakültesi, Jeoloji Mühendisliği Bölümü, 23100 Elazığ

**** Maden Tetkik ve Arama Genel Müdürlüğü Maden Etüt ve Arama Dairesi, 06520 Ankara

Figure 1- Location map of the study area

PREVIOUS STUDIES

Many geological investigations have been carried out in and around the study area with different purposes. General and structural geological studies were carried out by Kovenko (1943), Tolun (1955), Rigo de Righi and Cortesini (1964), Altınlı (1966), Ketin (1966), Pişkin (1972), Yazgan (1972), Özçelik (1985), Sungurlu (1973, 1974), Yalçın (1976), Perinçek (1978,1979), Perinçek and Kozlu (1984), Yazgan and Asutay (1987), Yılmaz et al. (1992), Yiğitbaş et al. (1992, 1993), Parlak et al. (2004, 2009), Parlak (2006), Beyarslan et al. (2009), Yıldırım (2010), Uzunçimen et al. (2011). These studies have great significance in revealing the regional geological model and understanding the mineralization in the region. As to the studies related with the topic, the article was summarized below in more detail.

Turgay (1968) stated that there had been two types of ore mineralization in the region in a copper prospection project carried out in Siltikuş Hill (Ormanbaşı Hill), Sincik Settlement, Kahta – Adıyaman. He defined the primary type mineralizations as diabase and exhalative sedimentary copper – pyrite deposits. However; the secondary type mineralization was defined as ore veins belonging to a hydrothermal facies of an acidic magma.

Şaşmaz et al. (1999) stated that ore mineralizations they had detected in Çüngüş Derdere Site, Diyarbakır indicated the general features of Cyprus type deposits located at the upper horizons of an ophiolitic deposit which was formed as a result of the sea-floor spreading.

Gültekin (2004) stated that Ormanbaşı Hill mineralizations had been traced along tectonic lineaments. He also defined that mainly the units belonging to Pütürge metamorphics, Koçali complex and Çüngüş formation cropped out in the region and limonitization were the common type of alteration in this area. The author also stated that the mineralizations over the area were suitable to epithermal type of mineralization because of the presence of minerals indicating the low temperature conditions and structural – textural features.

Türkyılmaz (2004) defined that manganese mineralizations within the Koçali complex were in the form of irregular lenses and layers in pelagic radiolarites which belong to the Konak formation and that these mineralizations were exhalative hydrothermal in origin.

REGIONAL TECTONICS AND GEOLOGY OF THE STUDY AREA

The investigation area is located at the boundary of Southeast Anatolian Thrust Belt and Tauride Orogenic Belt (Ketin, 1966).

The Southeast Anatolian Orogenic Belt has developed as a result of geological events that had occurred during the closure of the southern branch of Neotethys which was bordered by Taurus at north and Arabian Platforms at south between Late Cretaceous – Miocene time period. The evolution of this belt especially consists of the movement of nappes relatively to the south, Arabian Plate between Late Cretaceous – Miocene (Yıldırım and Yılmaz 1991; Yılmaz, 1993; Yılmaz et al., 1993).

Southeast Anatolian Orogenic Belt consists of three different tectonic units which are E - W trending and separated from each other by north dipping main thrust planes (Yılmaz, 1990, 1993; Yılmaz et al., 1993). These tectonical units from north to south are the Nappe zone, Accretional Prism and the Arabian Platform (Figure 2).

The intensive tectonical activity that occurred at the end of Cretaceous and Miocene and caused the settlement of allochthonous units on the region has also given rise to the development of marine deposition at the same period and to the closure of the basins. Allochthonous units have taken their recent positions at the end of Upper Miocene as gravity sliding and overthrust sheets.

Units cropping out in and around the study area were investigated in two parts as allochthonous and autochthonous (lower and upper series) considering their locations in the region and mutual relations with neighboring units.

Late Cretaceous Koçali complex has tectonically been settled on Karadut complex (lower allochthonous series) at bottom and on the Kastel formation forming the uppermost horizons of the

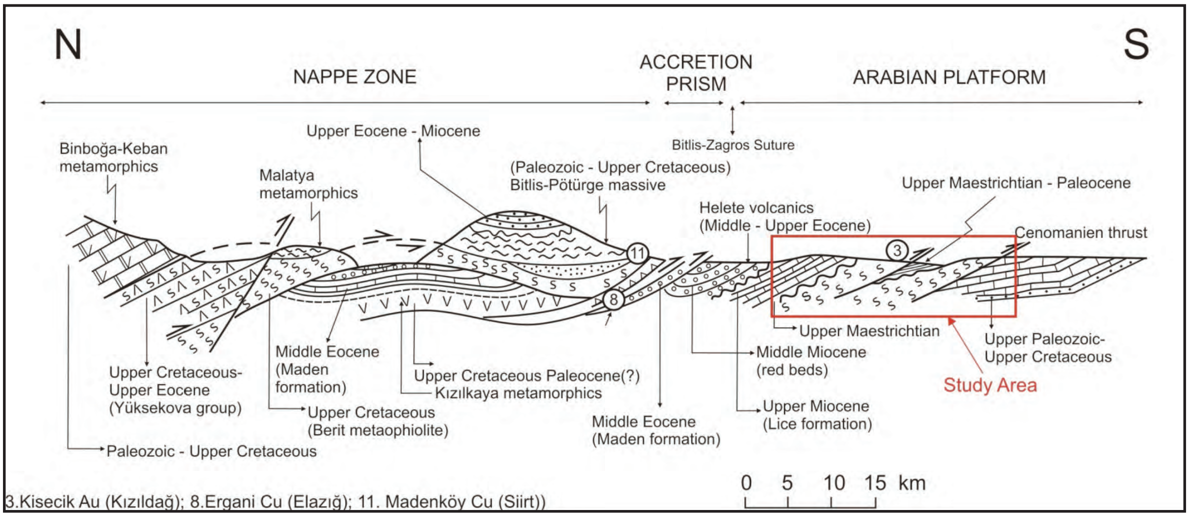

Figure 2- Structural model of SE Anatolian Orogenic Belt (modified from Yılmaz, 1993)

Arabian Plate. These are uncomformably overlain by Upper Maestrichtian – Paleocene transgressive deposits (Terbüzek formation, Besni formation and Germav formation) of the Arabian Platform belonging to the Autochthonous Series. The region has been transgressed at the beginning of Eocene and Lower Eocene – Lower Miocene transgressive deposits (Gercüş formation, Midyat formation, Gaziantep formation and Fırat formation) have uncomformably overlain units at bottom. Lice formation which is formed by the alternation of shale – marl – sandstone unconformably overlies this unit (Figures 3, 4 and 5).

The Çüngüş Formation belonging to the Upper Allochthonous Series, Maden complex, Kömürhan ophiolite (Yüksekova ophiolite) and Pütürge metamorphic tectonically settled over Autochthonous units in Middle – Upper Miocene. Since these tectono-stratigraphical units were tectonically associated with each other, their primary relations in them were completely disappeared (Figures 3, 4 and 5).

Since ore mineralizations in the study area has been observed in Koçali complex, this deposit has been mentioned below in more detail.

KOÇALİ COMPLEX

Sungurlu (1973) is the first investigator who nomenclatured and mapped the Koçali complex in three different formations as Tarasa, Konak and Kale formation. Tarasa formation is composed of volcanites (basalt, diabase, spilite), Konak formation is composed of the al-

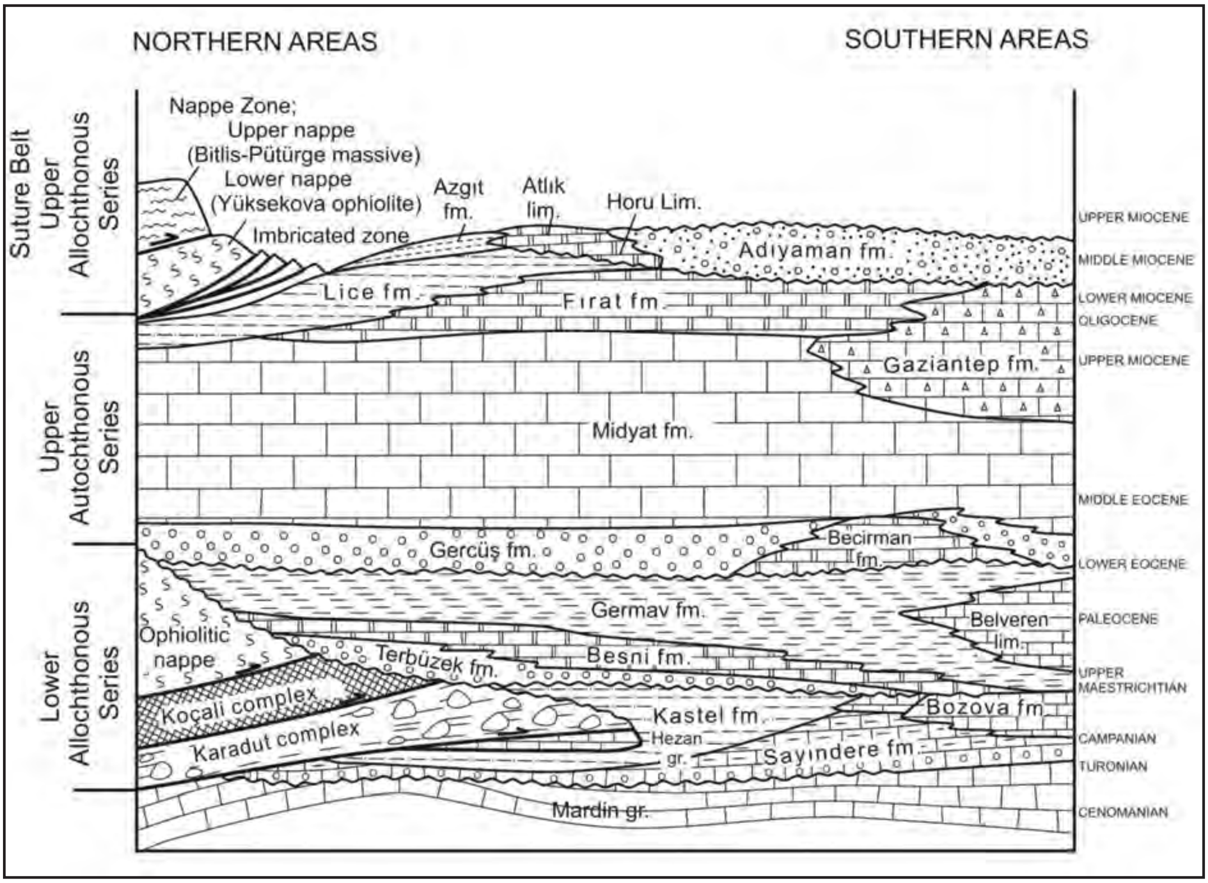

Figure 3- Generalized structural cross section of the Arabian Platform in SE Anatolia, from the suture zone at north to the north of Arabian Platform at south (modified from Yılmaz, 1993)

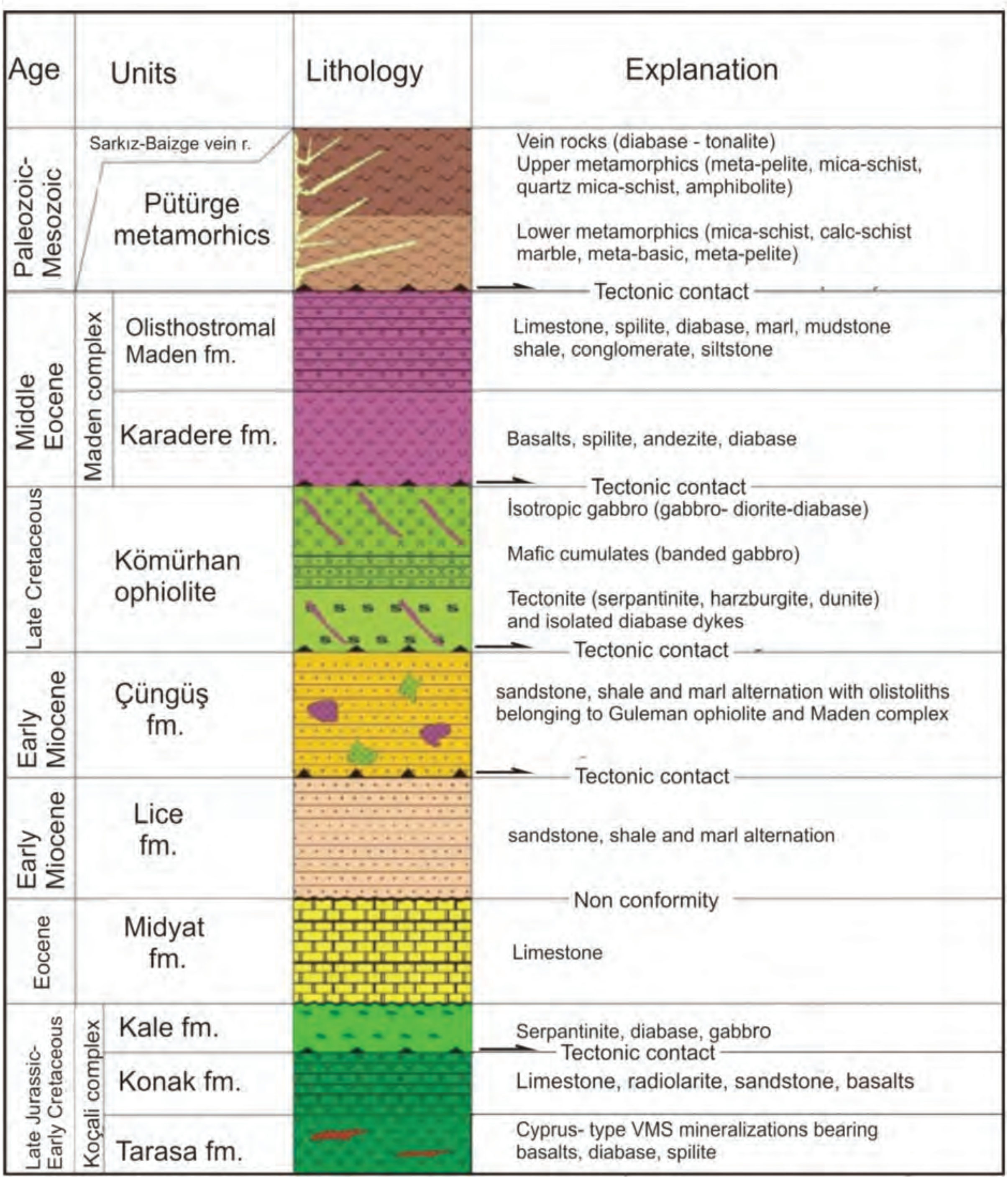

Figure 4- Tectono-stratigraphic columnar section of the study area (modified from Yıldırım, 2010)

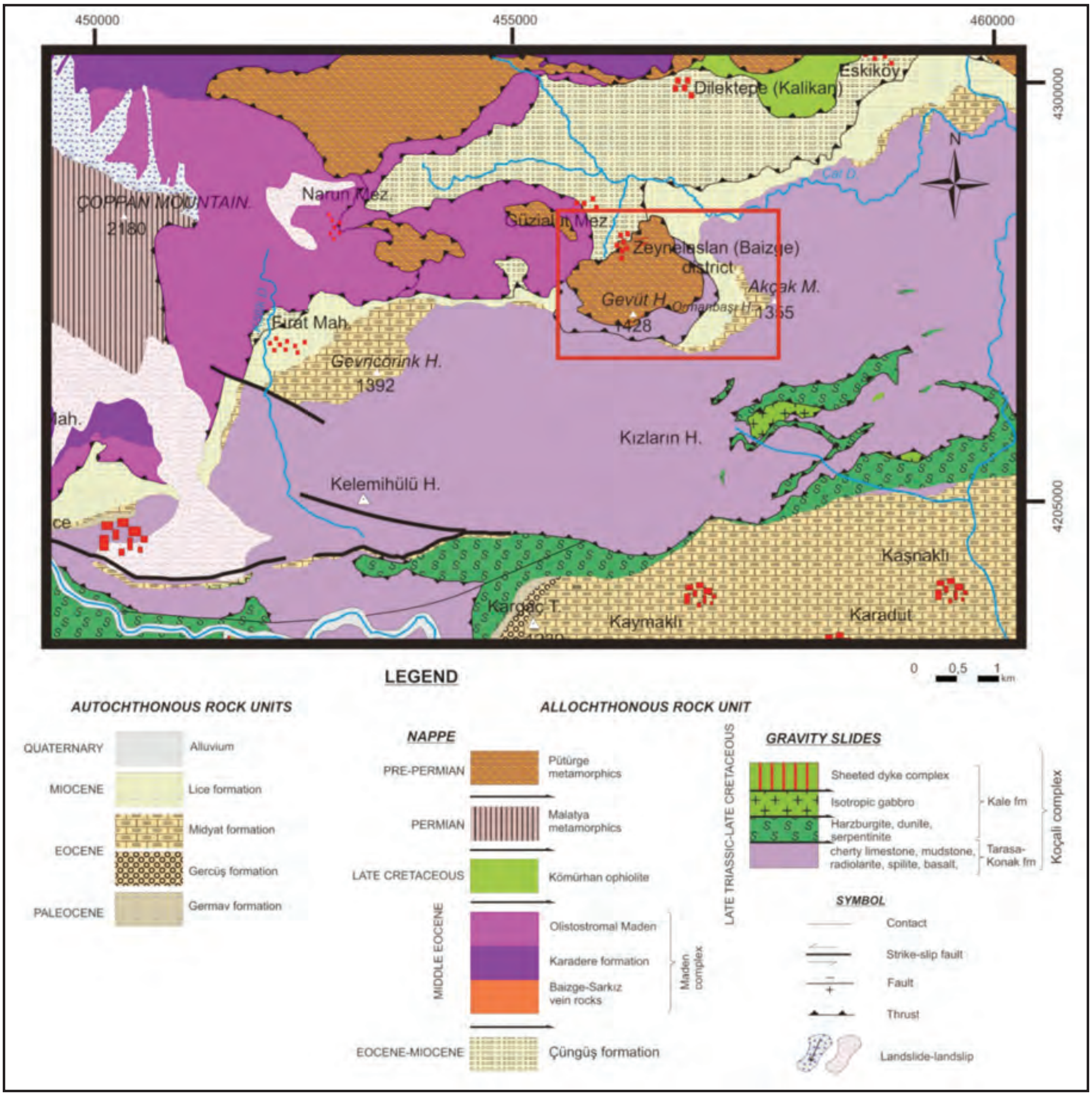

Figure 5- Geological map of the study area and its vicinity (modified from Perinçek, 1978, Herece, 2008)

ternation of sediments with volcanites and Kale formation is composed of serpentinite and diabase assemblages (Perinçek, 1978; Figure 4). The relations among these units are generally tectonics.

The age of the Koçali formation was given as Upper Jurassic – Lower Cretaceous by Sungurlu (1973). Koçali complex has been accepted as a part of Tethys Ocean which emplaced over the Arabian platform by gravity slides in Campanian–Maestrichtian (Rigo de Righi and Cortesini, 1964, Sungurlu, 1974; Perinçek, 1978). Yılmaz (1993) admits that Koçali complex was formed by ophiolitic melange and sedimentary blocks. He also accepts that the ophiolitic rocks which formed under oceanic regime at north of the Arabian Platform and ensimatic island arc materials which developed due to the north dipping subduction were formed by block and tectonic slices which emplaced on the Arabian Platform in Upper Cretaceous. Bingöl (1993 *a, b*) states that Koçali complex was formed by an extensional zone over intra-oceanic subduction zone dipping north and by a submarine volcanism outside the extensional axis or by an arc volcanism which was then pushed over the northern edge of the Arabian Platform during Campanian – Maestrichtian. Uzunçimen et al. (2011) indicated that Koçali Complex consists of pelagic sediments (such as pelagic limestones and cherts) together with sediment derived platforms and oceanic crust based basic volcanic rocks in SE Turkey. The age of this unit was given as Late Jurassic – Early Cretaceous (Sungurlu, 1973; Perinçek, 1978) but the authors have stated that the age had risen from Middle Carnian to Raetian due to its radiolarian content.

The Koçali complex in the study area was tectonically overlain and imbricated by Pütürge metamorphics of the Çüngüş formation at Ormanbaşı Hill. However; this complex is observed as thrusted over Lice formation (Figure 5). The deposit which was traced in SE – NW trend right at the southern part of Akçak Hill is unconformably overlain by Midyat formation (Figures 4 and 5). The unit extending as a thin tectonical slice at Ormanbaşı Hill is represented by mudstone – volcanite, cherty limestone and shale consisting Tarasa – Konak formations and by the Kale formation which consists of serpentinites extending as a thin slice between these units (Figure 4).

ORE GEOLOGY

Several Cu mineralizations were detected in recent years by MTA within volcanites belonging to Koçali Complex cropping out in and around Adıyaman City (Yıldırım et al., 2008 *a, b*; 2009; 2010 *a, b*; Yıldırım, 2011). It was also revealed that these mineralizations showed similar features with Cyprus type VMS mineralizations. Ormanbaşı Hill location was considered as a promising area for Cyprus type volcanogenic massive sulfide mineralization and was investigated in terms of base and precious metals (Cu-Zn-Pb-Au-Ag).

FIELD STUDIES

Although there are several tectono-stratigraphic deposits, ore mineralizations were only observed in Koçali complex as a zone compatible with a thrust plane which is approximately in NE –SW trend.

The Koçali complex forming the basement in and around the study area is imbricated around Ormanbaşı Hill and tectonically overlies Çüngüş, Lice and Midyat (Fırat) formations. The complex is represented by spilite, diabase, radiolarite mudstone, claystone, shale and serpentinites in the study area (Tarasa formation) and sporadically consists of materials related to Çüngüş formation.

Mineralizations generally occur in severely altered, spilitized basic volcanites. These volcanites are sub marine volcanic rocks that corresponds to upper layers of the Koçali complex and was nomenclatured as Tarasa formation by Sungurlu (1973) (Figures 4 and 6).

Mineralizations took place in the form of reworked lensoidal and layer like shapes within mudstone, diabase, spilite and claystone – shales. Altered zones can easily be distinguished with their brownish and reddish colors and by excessively oxidized views at surface (Figures 7a, b and c). Besides; secondarily developed malachite – azurite coatings were also observed on the serpentinite slice as well that underlies this alteration zone (Figure 7 d). These zones show thicknesses varying between 10 to 100 meters and extend up to 300 meters.

Figure 6- Spilitized pillow lavas of the Koçali complex (100m. NE of Zeynelaslan settlement)

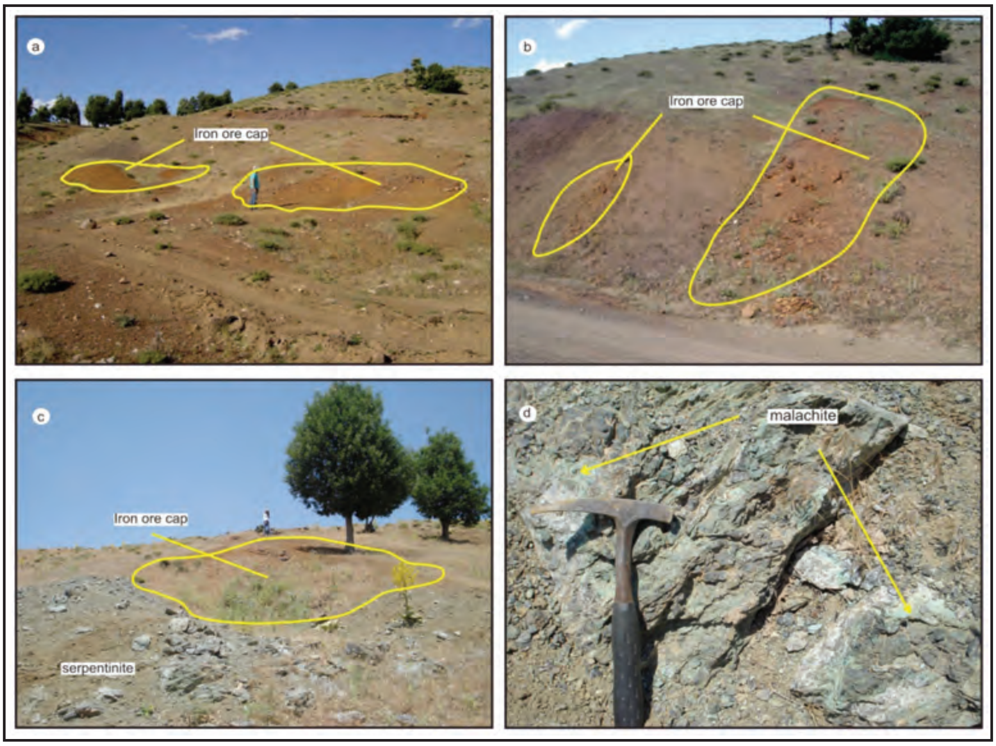

Figure 7- a-b; View from iron ore caps (gossan) in the mineralization area (looking towards NE) (Ormanbaşı Hill location, 100 m west of trench SY-6), c-d; Secondarily developed malachite and azurite occurrences within the iron ore cap at top and serpentinite slice at bottom (Ormanbaşı Hill location, trench SY- 6, looking towards NW)

Trenching

In Ormanbaşı Hill area where mineralizations generally crop out along thrust zones, six trenches were excavated perpendicular to zones where iron ore caps (gossan) occur in order the alteration zones to be traced better and to investigate their continuities (Figure 8). Trenches are maximum 65 m long, 1 m wide and 1.5 - 2 m deep. In some of them, silicious and pyritized zones were detected in which the stockwork structure was developed. However; in other

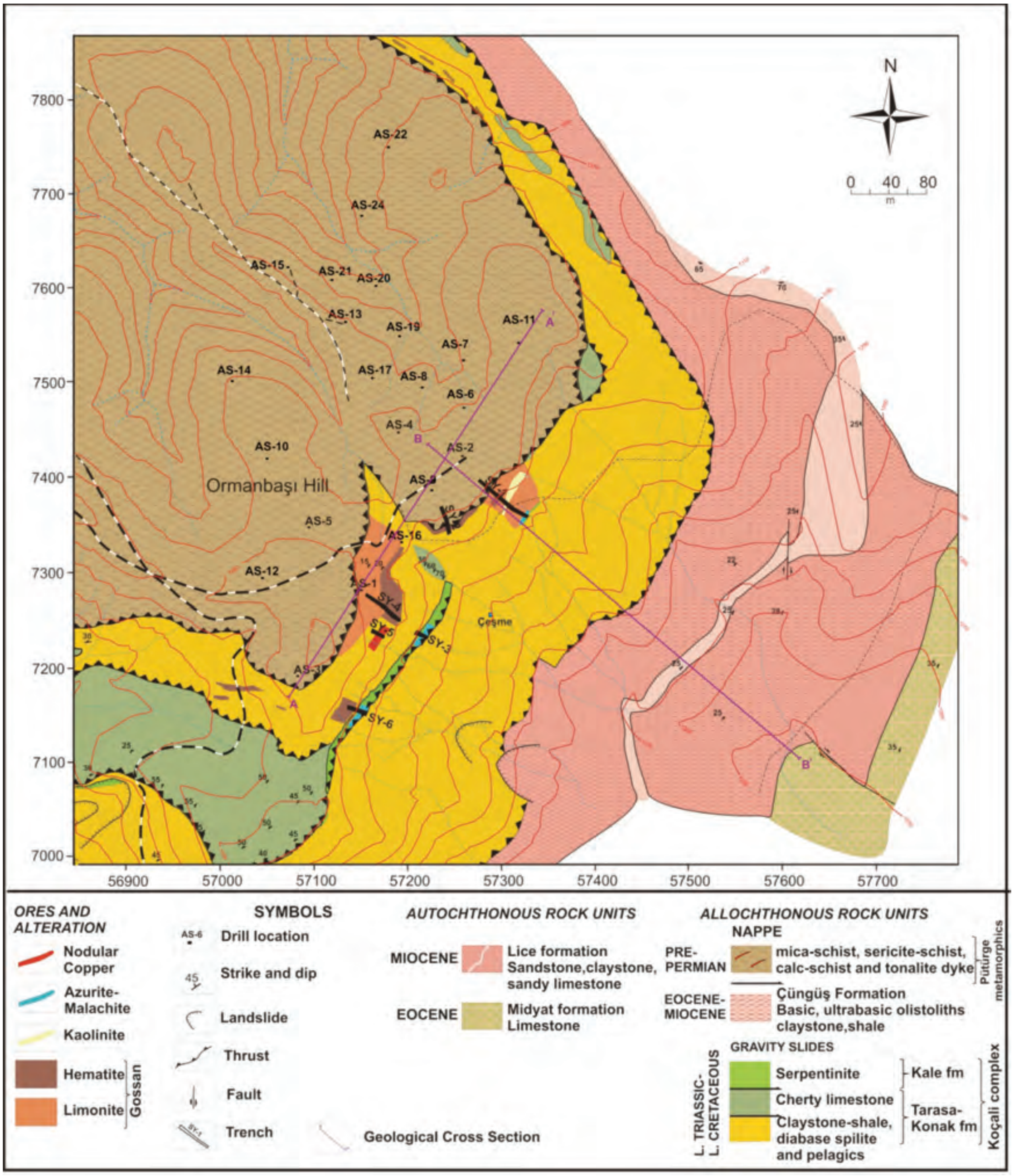

Figure 8- Ore geology map of the study area (Yıldırım, 2011)

trenches goethitic formations at levels which intense hematitization, limonitization within gossans and chalcozite - covellite bornite formations within layers of malachite and azurite were traced. Channel sampling from side walls of trenches were made to perform geochemical analyses. Maximum 3% Cu and 3480 ppb Au were obtained from samples taken in trenches.

Geophysical studies

As geophysical technique, the Induced Polarization (IP) method was performed in order both to determine the distribution of available mineralized zones within the study area and the location of deep-seated mineralizations. Within this purpose, profiles were drawn perpendicular to mineralization zones (SE–NW trending) (Figure 8 and 9). The sulphidization grade of geological structures, the geometry of these sulfidic structures and resistivity differences with respect to adjacent units were investigated in the study area (Bekar, 2010).

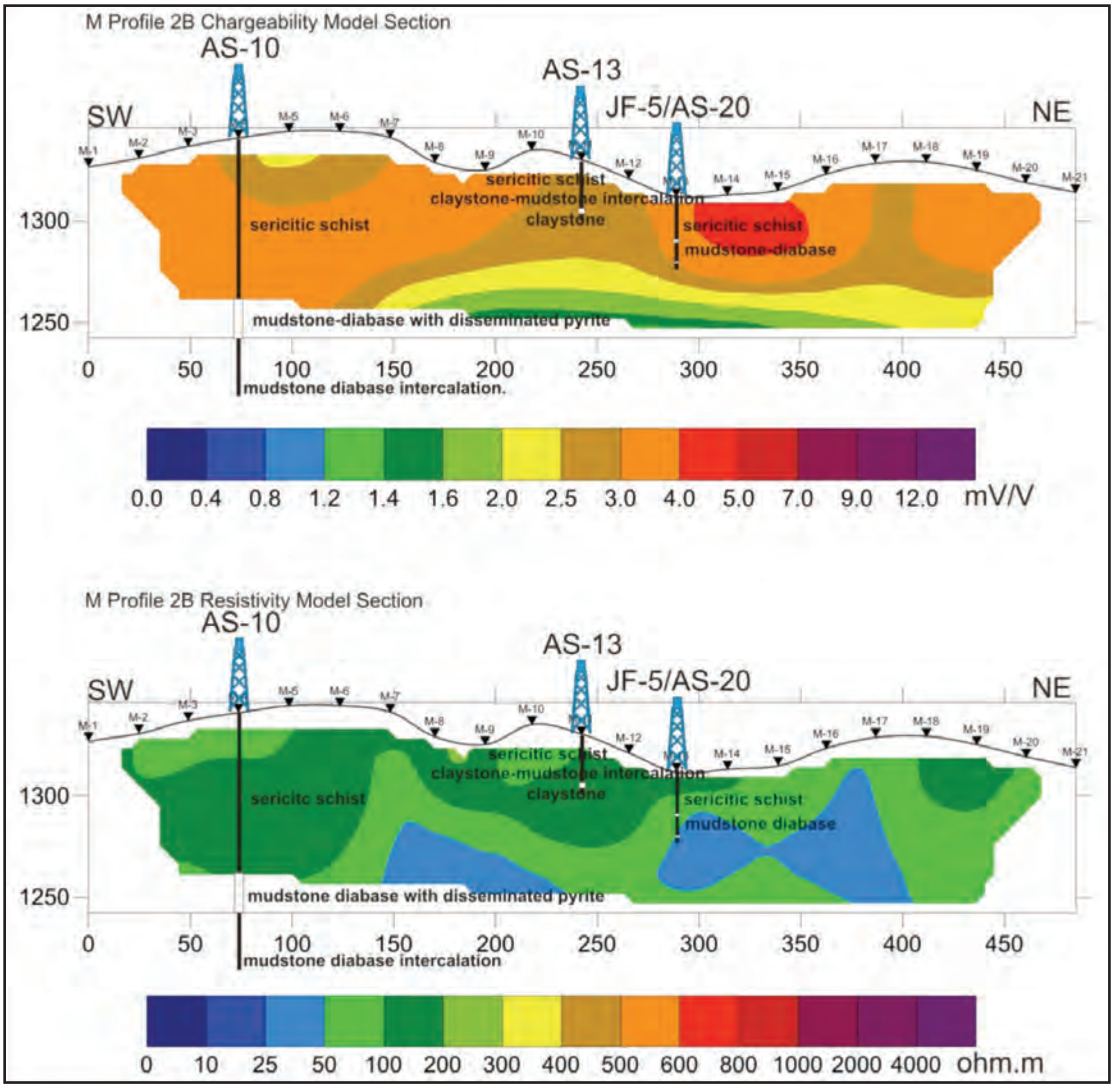

Figure 9- Back analysis of resistivity and chargeability for M- Y profiles (Bekar, 2010)

In Ormanbaşı Hill region, values from the area where mineralization was established by available drillings were obtained even less than the average chargeability values of the area (Figure 9). These low values were interpreted as these mineralizations represent an allochthonous view, do not show any continuity, thin out and thicken in places. These were also considered as units taking place within available mineralizations gave chargeability value (Bekar, 2010).

Drilling investigations

In Ormanbaşı Hill, Sincik (Adıyaman) investigation area, field studies and geophysical anomalies related to exploration and reservoir analyses were correlated and total length of 1933,25 m drilling were carried out in 25 wells. After determination studies had been completed, sample intervals according to the change in mineralization and alteration were determined bisecting core samples. The samples were prepared by quartering method then were submitted to analysis. In drillings; gossan, disseminated and veinlet chalcopyrite and sphalerite within massive pyrite, sporadically disseminated and stockwork levels, brecciated levels and pyrite and chalcopyrite levels were cut (Figures 10 and 11). Panel diagrams and geological cross sections made by the interpretation of well logs that had been obtained from

Figure 10- Massive ore mineral cut in drilling AS -2 and close up view from this bisected ore

Figure 11- Iron ore cap (gossan) that was cut in drilling AS-9 and view from cataclastic massive ore minerals in patches

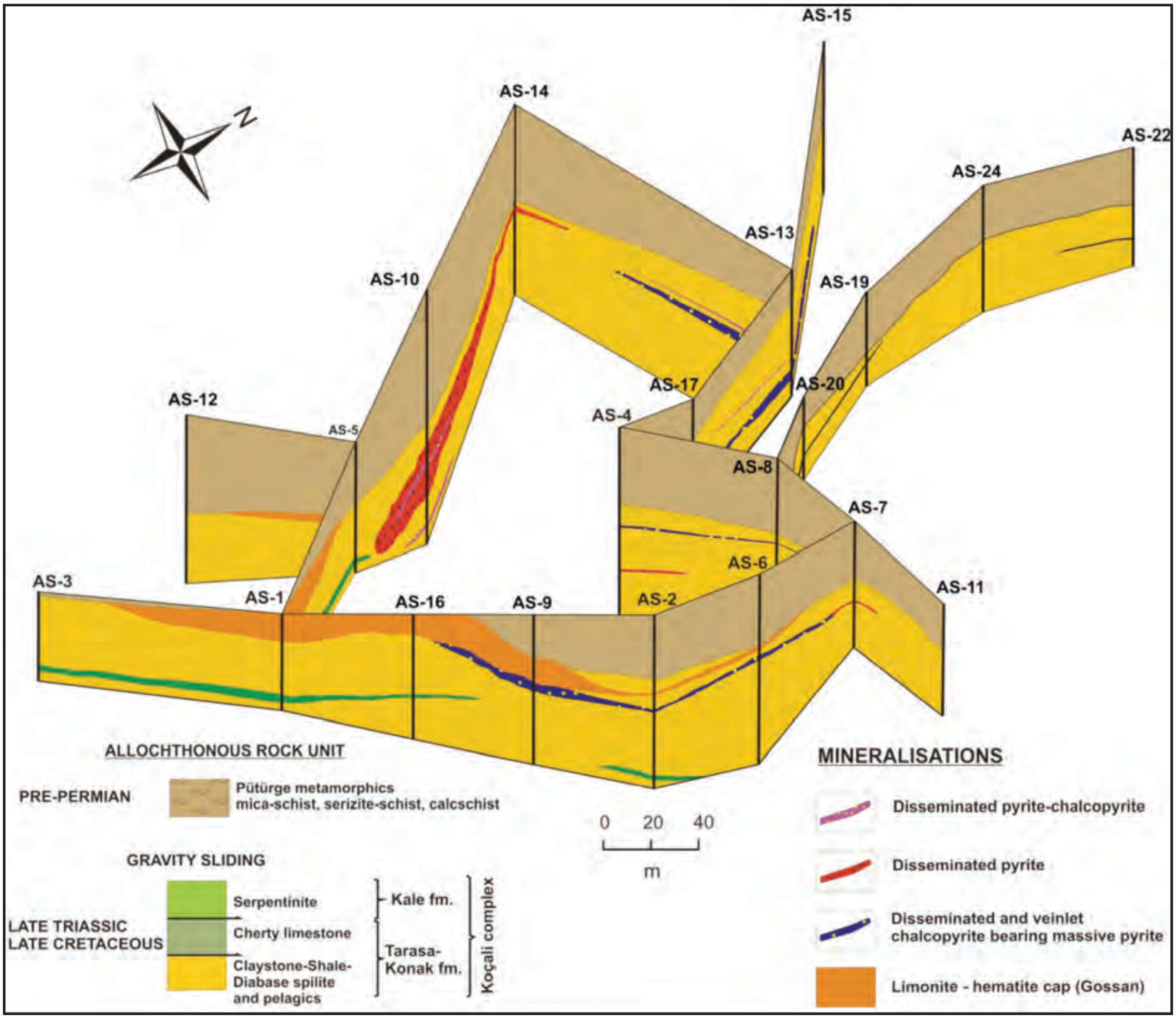

Figure 12- Panel diagram showing drillings in ore mineralization area (Yıldırım, 2011) (see Figure 8 for well locations)

drillings within study were given in Figures 12 and 13. The lateral and vertical variations of mineralized zones on panel diagram were obviously revealed. Mineralization is represented by massive pyrite towards deeper parts, however; it was formed by oxides at surface and at locations close to the surface (gossan). Mineralized sections sporadically show a thinning and thickening structure and this is clearly observed both in panel diagrams and in geological sections.

Alteration

Mineralizations which developed within volcanites of Koçali complex were generally formed from iron ore caps with limonite (also including pyrite), hematite and silica at the surface. Kaolinization was also observed in patches in these zones. However; alterations such as; chloritization, calcification, silicification, limonitization, hematitization, epidotization were generally observed on wall rocks surrounding mineralizations (Figure 14). Also, this type of alterations is frequently seen in sub marine volcanism.

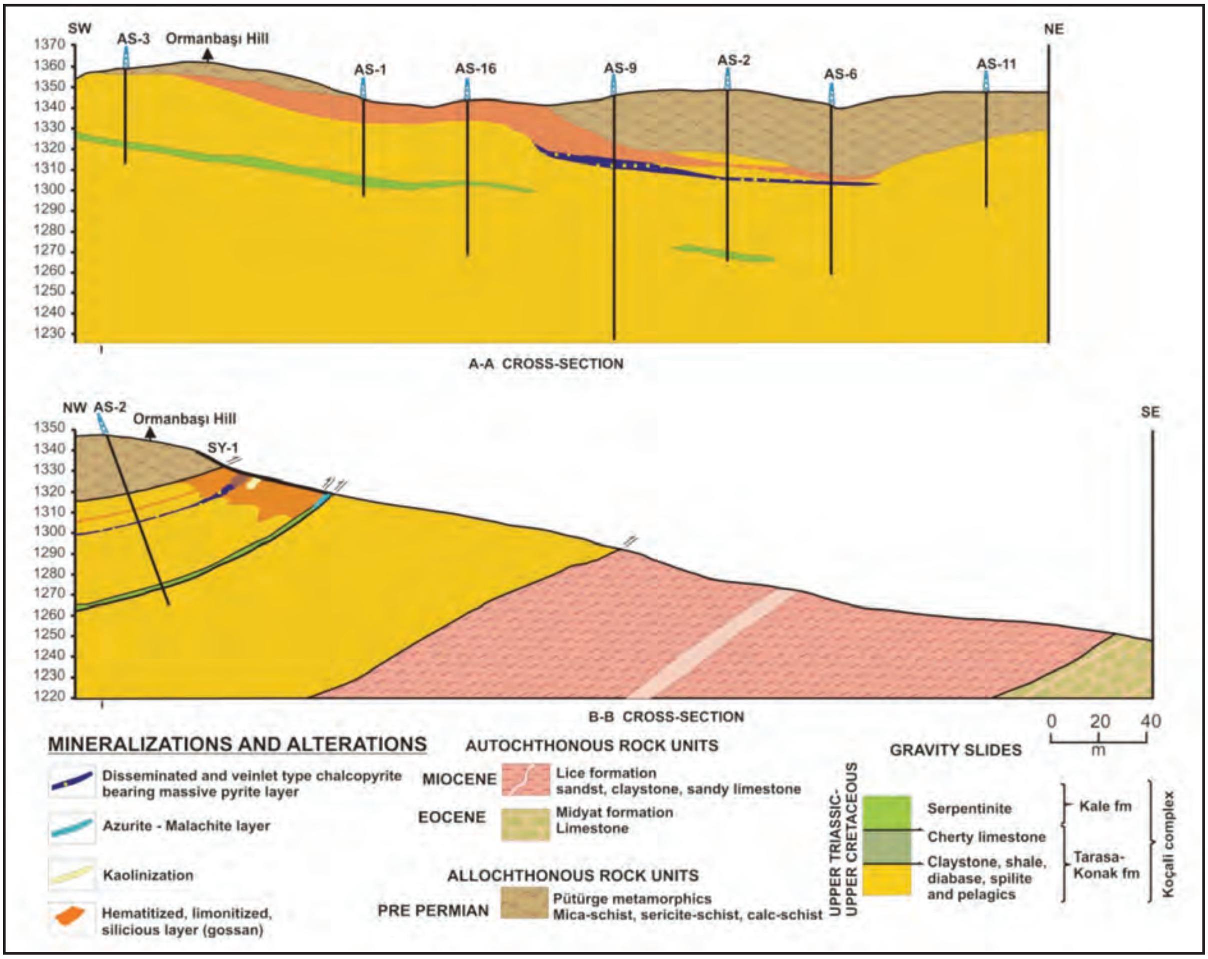

Figure 13- Geological cross sections passing through drillings in the ore mineralization area (Yıldırım, 2011) (see Figure 8 for well locations)

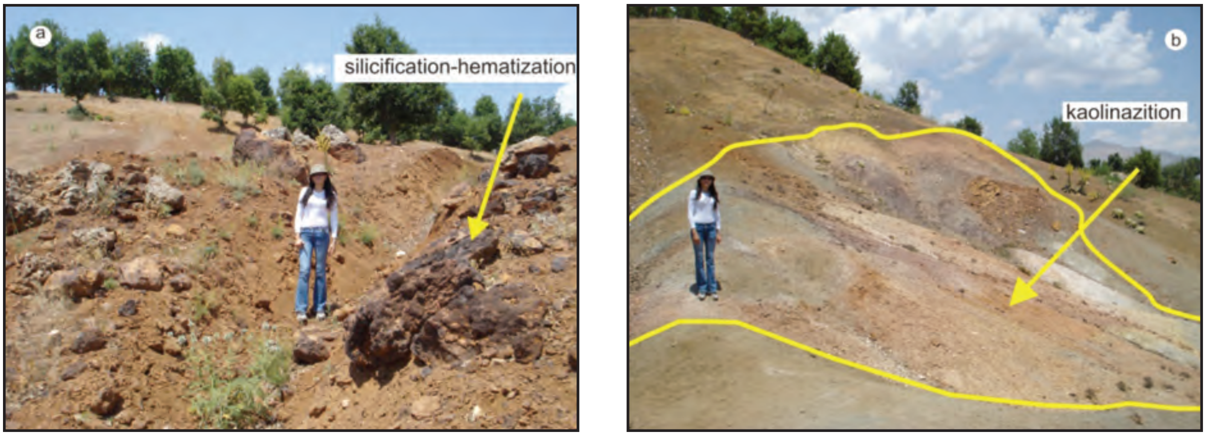

Figure 14- A view from alteration within mineralization zone (Ormanbaşı Hill location, SY-1 trench, looking towards NW)

LABORATORY STUDIES

Ore minerals and paragenesis

Pyrite, marcasite, chalcopyrite, sphalerite, bornite, chalcozine – covelline and native copper were detected as ore minerals due to macroscopic and microscopic studies for samples taken from mineralized zones at drillings and mineral exposures in the study area (Figure 15).

Geothite minerals with interstitial and colloidal textures were also encountered within iron ore cap at the surface. In sample with interstitial texture, Quartz and pyrite minerals were observed in veins or in such a way they had fulfilled voids (Figures 16 and 17).

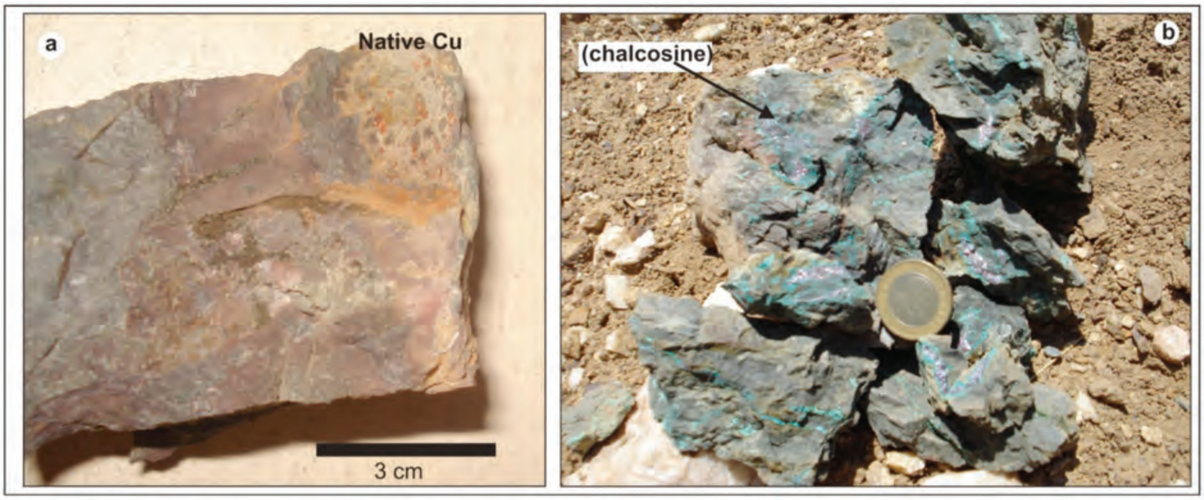

Figure 15- *a)* Native copper disseminations which developed on oxidation zone at surface (Trench SY-2), *b)* Malachite, azurite and chalcozine formations encountered in oxidation zone (Trench SY-1)

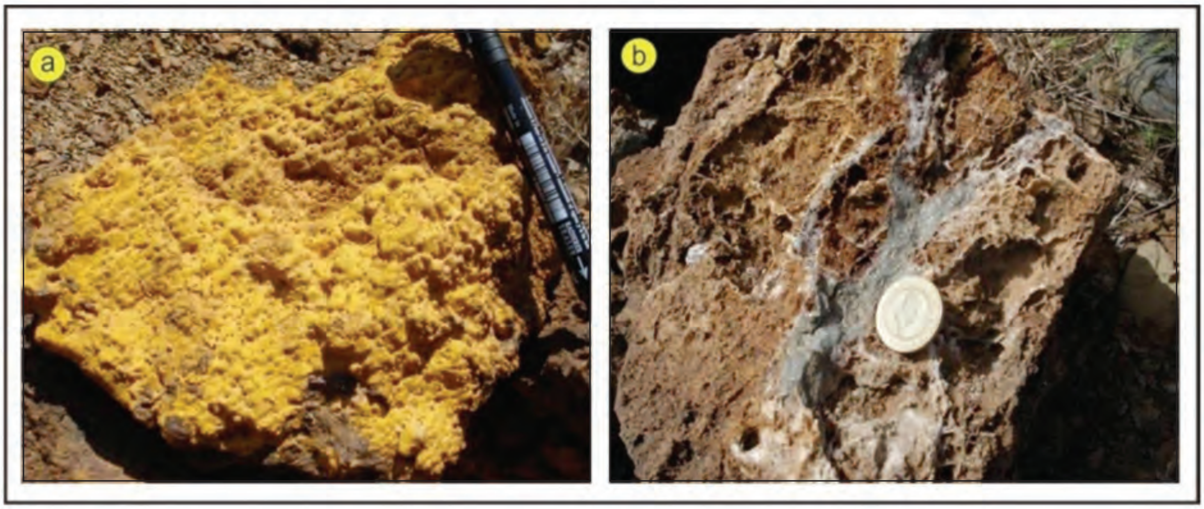

Figure 16- *a*) Colloidal texture developed in gossans (goethite), *b)* Pyrite – silica veins and interstitial texture developed in gossans

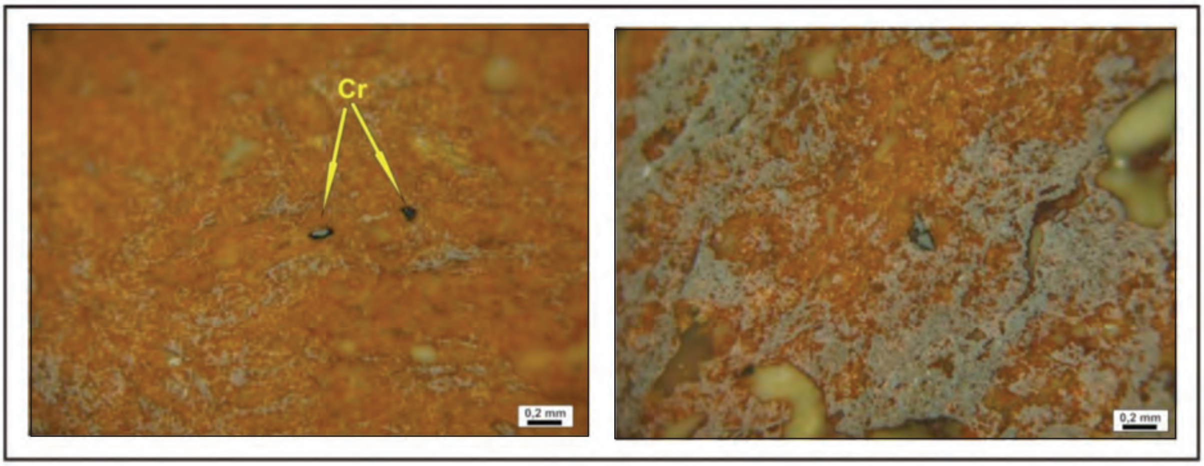

Figure 17- Limonite – hematite and goethite formations and microscope views of chromite granules encountered in gossans (Cr: chromite)

Limonite, hematite, goethite and chromite granules in them which had been reworked by tectonism were encountered in thin sections taken from gossans (Figure 17).

Pyrite is generally surrounded by sphalerite, chalcopyrite and gangue minerals (Figure 18) and is euhedral with smooth edges. However; chalcopyrite and sphalerite are encountered as matrix filling up pyrite granules. It indicates that, pyrite was formed earlier than sphalerite and chalcopyrite.

In paragenesis, pyrite is dominant mineral but chalcopyrite and sphalerite are present in fewer amounts. Chalcopyrite is the second most encountered ore mineral after pyrite and was formed after pyrite and sphalerite. Chalcopyrite has both confined pyrite and sphalerite and accumulated along cleavages and was encountered as irregular and amorphous granules. Besides; chalcopyrite has generally substituted pyrite and sphalerite (Figure 18). Chalcopyrite has turned into covelline and chalcozine along cleavages and edges in some thin sections (Figure 19).

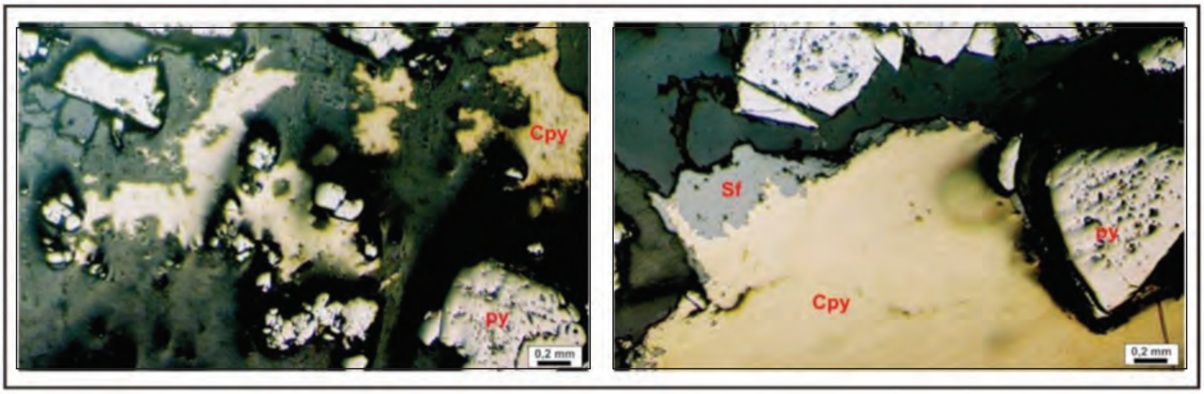

Figure 18- Euhedral pyrites, anhedral sphalerite and chalcopyrites encountered in massive pyrite ore mineral (Py: pyrite; Cpy: chalcopyrite; Sf: sphalerite) (core sample belonging to drilling AS-2)

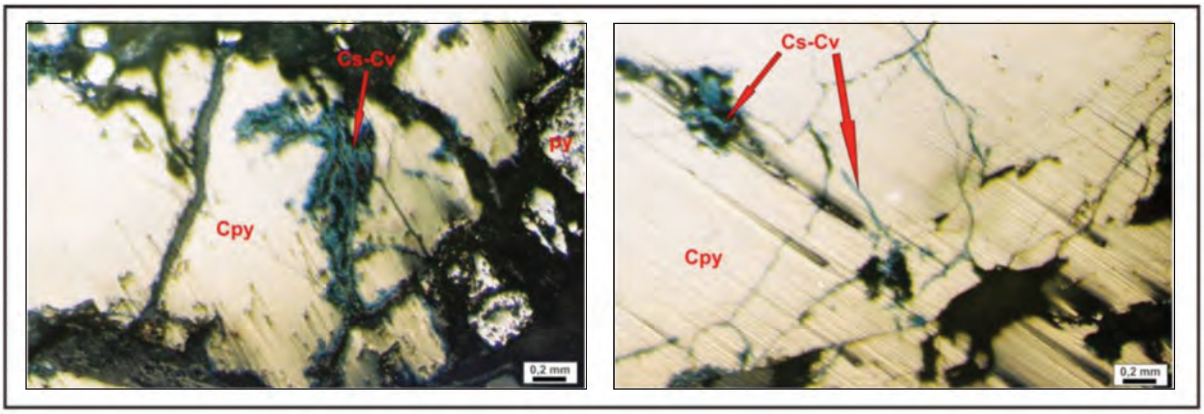

Figure 19- Secondarily developed chalcozine and covelline formations along fractures and cleavages of chalcopyrites within massive pyrite ore mineral (Cpy: chalcopyrite; Cs-Cv: chalcozine – covelline)

Sphalerite was less frequently encountered than pyrite and chalcopyrite. It was generally observed along cleavages and edges of pyrite, in the form of free granules and within chalcopyrite and seen in the form of anhedral granules.

Ore mineralizations present colloidal, zoned, euhedral to subhedral and cataclastic textures which is peculiar to massive sulfide deposits and were developed under low temperatures (Figure 20).

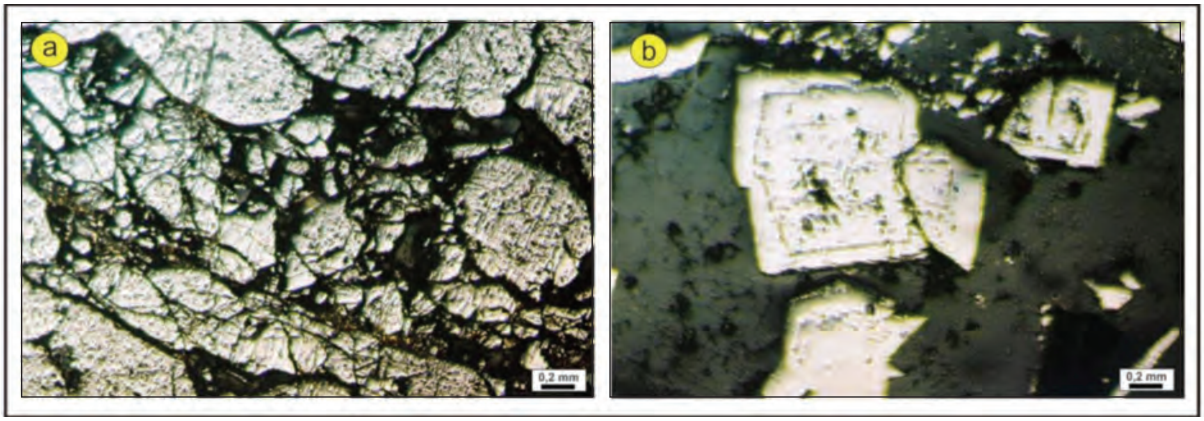

Figure 20- a) Cataclastic texture encountered in massive pyrite ore mineral, b) zoning developed in pyrites in massive ore

Cu mineralizations were only encountered in volcanites of Jurassic – Lower Cretaceous Koçali complex in the study area. Besides; manganese nodules with copper characterizing the oceanic environment were also observed within claystone – marls of the Koçali complex (Figure 21).

Mineralizations at surface were encountered in the form of limonitization, hematitization, argillitization and iron ore cap. However; the massive ore with pyrite were seen beneath the iron ore cap at surface. At deeper parts, disseminated – stockwork brecciated levels with pyrite and chalcopyrite takes place.

Figure 21- Manganese nodules with copper encountered in claystone and marl of the Koçali complex

Geochemical analyses and assessments

Among massive and stockwork ore samples within the study area, 15 of them were submitted to geochemical analysis to detect Cu, Pb, Zn, Ni Co, Mo, Sb, As, Bi Ag and Au contents (Table 1) by flame AAS/ICP-OES method at the Department of Mineral Analysis and Technologies of MTA. However; 8 ore/ore bearing rock samples collected at the surface were analyzed to detect major element oxide, trace and Rare Earth Elements (REE) by ICP-MS method in Activation Laboratories (ACTLABS) in Canada (Tables 2, 3 and 4).

Table 1- Base – precious metal contents of samples belonging to Sincik – Ormanbaşı Hill Mineralization (MTA- Ankara)

Sample No	Ore Type	Cu ppm	Pb ppm	Zn ppm	Ni ppm	Co ppm	Mo ppm	Sb ppm	As ppm	Bi ppm	Ag ppm	Au ppb	Depth (meters)
AS2-30	massive	18000	23	260	<10	_	30	<10	33	<10	4,3	250	41,70-42,70
AS6-18	massive	39000	457	23	<10	_	53	<10	<.20	<10	4,2	200	36,30-37,50
AS6-19	massive	28500	386	27	37	_	42	<10	<20	<10	3,9	140	37,50-38,30
AS8-20	massive	15250	30	445	20	_	38	<10	75	<10	6.9	170	39,55-40,25
AS9-15	massive	13100	49	4330	65	_	30	<10	28	<10	4.8	180	30,60-31,40
AS9-16	massive	22100	44	14200	<10	_	35	<10	<20	<10	4.5	160	31,40-32,60
AS9-17	massive	36120	100	27000	<10	_	30	<10	31	<10	7.8	300	32,60-34,00
AS9-18	massive	27900	31	2380	<10	_	124	<10	<20	<10	4.5	40	34,00-35,50
AS10-33	stockwork	10690	52	20360	<10	401	33	<10	23	<10	6	260	83,90-85,00
AS10-43	stockwork	33520	100	28230	<10	240	31	<10	56	<10	10.7	290	111,50-114,50
AS13-23	massive	34160	139	23400	<10	235	22	<10	22	<10	9.6	420	50,00-51,50
AS13-24	massive	19010	56	26900	<10	283	34	<10	33	<10	7.3	260	51,50-53,00
AS13-25	massive	16170	98	16330	<10	354	38	<10	<20	<10	5.8	300	53,00-54,15
AS-19-3	massive	15500	<10	295	<10	140	13	<10	20	<10	4.7	150	34,40-34,85
AS-20-9	massive	9470	31	91	135	105	11	<10	<20	<10	1.9	50	29,30-29,40

Table 2- Major oxide, trace element and REE contents of samples belonging to Sincik – Ormanbaşı Hill Mineralization

Sample No	Ore Type	SiO_2 %	Al_2O_3 %	Fe_2O_3(T) %	MnO %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	P_2O_5 %	Loss in fire %	Total %
S-2	Gossan,limonite hematite	33.68	0.70	52.32	0.05	0.17	0.15	0.06	0.06	0.10	0.04	11.22	98.57
S-7	Gossan,limonite, hematite	54.10	6.27	22.33	0.13	1.08	0.61	2.44	0.33	2.73	0.26	8.81	99.10
S-10	Gossan, pyrite	64.68	0.86	23.95	0.02	0.10	0.08	0.13	0.12	0.03	0.02	9.22	99.22
S-11	Serpantinites including malachite	37.72	2.51	8.13	0.35	30.18	0.25	0.04	0.03	0.005	0.04	15.21	94.46
S-15	Gossan, hematite, pyrite	75.64	1.09	17.79	0.01	0.08	0.06	0.11	0.10	0.56	0.01	3.07	98.53
S-13	Manganese nodule including malachite	17.89	3.87	39.18	0.02	0.80	0.12	0.43	0.45	0.24	0.58	1.90	65.49
S-18	Gossan, pyrite	69.48	1.7o	19.38	0.02	0.09	0.06	0.12	0.23	0.28	0.01	7.15	98.52
S-21	Gossan, malachite, limonite	83.01	2.63	6.55	0.02	0.08	1.21	0.13	0.08	0.01	0.05	3.66	97.43

Table 3- Trace element contents of samples belonging to Sincik – Ormanbaşı Hill Mineralization (ACTLABS – Canada)

Sample No	Sc ppm	Be ppm	V ppm	Ba ppm	Sr ppm	Y ppm	Zr ppm	Cr ppm	Co ppm	Ni ppm	Cu ppm	Zn ppm	Ga ppm	Ge ppm	As ppm	Rb ppm	Nb ppm	Mo ppm	Ag ppm	In ppm	Sn ppm	Sb ppm	Cs ppm
S-2	2	< 1	143	8	4	< 2	27	60	14	< 20	1710	310	9	2	190	< 2	2	> 100	> 100	< 0.2	13	10.6	< 0.5
S-7	22	< 1	496	154	63	< 2	175	250	54	30	2440	710	68	3	87	8	4	28	8.1	1.9	3	1.3	< 0.5
S-10	< 1	< 1	16	67	6	< 2	5	30	473	< 20	460	150	4	< 1	18	3	< 1	78	16.7	< 0.2	1	1.5	< 0.5
S-11	9	1	33	52	6	5	< 4	3110	394	2420	27900	770	< 1	1	6	< 2	< 1	8	< 0.5	< 0.2	< 1	< 0.5	< 0.5
S-15	5	< 1	42	101	9	5	40	40	75	< 20	260	40	3	2	31	2	< 1	83	3.7	< 0.2	4	2.8	< 0.5
S-13	12	1	216	49	16	4	35	260	36	50	28000	100	4	< 1	32	16	2	4	< 0.5	< 0.2	< 1	< 0.5	1.3
S-18	3	< 1	51	720	17	< 2	26	50	89	< 20	430	90	10	1	20	4	< 1	41	8	< 0.2	4	3.4	< 0.5
S-21	2	< 1	41	81	32	5	5	40	61	30	19800	360	< 1	< 1	6	< 2	< 1	11	< 0.5	< 0.2	< 1	1	< 0.5

Table 4- REE contents of samples belonging to Sincik – Ormanbaşı Hill Mineralization (ACTLABS – Canada)

Sample No	La ppm	Ce ppm	Pr ppm	Nd ppm	Sm ppm	Eu ppm	Gd ppm	Tb ppm	Dy ppm	Ho ppm	Er ppm	Tm ppm	Yb ppm	Lu ppm	Hf ppm	Ta ppm	W ppm	Tl ppm	Pb ppm	Bi ppm	Th ppm	U ppm
S-2	2.2	2.6	0.36	1.4	0.3	0.09	0.3	< 0.1	0.4	0.1	0.3	0.06	0.4	0.08	0.4	0.1	4	2.7	177	0.5	0.7	2.2
S-7	3	4.9	0.36	1	0.2	0.06	0.3	< 0.1	0.5	0.1	0.5	0.09	0.7	0.12	4.1	0.3	1	1.8	142	< 0.4	0.6	0.4
S-10	1	1.5	0.19	0.6	0.1	< 0.05	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.05	< 0.1	< 0.04	< 0.2	< 0.1	12	< 0.1	12	1.1	0.3	0.6
S-11	3	25.1	1.43	6.8	2	0.51	1.7	0.3	1.4	0.2	0.6	0.09	0.6	0.09	< 0.2	< 0.1	3	0.2	< 5	< 0.4	< 0.1	0.5
S-15	5.3	11.9	1.61	7.3	1.4	0.41	0.9	0.2	0.9	0.2	0.7	0.11	0.8	0.13	0.9	< 0.1	6	< 0.1	< 5	1.6	0.2	2.2
S-13	7.2	19.2	2.51	10.5	3	0.84	2.6	0.5	2.6	0.5	1.2	0.17	1.1	0.17	1	0.2	2	0.6	22	< 0.4	2.6	2.4
S-18	1.1	2.3	0.31	1.3	0.4	0.18	0.4	< 0.1	0.6	0.1	0.4	0.06	0.4	0.07	0.4	< 0.1	3	0.2	25	< 0.4	0.3	3
S-21	3.2	6.8	1.13	5.3	1.4	0.39	1.3	0.2	1.2	0.2	0.6	0.09	0.5	0.08	< 0.2	< 0.1	2	0.2	< 5	< 0.4	0.2	2

The classification of VMS deposits in terms of base metals in the world is seen in figures 22a and b. Although Pb content is low, Cu and Zn contents are high in mineralization at Ormanbaşı Hill location. This is one of the typical characteristics of VMS deposits associated with ophiolites (Galley and Koski, 1999). According to this classification, it is seen that samples plot into Cyprus type volcanogenic massive sulfide deposits area (Figures 22 a, b).

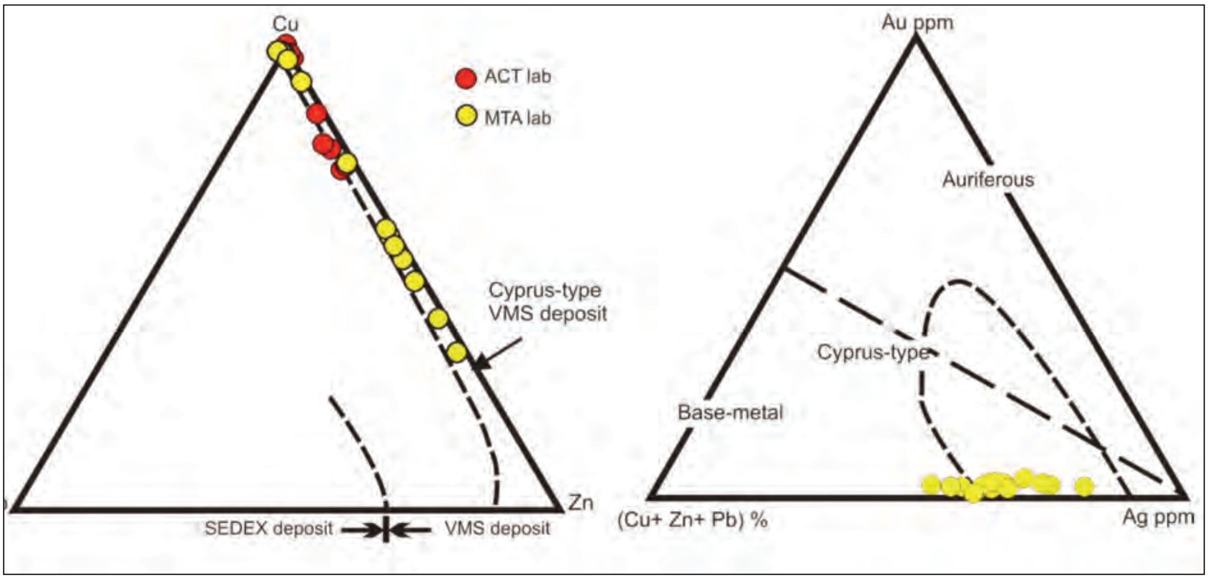

Figure 22- The distribution of samples belonging to Sincik – Ormanbaşı Hill Mineralization using; a) Cu–Pb–Zn discrimination diagram (from Galley and Koski, 1999) and b) Au-(Cu+Zn+Pb)+Ag discrimination diagram (Barrie and Hannington, 1999) (according to Galley and Koski, 1999)

Trace element and REE contents in pyrites are important to understand the origin of mineralizations. It is seen that REE contents of pyritic ore samples in Ormanbaşı Hill present a trend close to chondrite values in chondrite normalized diagram and there is not observed a high enrichment (Figure 23). This shows that, the source of metals forming the mineralization are not marine sedimentary but are associated with magmatic rocks.

The low Pb contents (Galley and Koski, 1999) of Pb, Cu, Ag, Au, Zn element contents in samples belonging to Ormanbaşı Hill mineralizations in primitive mantle normalized spider diagrams show a resemblance to Cyprus type VMS deposits (Figure 24).

Co/Ni ratio is used as a potential discriminator between magmatic – hydrothermal and sedimentary environments. Co/Ni ratios are less than 1, although high Co and Ni contents are encountered in pyrite and pyrrhotine in sedimentary, volcanogenic or diagenetic source materials (Cambel and Jarkovsky, 1967). Co and Ni contents are generally low in hydrothermal source sulfides (less than 100 ppm) and the ratio of Co/Ni is much higher than 1 (Cambel and Jarkovsky, 1967). Although the amount of Ni is higher than Co element on earth crust, Co/Ni ratios in hydrothermal pyrites are above 1. Co element is leached from wall rocks easier than Ni, then is taken into solution and diluted in deposits (Güleç and Erler, 1983). During analyses carried out in massive pyrites belonging to Ormanbaşı

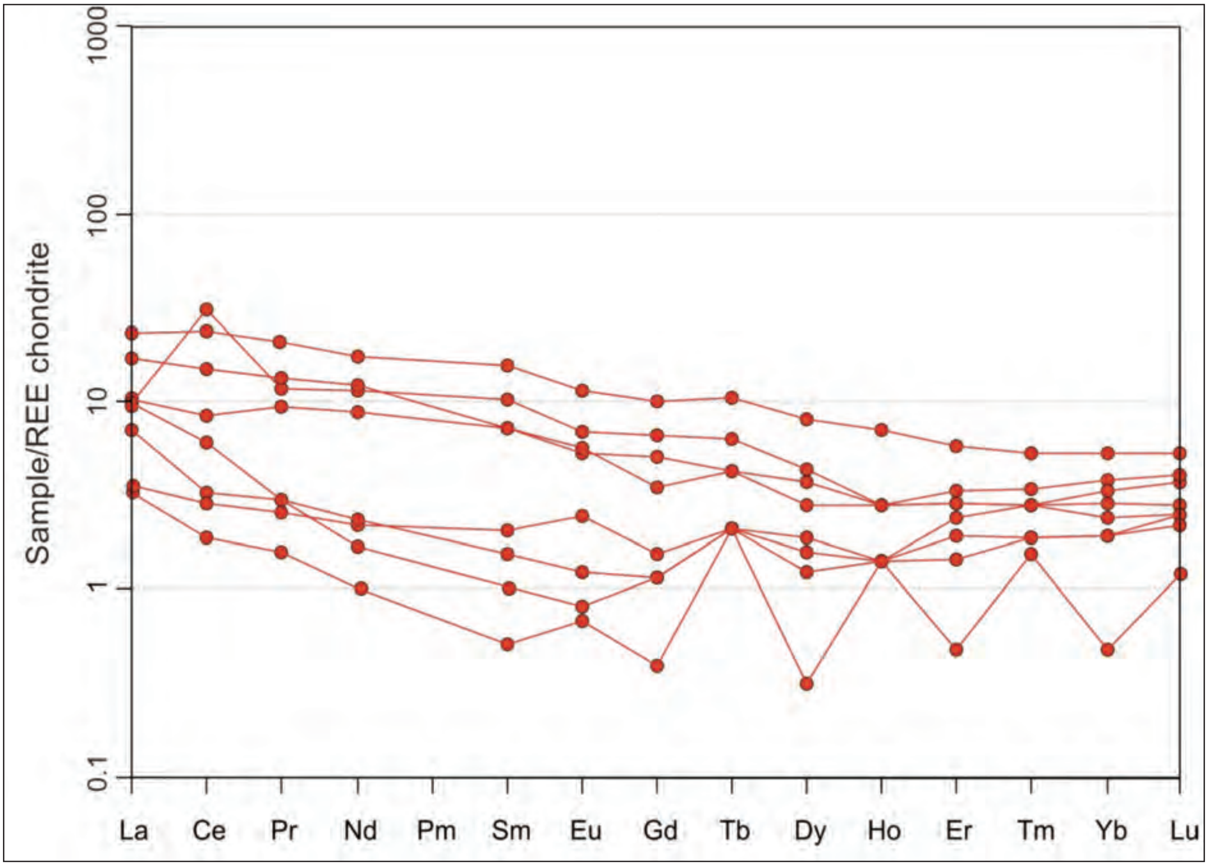

Figure 23- Chondrite normalized (Boynton, 1984) REE multi element distributions for samples belonging to Ormanbaşı Hill mineralizations

Hill mineralizations, Co/Ni ratios were seen higher than 1 and the content of Ni is low. This phenomenon was interpreted as the hydrothermal processes had been effective in mineralizations.

SOTOPE STUDIES

$\delta\ ^{34}$S analysis were carried out in laboratory of the Lausanne University (Switzerland) in 2 samples which had been selected from ore minerals in the study area. In sulphur isotope studies; it is considered that, if the average ^{34}S for the deposit is 0, then it is deep and is homogenous source, if S is negative then it indicates a bacteriological activity and sedimentary deposition (Rollinson, 1993). For magmatic rocks ^{34}S is 0, for hydrothermal solutions associated with volcanism ^{34}S is (+) and in sedimentary rocks ^{34}S ranges in between -10 and -40 (Rollinson, 1993).

In pyrite and chalcopyrite samples within the study area ^{32}S/^{34}S ratios were found as 6.9 and 7.6 (Table 5).

Sample No Explanation $\delta\ ^{34}$S‰ S-19 Pyrite- Chalcopyrite (surface) 7.6

S-32 Pyrite- Chalcopyrite (drilling) 6.9

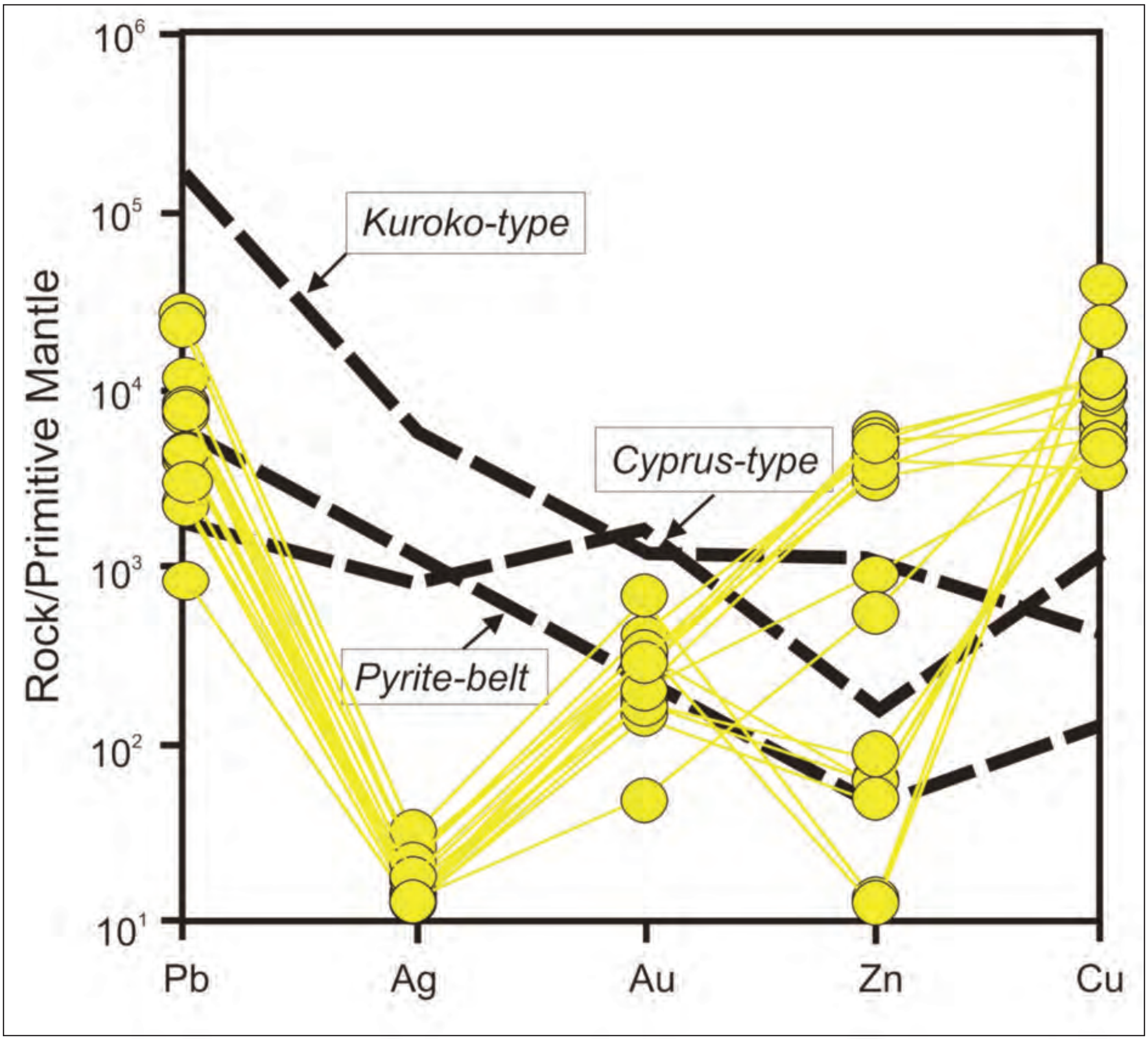

Figure 24- Spider diagram (primitive mantle normalized) of Pb, Ag, Au, Zn and Cu contents for samples belonging to Ormanbaşı Hill mineralizations (Galley and Koski, 1999)

Table 5- $^{32}S/^{34}S$ values of two samples belonging to Ormanbaşı Hill mineralization (Lausanne University, Switzerland)

Sample No	Explanation	$\delta^{34}S‰$
S-19	Pyrite- Chalcopyrite (surface)	7.6
S-32	Pyrite- Chalcopyrite (drilling)	6.9

When minerals in Sincik and Torodos volcanogenic massive sulfide deposits were compared with each other, it was seen that these exhibited similar sulfur isotope values. These values are both compatible with sulfur ratios in hydrothermal solutions associated with volcanism and with Cyprus type VMS deposits on the world (Figure 25) (Rollinson, 1993).

δ ^{34}S values of pyrites taken from massive sulfide deposits which was observed in Torodos ophiolites range between -1.1 and 7.5 ‰. However; these values were restricted to +4 and +7 ‰ (Clark, 1971; Hutchinson and Searle, 1970; Jamieson and Lydon, 1987). Variations within this interval can be observed even in the same deposit, but it is clear that sulfurs in this sulfide deposit were mainly derived from magmatic rocks.

RESULTS AND DISCUSSIONS

The ophiolites originated within layers of oceanic crust but these were then placed on the continental crust. Therefore; these were considered as closely being associated with sea water since these had remained at the sea bottom throughout long geological history. The interaction of rocks with sea water is inevitable especially for basalts located at the uppermost part of the ophiolitic series and plate dike complex underneath the basalts and even partly for gabbroic

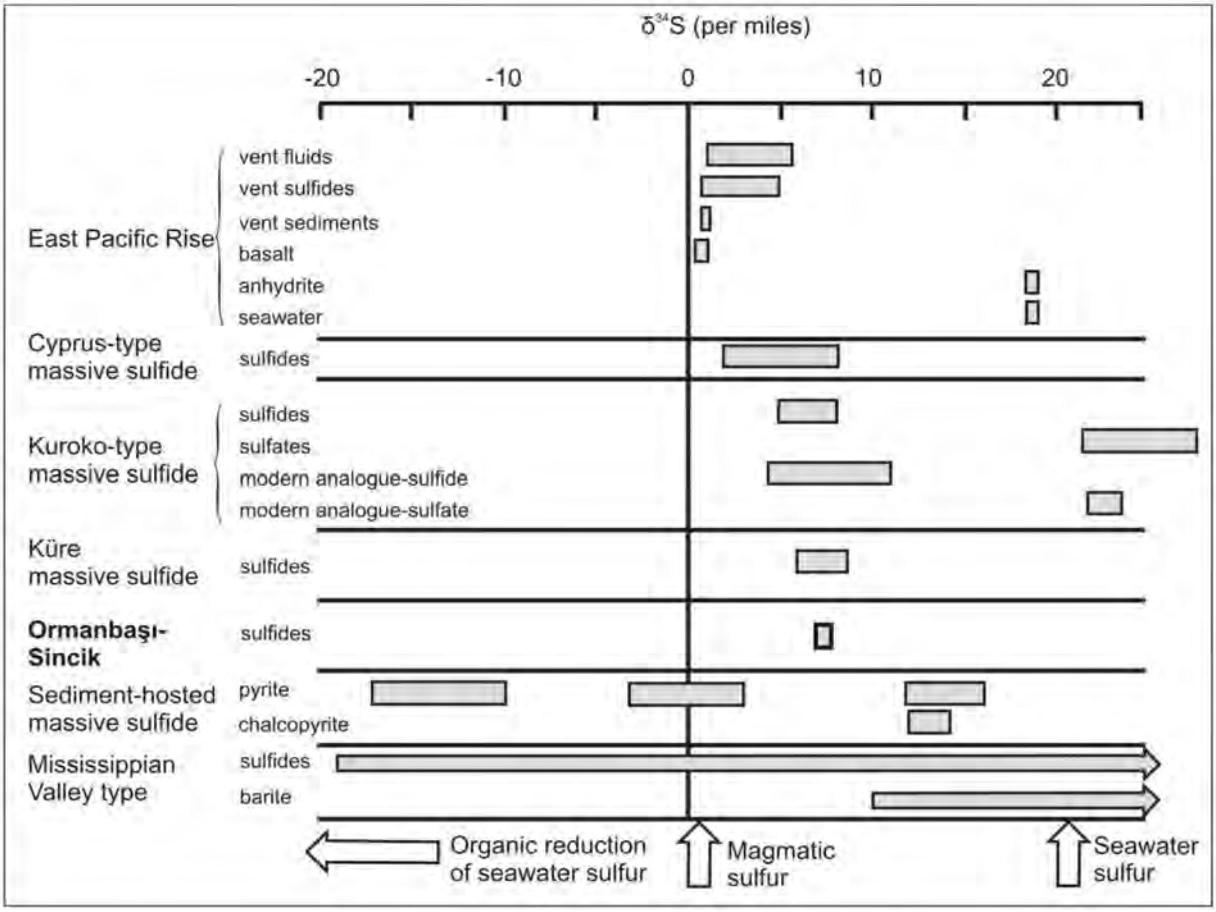

Figure 25- δ ^{34}S isotope values in the study area and in some massive sulfide deposits (Rollinson, 1993)

sections. This interaction in many cases creates great mineralogical and geochemical changes. The cycling fluid penetrates rock units intruding into oceanic crust and causes significant changes in chemical compositional with the effect of high temperature (İmer, 2006). These fluids which have become hydrothermal solution reach the sea bottom and spreads over the bottom rising up by the effect of adiabatic pressures through tectonic fracture and fissures together with other volcanic materials in active volcanic systems.

Metal sulfides suddenly precipitate in situ or at short distances due to rapid cooling, sudden change in pH and Eh and by the effect of sea water in this medium. The spread of mineralized solutions over the sea bottom through fracture and fissure lines corresponds to the periods which the rate of magma development with silica composition is minimum. Fumeroles which occur towards the end of sea bottom volcanic activity could also form mineralization in such ore formations. Some investigations in Japan revealed that fumeroles had formed massive sulfide deposits due to their repetitive activities (Tatsumi, 1970; Sato, 1974).

In previous studies, Gültekin (2004) has stated that Ormanbaşı Hill mineralizations had been traced along tectonical lines and mineralizations in this area were suitable to epithermal type of mineralization due to the presence of minerals showing low temperature conditions and structural – textural features. Not only the presence of mineralization to be only in Koçali complex or being deposited over thrust plane but also the mineral paragenesis, textural features, alteration types, chemical and isotopic findings all indicate that these mineralizations are Cyprus type VMS mineralization in this study. Besides; low temperature minerals which were encountered at the surface could extensively be found at gossan levels of Cyprus type VMS mineralizations (Savkins, 1990).

Mineralizations in the region are available in Koçali complex and are compatible with the general lineation of the Southeast Anatolian Thrust Belt. Mineralizations are observed in mudstone, diabase, spilite, claystone and shales, allochthonous and are in the form of lenses and layers. It is therefore similar to Çüngüş (Derdere) mineralization with these features (Şaşmaz et al., 1999). Mineralizations are generally massive in character and are sporadically observed as stockwork and disseminated. However; there are pyrite, chalcopyrite, sphalerite, pyrrhotine, chalcosine and covelline in mineral paragenesis. While this is seen as an iron ore cap especially at the surface, it passes into massive ore at depths. Colloidal, euhedral to subhedral, cataclastic and zoning textures peculiar to massive sulfide deposits that had developed at low temperatures were encountered.

It is seen that hydrothermal alterations observed in Koçali complex widely bear the traces of low graded oceanic bottom metamorphism. Hence; the metamorphic paragenesis prevailing in the study area is represented by the metamorphic mineral assemblage as quartz + albite + chlorite + epidote. These minerals which are typically observed in altered ophiolitic rocks present pressure and temperature conditions belonging to green schist facies.

The base metal association in Sincik mineralization is Fe – Cu – Zn which originated in sulfide forms. The metals which were found in mineralized zones should have been taken into solution mainly by being leached from the base rock as a result of the hydrothermal fluid cycle. Later on; these should have been occupied in the form of sulfur compounds in hydrothermal solutions and precipitated at the sea bottom and/or shallow depth conditions in the form of sulfuric compounds in upper zones due to temperature decrease, sudden Eh/pH change and rapid geochemical variations in the sea water.

Looking at the metallic composition in Sincik mineralization, it was easily seen that Cu had higher concentration compared to Zn and Pb. As a result of analyses carried out in MTA and ACTLAB, the average Cu concentrations in these mineralizations were obtained as 2.2 and 1.0 %, respectively. These Cu values show resemblance with Torodos massive sulfide mineralization (average Cu: 2.78 %) (Constantinou and Govet,1973; Hanington et al., 1998).

When the sulfur isotope values of pyrites taken from the study area was correlated with the isotope values in Torodos massive sulfide deposits, there was observed a similarity between these mineralizations.

As a result; it was concluded that mineralizations exhibited the general features of Cyprus type volcanogenic massive sulfide deposits and had no relation with the epithermal type mineralization which had been defined in previous studies. Future studies should be focused on the establishment of conjugates of these formations along the belt and on the correlation of these formations with other formations. In doing so; a new Cyprus type VMS metallogenic belt could be established along the Southeast Anatolian Thrust Belt.

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REFERENCES

Altınlı, İ. E., 1966. Doğu ve Güneydoğu Anadolu’nun jeolojisi. MTA Bulletin, 66, 35-74.

Barrie, C. T. and Hannington, M. D., 1999. Classification of volcanic-associated massive sulfide deposits based on host-rock composition. Reviews in Economic Geology, v. 8, 1-11.

Bekar, K., 2010. Adıyaman – Sincik – Ormanbaşı Tepe Sahasının IP Yöntemi ile Araştırılması. 3. Yer Elektrik Çalıştayı, Genişletilmiş Özet Kitabı, Ankara Üniversitesi Ilgaz ÖRSEM Tesisleri, Çankırı, 24-26 Mayıs 2010.

Beyarslan, M., Bingöl, A. F. and Yıldırım, N., 2009. Koçali Ofiyolitik Karmaşığının petrolojik ve tektono-magmatik özellikleri (Adıyaman). Tübitak Project (107Y344). (unpublished).

Bingöl, A.F., 1993 *a.* Çermik-Çüngüş ve Dicle Yöresi Magmatik Kayaçlarının Petrografik Özellikleri. F.Ü. Fen Bilimleri Enstitüsü Fen ve Müh. Bilimleri Dergisi, 5/1, 1-9.

————, 1993 *b.* Çermik Yöresinde Koçali Karmaşığı’nın Jeokimyası. Doğa ve Yer Bilimleri Dergisi, 55-61.

Boynton, W.V., 1984. Cosmochemistry of the rare earth elements: meteorite studies. In: Henderson, P. (Ed.), Rare Earth Element Geochemistry. Elsevier, Amsterdam, 63–114.

Campel, B. and Jorkovsky, J., 1967. Geochemie der Pyrite einiger Lagerstätten der Tschechoslowakei. VSAV Bratislava, 493p.

Cengiz, R., 1991. Doğanşehir Malatya Yöresinin Jeolojisi Maden Jeolojisi ve Jeokimyası. Maden Tetkik ve Arama Genel Müdürlüğü, Report No: 10317, Ankara (unpublished).

Clark, L.A., 1971. Volcanogenic ores: comparison of cupriferous pyrite deposits of Cyprus and Japanese Kuroko deposits. Soc. Mining Geologists Japan, Special Issue 3, 206-215.

Constantinou, G. and Govett, G.J.S., 1973. Geology, geochemistry and genesis of Cyprus sulfide deposits. Economic Geology 68, 843-858.

Galley A.G. and Koski, R.A., 1999. Setting and characteristics of ophiolite-hosted volcanogenic massive sulphide deposits in Barrie, C.T., and Hannington, M.D., eds., Volcanic-Associated Massive Sulphide Deposits: Processes and Examples in Modern and Ancient Settings: Reviews in Economic Geology, v. 8, 215-236.

Güleç, N. and Erler, A., 1983. Masif sülfit yataklarındaki piritlerin karakteristik iz element içerikleri. TJK Bulletin, 26, 2, 145-152.

Gültekin, B., 2004. Sincik (Adıyaman) yöresi bakır ve altın içeren kuvars damarlarının oluşumu ve kökeni. Yüksek Lisans Tezi, Hacettepe Üniversitesi Fen Bilimleri Enstitüsü, Ankara (unpublished).

Hannington, M.D., Galley, A.G., Herzig, P.M. and Petersen, S., 1998. Comparison of the TAG mound and stockwork complex with Cyprus-type massive sulfide deposits, In: Herzig, P.M., Humphris, S.E., Miller, D.J., and Zierenberg, R.A., (eds.), 1998. Proceedings of the Ocean Drilling Program, Scientific Results 158, 389-415.

Herece, E., 2008. Doğu Anadolu Fayı (DAF) Atlası. MTA Special Issue, 13, Ankara.

Hutchinson, R.W. and Searle, D.L., 1970. Strata bound pyrite deposits in Cyprus and relations to other sulfide ores. Soc. Min. Geol. Jpn. Spec. Iss. 3, 198-205.

İmer, A., 2006, Genesis Of The Karaali (Ankara, Turkey) Fe-Cu Sulfide Mineralization, A thesis submitted to the Graduate School of Natural and Applied Sciences of the Middle East Technical University, Ankara, 175.

Jamieson, H. E. and Lydon, J. W., 1987. Geo chemistry of a fossil ore-solution aquifer: chemical exchange between rock and hydrothermal fluid recorded in the lower portion of research drill hole CY-2a, Agrokipia, Cyprus. In: Robinson, P. T., Gibson, I. L. and Panayiotou, A., (eds.), Cyprus Crustal Study Project: Initial Report, Holes CY-2 and 2a. Ottawa, Ontario, Canada, Geological Survey of Canada, 139-152.

Ketin, İ., 1966. Anadolu'nun tektonik birlikleri. Mineral Research and Expoloration Bulletin, 66, Ankara, 20-34.

Kovenko, V., 1943. Visite de la region de Pütürge, vilayet de Malatya. MTA Rep. No: 1393, Ankara.

Özçelik, M., 1985, Malatya güneydoğusundaki magmatik kayaçların jeolojisi ve tektonik ortamına jeokimyasal bir yaklaşım. TJK Bulletin, 28, 1, Ankara, 19-35.

Parlak, O., 2006. Geodynamic significance of granitoid magmatism in southeast Anatolia: Geochemical and geochronogical evidence from Göksun-Afşin (Kahramanmaraş, Turkey) region. International Journal of Earth Sciences, 95, 609-627.

————, Höck, V., Kozlu, H. and Delaloye, M., 2004. Oceanic Crust Generation in an Island Arc Tectonic Setting, SE Anatolian Orogenic Belt (Turkey). Geological Magazine, 141, 583-603.

————, Rızaoğlu, T., Bağcı U., Karaoğlan F. and Höck V., 2009. Tectonic significance of the geochemistry and petrology of ophiolites in southeast Anatolia, Turkey. Tectonophysics, 473, 1-2, 173-187.

Perinçek, D.,1978. Çelikhan- Sincik- Koçali (Adıyaman ili) alanının jeolojisi ve petrol olanaklarının araştırılması. Ph.D. Thesis, İstanbul Üniv. Fen Fak. Tatbiki Jeol. Kürsüsü, 212.

————, 1979. Geological Investigation of the Çelikhan-Sincik- Koçali Area (Adıyaman Province). İst. Üniv. Fen. Ed. Mec. Seri: B, 127-147.

———— and Kozlu, H., 1984. Stratigraphy and structural relations of the units in the Afşin – Elbistan - Doğanşehir region (Eastern Taurus). Tekeli, O. and Güncüoğlu, M.C. eds. Int. Symp. on the geology of the Taurus Belt, proceedings, 181-198.

Pişkin, Ö., 1972. Etude mineralogique de la region situee a L'Est de Çelikhan (Taurus ori-Adıyaman –Türkiye). TJK Bulletin,21/2, 107-111.

Rigo de Righi, M. and Cortesini, A., 1964. Gravity tectonics in foothills Structure belt of Southeast Turkey. Bulletin American American Association of Petroleum Geologists, v.48, 1911-1937.

Rollinson H.R., 1993. Using Geochemical Data: Evaluation, Presentation, Interpretation, Longman. UK. 352.

Sato, T., 1974. Distribution and geological setting of the kuroko deposits. Society of Mining Geologists of Japan, Special Issue 6: 1-10.

Sawkins, F.J., 1990. Metal Deposits in Relation to Plate tectonics. 2nd ed., Springer, Verlag, New York, 461p.

Sungurlu, O., 1973. VI. Bölge Gölbaşı – Gerger arasındaki sahanın jeolojisi. TPAO Report No: 80, Ankara (unpublished).

————, 1974. VI. Bölge Kuzey sahalarının jeolojisi. TPAO Report no: 871, Ankara.

Şaşmaz, A., Gülenay, G. and Sağıroğlu, A., 1999. Taşınmış Kıbrıs tipi bakır cevherleşmelerine tipik bir örnek: Derdere (Çüngüş-Diyarbakır) cevherleşmeleri. TJK Bull. 42, 1, 105-117.

Tatsumi, T., 1970. Volcanism and ore genesis. University of Tokyo Press, Tokyo, 448p.

Tolun, N., 1955. Besni, Adıyaman, Samsat arası bölgelerin jeolojik etüdü. MTA Report No: 2251, Ankara (unpublished).

Turgay, I., 1968. Adıyaman-Kahta ilçesi Sincek Nahiyesi Siltikuş Tepe Bakır Aramaları PS Etüdü. MTA Report No: 4320, Ankara (unpublished).

Türkyılmaz, B., 2004. Çelikhan-Sincik Arasında Yüzeyleyen Magmatik Kayaçların Petrografisi ve Petrolojisi, Ph. D. Thesis, Fırat Üniversitesi Fen Bilimleri Enstitüsü, Elazığ (unpublished).

Uzunçimen, S., Tekin, U.K., Bedi Y., Perincek D., Varol E. and Soycan H., 2011. Discovery of the Late Triassic (Middle Carnian–Rhaetian) radiolarians in the volcano-sedimentary sequences of the Kocali Complex, SE Turkey: Correlation with the other Tauride units. Journal of Asian Earth Science, 40, 1-4, 180-200.

Yalçın, N., 1976. Narince-Gerger (Adıyaman ili) alanının jeoloji incelemesi ve petrol olanaklarının araştırılması. Ph. D. Thesis, İ.Ü. Tatbiki Jeoloji Kürsüsü.

Yazgan, E., 1972. Etude geologique et petro graphique du complexe ophiolitique de la region situee au sud-est de Malatya (Taurus oriental, Turquie) et de sa couverture volcanosedimentaire. These no: 1575, Univ. Geneve, 236p.

——— and Asutay, H.J., 1987. Malatya Güneydoğusunun Jeolojisi ve Doğu Toroslar’ın Jeodinamik Evrimi. MTA Report No: 8272, Ankara (unpublished).

Yıldırım, E., 2010. Çelikhan-Sincik Arasında Yüzeyleyen Magmatik Kayaçların Petrografisi ve Petrolojisi. Doktora Tezi, Fırat Üni. Fen Bilimleri Ens., Elazığ, 244. (unpublished).

Yıldırım, M. and Yılmaz, Y., 1991. Güneydoğu Anadolu orojenik kuşağının ekaylı zonu. Türkiye Petrol Jeologları Derneği Bülteni, 3, 57-73.

Yıldırım, N., 2011. Ormanbaşı Tepe (Sincik-Adıyaman) Bakır Cevherleşmesinin Maden Jeolojisi Raporu. MTA Report No: 3301, Ankara (unpublished).

———, Ay, Y., Aydın, A., Yığmatepe, M., Kalı, B. and Yıldırım, E., 2008 *a*. Koçali Karmaşığı İçerisindeki Taşınmış Kıbrıs Tipi Masif-Sülfit (Cu) Cevherleşmelerine Yeni Bir Örnek, Ormanbaşı Tepe (Sincik-Adıyaman) Cevherleşmeleri. 61. TJK Abstracts.

———, Aydın, A., Ay, Y., Yığmatepe, M. and Yıldırım, E, 2008 *b*. Ormanbaşı Tepe (Sincik-Adıyaman) Cevherleşmelerinin Kıbrıs Tipi Masif-Sülfid (Cu) Cevherleşmesi Olduğuna Dair Bulgular. Prof. Dr. Servet YAMAN Maden Yatakları-Jeokimya Çalıştayı, Ç. Ü. Jeoloji Mühendisliği Bölümü (Adana).

———, ———, Yığmatepe, M., Akgül, M. and Yıldırım, E., 2009. Levha dayk karmaşığı içerisindeki Kıbrıs tipi masif sülfid cevherleşmelerine Türkiye’den bir örnek: İncekoz (Adıyaman) Cu cevherleşmesi. 62. TJK Abstracts, 220-221.

———, Ay, Y., Çakır, C., İlhan, S., Dönmez, C. and Yıldırım, E., 2010 *a*. Koçali Ofiyolitik Karmaşığı’nın Metalojenik (Cu-Au) Önemi, IV. Ulusal Jeokimya Sempozyum Bildirileri, Elazığ, 79-80.

———, İlhan, S., Akyıldız, M., Yıldırım, E., and Dönmez, C., 2010 *b*. The Importance of the Ophiolites of the Southern Branch of the Neotethys (Koçali Ophiolitic Complex), in Terms of the Cyprus type VMS Deposits. 7. Uluslararası Doğu Akdeniz Jeolojisi Sempozyumu, Çukurova Üniversitesi, Jeoloji bölümü, Adana.

Yılmaz, Y., 1990. Comparisons of young volcanic association of western and eastern Anatolia formed under a compressional regime: a review. Journal of Volcanology and Geothermal Research, 44, 69-87.

————, 1993. New evidence and model on the evolution of the southeast Anatolian orogeny. Geological Society of American Bulletin, 105, 251-271.

————, Yiğitbaş, E., Yıldırım, M. and Genç, Ş.C., 1992. Güneydoğu Anadolu metamorfik masiflerinin kökeni. Türkiye 9. Petrol Kong., Proceedings, Ankara, 296-306.

Yıldırım, Y., Yiğitbaş, E. and Genç, C. 1993. Ophiolitic and metamorphic assemblages of Southeast Anatolia and their significance in the geological evolution of the orogenic belt. Tectonics, 12, 1280–1297.

Yiğitbaş, E., Yılmaz, Y. and Genç, Ş. C., 1992. Güneydoğu Anadolu orojenik kuşağında Eosen nap yerleşmesi. Türkiye 9. Petrol Kongresi, Proceedings, 307-318.

————, Genç, Ş. C. and Yılmaz, Y., 1993. Güneydoğu Anadolu orojenik kuşağında Maden grubunun tektonik konumu ve jeolojik önemi. A. Suat Erk Sempozyumu, Bildirileri, Ankara Üniversitesi Fen Fakültesi, 251-264.