Mineral Res. Expl. Bull., 136, 1-16, 2008

MINING GEOLOGY OF THE GOLD OCCURRENCES RELATED TO THE ARSENOPYRITES OF İZMİR-ÖDEMİŞ REGION

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ABSTRACT.- This study presents the results of the mineralogical, petrographical and geochemical investigations of the gold bearing vein-like arsenopyrite occurrences and mica schist, amphibole schist and amphibolite host rocks cropping out in the close vicinities of Elmacıgediği, Zeytinlik, Yılanlıkale and Kemer regions in the northeast of Ödemiş, İzmir. All investigated areas are located in the Ödemiş submassif of the Menderes Massif which consist of schists, gneisses and amphibolites. These units are formed under the conditions of medium grade metamorphism. Garnet-biotite-amphibolite, amphibole schists and mica schists crop out in the study area. They are generally rich in biotite and/or muscovite and in some localities garnet. The amphibolites which are formed as lense-like bodies, are more than several hundreds of meters in length and several tens of meters in thickness and are aligned parallel to the schistosity of mica schists. Geochemical analyses have been carried out on 11 selected samples. In the major oxides versus SiO_2 diagrams, ores mica schists and amphibolites/amphibole schists plot in different areas. Very high positive correlation coefficients among Au-Ag-Sb-Bi and Se are held from the trace element data of 7 samples taken from Zeytinlik area in statistically evaluation. Ore microscopical studies indicate two different stages for ore mineralizations as syngenetic and postmetamorphic. Mineralizations are formed both related with elements of basic magmatic rocks carried by solutions into the sedimentary basin and afterwards, the elements related with more asidic solutions. Mineralizations are remobilized during and/or after the metamorphism of the region.

Key words: Menderes Massif, Ödemiş submassif, arsenopyrite, gold, İzmir

INTRODUCTION

Some deposits are especially observed in Precambrian aged Canadian Greenstone Belts in the world when gold deposits in metamorphic terranes are investigated (Strachan and Moffett 1985, Kuhns 1988, Sawkins 1990). It is possible to see gold deposits related to the metamorphic rocks, metamorphosed volcanic and/or ultramafic rocks, or the rocks over the metamorphic basement in the Menderes Massif, Çanakkale, Hatay and Kastamonu in Turkey (Önal et. al., 1986, Kayhan 1991, Aydal 2000).

73 gold occurrences as gold bearing arsenopyrite and quartz veins have been found out during the detailed studies of MTA General Directorate carried out around Ödemiş and Çine Submassifs of Menderes Massif and Uşak and Eşme provinces at the eastern part of the Massif (Dilek and Kayhan 1987, Kayhan 1991). Gold and spatially tungsten have been determined in some analyses at Mursallı, Zeytinlik, Höyük Tepe, Elmacıgediği, Yılanlıkale, Akçakmakgediği, Küçük Avulcuk and Kemer occurrences around Ödemiş in Ödemiş Submassif (Dilek and Kayhan 1987, Kayhan 1991, Andiç 1992, Gonca 1992).

Scheelite and arsenopyrites occur in metamorphic rocks ,especially in amphibolites, in the region. Arsenopyrites form in schists in some regions and in amphibolites in other regions. Veinlike arsenopyrite mineralizations are followed sometimes in coincidence with the schistosity of schists and in some places cutting the schistosity planes. The thicknesses of the veins vary between a few cm's and 10 cm, while the length of veins reach up to 70 meters.

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The origin of the gold mineralizations in both arsenopyrite and quartz veins in the Massif are interpreted as either related with hydrothermal veins or fracture fillings due to hydrothermal mobilizations from stratabound ore levels of sedimentary origin which are affected from Varistic and Alpine Orogeny (Uzkut 1977, Çağatay and Eyüpoğlu 1979, Dilek and Kayhan 1987, Kayhan 1991, Andiç 1992, Gonca 1992). In this study, the origin of the mineralizations will be evaluated according to the collected geological data.

GENERAL GEOLOGY, MINERALOGY AND PETROGRAPHY

Geological, mineralogical and petrographical investigations are carried out in Elmacıgediği, Zeytinlik, and Yılanlıkale districts at the İzmir L20 a4 sheet. Since Kemer and Yılanlıkale districts are close settlements, these two occurrences will be interpreted together (Figure 1).

Elmacıgediği Area

This area is located 12 km northwest of Gölcük, east of Ödemiş-Bozdağ road. Garnet-mica schists and amphibolites crop out at the study area. Mica schists are generally brown and yellowish in colors. Schistosity of mica schists show strikes of E-W in general and rarely NW-SE and dip directions of S or SW with 40 to 70 degrees. The strikes of arsenopyrite bearing veins are E-W, NNW-SSE and N-S. Main minerals in mica schists are generally sillimanite, kyanite, biotite, muscovite, quartz, garnet and staurolite. Biotites are altered to hydrobiotites especially in close parts to the ore bearing zones. Some biotites have zircon inclusions (Plate I - Figure 1).

Lens-shaped amphibolites have more than a few hundred meters in lenghts and a few ten of meters in thicknesses. Greenish to blackish colored amphibolites contain coarse-grained minerals which are characterized by amphiboles, garnets, biotites and plagioclases. Microscopic investigations indicate that amphiboles are hornblendes according to their greenish pleochroisms. They display hypidioblastic to xenoblastic textures (Plate I - Figure 2). Xenoblastic plagioclases have polysentetic twinnings. Opaque mineral inclusions are common in the hypidioblastic and idioblastic garnets which are often developed in secondary fractures. Hypidioblastic biotite porphyroblasts exhibit brown pleochroisms. Quartz, muscovite, sphene, rutile and opaque minerals are also observed in thin sections.

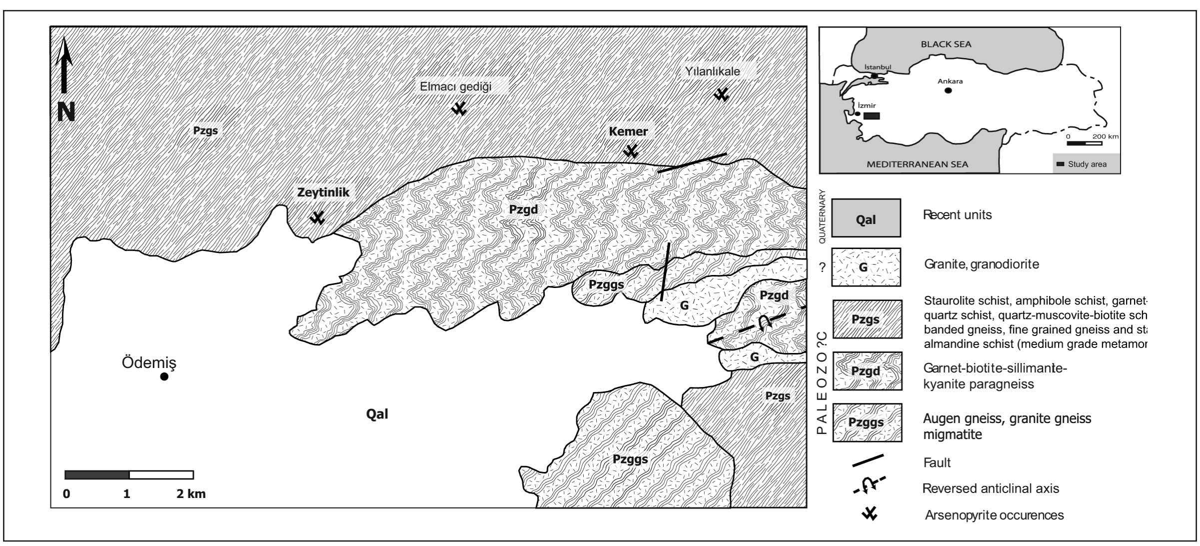


Figure 1- Regional geologic map of the investigated area (modified from Dilek and Kayhan, 1987).

Zeytinlik Area

This area is located at NE of Zeytinlik village which is 4 km away from Ödemiş in NE direction and on Gölcük road.

Massive arsenopyrite veins and veinlets are generally concordant with the schistosity of the biotite-quartz-muscovite-garnet schists at this area. The strike and dip of the veins are N62E / 46NW. The thicknesses of massive arsenopyrite veins vary between 10-15 cm and their lengths are in a few meters. In another location of the Zeytinlik area, a quartz lens with a 2,5 meter thickness is also observed which includes fine grained arsenopyrite disseminations. East of this location, arsenopyrite mineralizations which cut the schistosity of the rocks, crop out varying up to 10 cm thicknesses.

According to previous geological and petrographical studies, mica schist are classified as staurolite and garnet bearing kyanite-mica schists and garnet-mica schists. While kyanite crystals display more than 6 cm sizes, garnet crystals vary 1-2 cm in sizes (Kayhan 1991). Garnet mica schists are seen rarer than the other one. Biotite, quartz and plagioclases are determined as main minerals in the microscopical investigations. Biotites are generally hybidioblastic to xenoblastic in forms and show brownish pleochroisms (Plate I - Figure 3). They are affected from deformations and in some thin sections are observed as altered to chlorite and hydrobiotite (Plate 1 - Figure 4). Biotites are dark red to dark brown in colors when iron rich solutions affect the rocks, which caused opacitisation of the biotites. So, the biotites in ore samples are quite different from the other biotites. Biotites have sometimes inclusions. Muscovites appear in small amounts and are bended due to deformations.

Two kinds of quartz grains have been determined during microscopical studies. One type is fine grained quartz in mica schists and the other type is the coarser grains. Quartzs have xenoblastic textures and show undulating extinction.

In some thin sections, tourmaline, apatite, and zircon are observed as detritic grains, which are very fine grained and rounded. Rutiles are recognizable with their opaque and reddish colours. Opaque minerals take place parallel to schistosity.

Xenoblastic quartz are as veinlets with coarser grain sizes in ore samples. Biotites are also xenoblastic and bended. They are sometimes chloritized. Biotites exhibit dark red to dark brown colours due to iron bearing solutions and are fractured at these samples.

Kemer and Yılanlıkale Areas

Kemer area is located in the east, northeast of Zeytinlik Village and 9 km northeast of Ödemiş. It is on the road from Kemer to Yılanlıkale. The area is covered by mica schists and amphibolites which contains quartz-arsenopyrite mineralizations. These mineralizations are concordant with the schistosity of the rocks. The strikes and dips of the mineralizations are measured as N55E / 30SE and N80W / 76SW.

Amphibolites at Kemer area are lenticular and display massive character compared to mica schists caused by large scale boudinage. Amphibole, garnet, epidote, and plagioclase bearing amphibolites have dark greenish to blackish colours.

Amphiboles show medium to strong green pleochroism and identified as hornblendes. Xenoblastic hornblendes are fine grained and clustered.

Garnets are generally hypidiblastic to xenoblastic in textures. Both isotropic to anisotropic garnets are observed in thin sections. Some garnets are fracturated and epidotized due to hydrous solutions. Opaque minerals as inclusions occur in pinkish garnets which are supposed to be almadine type. In some sections, pinkish coloured garnets are accepted as secondary in origin and are found in veinlets.

Epidotes are also generally hypidioblastic to xenoblastic in forms. In some sections, the amount of epidotes are high (Plate 1 - Figure 6) which are determined as clinozoisites.

Plagioclases are fine grained and exhibit rounded crystals. Hypidioblastic to xenoblastic plagioclases present albite twinnings. They are brecciated and cataclastic.

Quartz are observed in very small amounts. Less than 5% amounts of quartzs display xenoblastic textures. Titanite (Plate 1 - Figure 5), rutile, zircon, and opaque minerals are accessories in thin sections.

Yılanlıkale area is located approximately 2 km's northeast of Kemer village and 3.5 km's southeast of Bozdağ. It crops out at the Kemer-Yılanlıkale road trench. Arsenopyrite mineralizations occur as fillings of veins and veinlets in the fault and fracture systems of mica schists. These mineralizations cut the rocks as stockworks. Quartz-arsenopyrite vein clusters have 1 cm to 50 cm thicknesses in a 120 m zone. Quartz lenses are squeezed and fractured due to chaotic tectonic events. The schistosities of mica schists are measured as N30-60W / 30-50W. The rocks in this area exhibit very similar mineralogical and petrographical features. Therefore, only minerals in ore samples and their features will be given in the following text.

In some ore samples, biotite flakes occur along the fractures and have brownish strong pleochroism. Biotites are lost their flaky appearances caused by ore solutions and due to hydrobiotitization and gained reddish colours.

Hypidioblastic muscovites are the products of biotite with 1-2% modal compositions. Quartz are generally as secondary veins. They are xenoblastic grains with mosaic textures. In ore rich zones, quartz are coarser than the other zones (Plate 1 - Figure 6).

Hypidiblastic plagioclases do not show albite type twinning and zonation. Porphyroblastic plagioclases are fractured and cracked with the effect of ore veins. Some of them are fracture fillings at ore zone sections. Titanite inclusions are observed in plagioclases. Shear fracturing in two directions are generally main features at this kind of ore samples. Due to fracturing, ore minerals are scattered to every directions in sections.

Small amount of amphiboles (hornblendes) as clusters, zircon bearing biotites as hypidioblasts to idioblasts, titanite and apatites, are the other minerals in these zones. Fractured and brecciated ores are silicified, carbonatized and scoroditized in most of the locations.

ORE MICROSCOPY

One sample (KM -3) from Kemer area, one sample (YK-2) from Yılanlıkale area and four samples (ZT-1, ZT-4, ZT-5, and ZT-10) from Zeytinlik area are ore microscopically investigated. The features of ore minerals are given below:

Observations are made in oil environment and under 250 magnifications. At the end of this chapter, a short summary of ore microscopy section of MTA-Italian project (SNIA TECHINT-RIMIN-GEOEXPERT ITALY, 1991) will be presented and correlations with this study will be done.

At ZT-1, ZT-4 and ZT-5 samples from Zeytinlik area, no scheelite mineral could be found in the polished sections, so investigations about the features of this mineral could not be given.

Arsenopyrite.- Main ore minerals of the sections are arsenopyrites up to 3.5-4 mm in sizes. They are cataclastic and generally idiomorphic. Due to tectonism, arsenopyrites are replaced by scorodites along their edges and cleavages (Plate 2 - Figure 1). In some parts of polished sections, arsenopyrite relicts are observable among scorodites. Some of them are as grains while others as disseminations. Disseminated ones show maximum 3 cm sizes. Sometimes, scorodites lie as zones between silicates and arsenopyrites. Fine magnetite and pyrite grains occur in arsenopyrites. Because of this feature, arsenopyrites are younger than magnetites and pyrites.

Scorodite.- They are secondary minerals as a result of weathering products of arsenopyrites. Green coloured scorodites are observed along the cracks of arsenopyrites. Arsenopyrite skeletals are formed as a result of replacement of scorodites at Yılanlıkale area. Colloform textures are the products of this event.

Native Gold.- Native gold grains vary in sizes up to 110 m x 250 m. In some parts of the sections, gold grains are scattered separately while in other parts as fine grained clusters. Native gold grain inclusions are in arsenopyrites or in scorodites. (Plate 2 - Figure 2) Gold grains fill the cracks of arsenopyrites in some places which indicate that those kind of gold grains are formed younger than arsenopyrites.

Pyrite.- Pyrites are observed mostly in arsenopyrites as subhedral to euhedral cataclastic crystals and sometimes as skeletons (Plate II - Figure 3). Pyrites are older than arsenpyrites because they are surrounded by arsenopyrites. This kind of pyrites are 0.3 - 0.4 mm in sizes. In some sections, growing traces can be seen between pyrites and marcasites. Some pyrites which are up to 1 mm sizes are formed as pseudomorphs of hexagonal pyrrhotite grains (Plate II - Figure 4). Pyrrhotite, marcasite and magnetite occur both in arsenopyrites and silicate minerals at host rock. Sometimes, chalcopyrites surround of pyrites.

Chalcopyrite.- Crystals up to 0.2 mm are formed together with arsenopyrites and as fillings of arsenopyrite cracks. In some places, they surround pyrites (Plate II - Figure 5). The youngest ore mineral in polished sections are beleived to be chalcopyrites. The arsenopyrite-chalcopyrite association are found especially at Kemer area and are 150 µm in sizes which are replaced by limonite and covellite (Plate II - Figure 6).

Other Opaque Minerals.- Rutiles are as tiny needles in 200 µm sizes and take place paralel to schistosity. Titanites are in very small amounts. Both opaque minerals are observed in biotites. On the other hand, rutiles after ilmenite occur in gangue minerals. Rounded-elipsoidal pyrrhotite grains form in amphibolites of Zeytinlik area.

SUMMARY OF ORE MICROSCOPIC STUDIES OF MTA-ITALIAN PROJECT

Elmacıgediği Area

First, pyrrhotite, arsenopyrite and scheelite paragenesis and at second stage chalcopyrite and marcasite association represent synmetamorphic mineralization. Marcasite could be an alteration product of pyrrhotite. The crystal sizes of pyrrhotite, pyrite, arsenopyrite and scheelite are less than 1 mm. Chalcopyrite and marcasites are finer than 0.1 mm in sizes. No free gold has been detected.

Zeytinlik Area

Euhedral arsenopyrites up to 2 cm in sizes exhibit elongated crystals. The grains are generally in silicates as poikiloblastic to porphyroblastic growths. Marcasite, stibnite and chalcopyrites are as intergrowths and fracture fillings.

Native gold occur both as inclusions in coarse grained arsenopyrites and at fine cracks which are filled by bismuthinite, chalcopyrite and quartz in arsenopyrites with less than 10 µm sizes.

Chalcopyrite are maximum 0.03 mm in sizes. They occur together with marcasite, bismuthinite and gold at small cracks.

Marcasites occur at the center of arsenopyrites with less than 0.5 mm. Primary pyrrhotites are possibly replaced by marcasites. They show sometimes intergrowths with chalcopyrites.

Scheelites up to 1 cm grains are as euhedral to subhedral porphyroblasts grown paralel to schistosity.

Yılanlıkale Area

Poikiloblastic and euhedral arsenopyrite crystals are brecciated due to secondary processes. Pyrite, pyrrhotite and chalcopyrite minerals occur at the cracks of arsenopyrites. Free gold and bismuthinite could not be seen. These minerals are as inclusions in less than 10 μm sizes.

ORE MICROSCOPIC CORRELATION AND INTERPRETATION

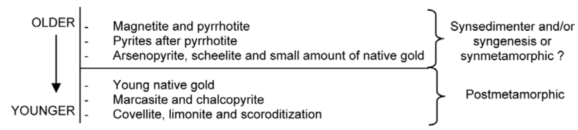
Arsenopyrites are euhedral and are found among silicate minerals and contain marcasite and chalcopyrite crystals at cracks and fractures of arsenopyrites. These features are the main similarities between this study and MTA-Italian Project. New finding at this study is that arsenopyrites occur both as grains and disseminations. They are younger than magnetites and pyrites and cataclastic and also scoroditized. For gold grains, they occur in arsenopyrites and at their cracks. This observation is the same at both studies. On the other hand, in this study, native gold grains are observed both separately and clustered, vary up to 250 μm in sizes and are found as free gold grains in scorodites.

Pyrites are found in the polished sections of this study, on the contrary marcasites are observed during MTA-Italian Project.

Bismuthinite, scheelite and stibnite are determined at MTA-Italian Project.

If all ore paragenesis data are interpreted all together :

1) Formation sequence of ore minerals from older to younger :



2) Euhedral arsenopyrites and their concordance to schistosity at Zeytinlik and Elmacıgediği areas are characteristics of this study. Vein type ore mineralizations and no ore mineral association which are seen at other areas, are observed at Yılanlıkale area should look like to indicate a late stage mobilization.

GEOCHEMISTRY

MAJOR AND TRACE ELEMENT ANALYSES AND EVALUATIONS

According to results of petrographical studies, 11 representative samples are selected from different zones of every area and chemically analysed. 7 samples from Zeytinlek area, 2 from Elmacıgediği area, 1 from Kemer and 1 from Yılanlıkale area belong to analysed samples. Analytical results from MTA-Italian Project samples are also used for correlations. Rock descriptions and analytical data are given at Table 1, 2, 3, 4, 5, and 6.

Elmacıgediği Area

All major oxide analyses are concordance with each other at amphibole schist samples. But at the sample named amphibole schist - amphibolite (EG-2a), SiO_2 content is a little bit lower, Fe_2O_3 content is higher. Analytical results of ore bearing sample (7579) are very similar to rock sample, which can be explained by low amount of ore. On the other hand, higher Fe_2O_3 content could be related to ore minerals. In addition, the similarities of major oxides with amphibolite or amphibole schists should point out that ore bearing solutions from their host rocks.

Trace element contents given on Table 4 were difficultly interpreted with the MTA-Italian Project

Table 1- Descriptions of analysed samples collected from study area

Sample Number	Locality	Description
EG-2a	Elmacıgediği	Garnet-amphibole schist-amphibolite contact
EG-6	Elmacıgediği	Amphibole schist
KM-1	Kemer	Ore sample (arsenopyrite)
YK-2	Yılanlıkale	Arsenopyrite ore (concentration)
ZT-1	Zeytinlik	Ore sample (arsenopyrite)
ZT-2	Zeytinlik	Biotite-muscovite-gaarnet-staurolite schist
ZT-3	Zeytinlik	Biotite-muscovite schist
ZT-4	Zeytinlik	Ore sample (arsenopyrite)
ZT-5	Zeytinlik	Ore sample (arsenopyrite)
ZT-6	Zeytinlik	Muscovite-biotite schist
ZT-10	Zeytinlik	Ore sample (arsenopyrite)

Table 2- Descriptions of analysed samples collected during MTA-Italian Project studies

	Sample Nr.	Locality	Description
MTA-Italian Joint Venture Project	7579	Elmacıgediği	Ore sample (arsenopyrite)
	8368	Elmacıgediği	Amphibole schist
	8369	Elmacıgediği	Amphibole schist
	TR-M-10	Yılanlıkale	Arsenopyrite ore (compiled sample)
	8381	Yılanlıkale	Ore sample (arsenopyrite)
	8414	Yılanlıkale	Arsenopyrite ore (concentration)
	8415	Yılanlıkale	Ore sample (arsenopyrite+quartz vein)
	7541	Zeytinlik	Quartz vein (Pyrite-arsenopyrite-wolframite)
	7544	Zeytinlik	Schist
	7545	Zeytinlik	Schist
	7548	Zeytinlik	Schist
	8375	Zeytinlik	Mica schist
	8378	Zeytinlik	Prasinite (meta volcanite)
	8426	Zeytinlik	Garnet amphibolite
	8429	Zeytinlik	Garnet – mica schist
	8432	Zeytinlik	Biotite gneiss
	8433	Zeytinlik	Mica schist
	8441	Zeytinlik	Garnet amphibolite
	TR-M-9	Zeytinlik	Arsenopyrite ore (compiled sample)
	TR-Au-Z1	Zeytinlik	Arsenopyrite ore (compiled sample)

samples due to their low detection limits of analyses. But by the comparison of 7579 sample to EG-2a and EG-6 samples, most of the results exhibit great similarities, except W, Mo, Cu, As, Sb, Au and Ni contents. It indicates that ore bearing samples and amphibolite / amphibole schists have similar trace element contents. Above given elements are connected with ore mineralizations.

High value of W at 7579 sample points out scheelite presence. Cu and As contents are also very high in ore sample.

Table 3- Results of analysed samples collected from study area (analyses are made at ACME Analytical Lab., Canada by ICP-ES and MS method)

Sample Nr →	ZT-1	ZT-2	ZT-3	ZT-4	ZT-5	ZT-6	ZT-10	EG-2a	EG-6	KM-1	YK-2
SiO_2(%)	45.74	61.64	62.68	42.02	61.64	62.54	46.75	55.85	64.54	43.76	4.17
Al_2O_3(%)	11.88	17.38	17.90	9.32	10.10	17.49	2.83	16.56	13.83	14.57	0.80
$Fe_2O_3^*$ (%)	16.94	6.95	4.91	21.45	10.63	4.49	22.29	8.49	6.15	13.29	37.97
MgO(%)	1.17	2.96	2.02	1.42	0.43	1.84	0.12	3.84	2.70	0.75	0.02
CaO(%)	3.82	1.59	1.03	2.54	3.08	1.15	0.41	8.72	7.30	21.02	0.17
Na_2O(%)	1.54	1.68	2.25	1.17	1.14	2.48	0.73	2.60	1.54	0.12	0.05
K_2O(%)	0.86	3.67	4.04	0.64	0.87	3.66	0.19	0.26	0.21	0.03	0.25
TiO_2(%)	0.27	0.95	0.44	0.23	0.39	0.44	0.22	0.96	0.92	0.57	0.07
P_2O_5(%)	0.55	0.19	0.02	0.62	0.18	0.05	0.11	0.68	0.25	0.08	0.04
MnO(%)	0.01	0.06	0.02	0.01	0.01	0.02	< .01	0.16	0.14	0.42	< .01
Cr_2O_3(%)	0.049	0.039	0.056	0.026	0.047	0.048	0.031	0.044	0.090	0.030	0.019
LOI	10.9	2.4	3.7	18.5	9.7	3.8	17.1	1.6	1.3	4.7	51.4
TOT/C	0.13	0.12	0.29	0.34	0.22	0.33	0.01	0.03	0.07	0.03	0.02
TOT/S	4.37	0.03	0.03	4.92	1.17	0.04	2.72	0.10	0.02	0.13	14.34
SUM	93.89	99.72	99.41	98.02	98.34	98.29	90.93	99.98	99.36	99.44	94.98

Sample Nr →	ZT-1	ZT-2	ZT-3	ZT-4	ZT-5	ZT-6	ZT-10	EG-2a	EG-6	KM-1	YK-2
Co(ppm)	10.2	9.9	12.7	11.4	2.2	9.9	27.1	21.7	19.9	11.1	30.0
Cs(ppm)	3.1	6.2	5.6	2.7	2.0	4.9	0.6	0.9	2.6	<0.1	0.7
Ga(ppm)	19.4	24.2	24.5	16.2	24.7	22.5	4.5	16.7	17.9	20.2	3.0
Hf(ppm)	2.8	5.4	4.2	2.2	3.7	4.0	1.4	4.8	5.2	2.6	<0.5
Nb(ppm)	5.7	13.8	8.4	4.2	7.6	7.8	3.2	11.9	12.0	13.4	1.1
Rb(ppm)	42.5	114.8	127.0	32.7	39.6	95.2	7.9	5.0	5.4	0.6	9.3
Sn(ppm)	<1	4	3	<1	3	3	2	4	8	25	<1
Sr(ppm)	446.8	264.1	209.6	235.6	501.0	204.3	195.0	356.6	283.6	205.5	30.4
Ta(ppm)	0.3	1.0	0.6	0.3	0.5	0.6	0.3	0.9	0.8	0.9	<0.1
Th(ppm)	5.5	10.3	9.6	5.8	11.1	10.4	1.9	9.1	7.4	17.4	1.0
U(ppm)	3.8	3.3	7.4	3.4	5.3	4.5	0.4	3.6	2.2	4.6	0.1
V(ppm)	102	124	141	77	68	131	24	94	71	140	27
W(ppm)	11.8	3.2	5.9	71.3	4005.4	15.2	14.4	2.7	4.8	3.5	18.6
Zr(ppm)	98.0	193.4	144.3	81.0	139.4	130.8	42.6	176.2	168.7	88.1	11.9
Y(ppm)	40.3	34.4	25.1	24.0	30.6	29.2	6.9	38.2	34.6	49.7	1.1
Mo(ppm)	5.8	0.8	8.5	4.4	12.1	10.3	4.5	1.3	1.3	0.7	2.7
Cu(ppm)	70.9	40.3	115.4	56.3	158.0	45.2	1.6	47.3	4.7	74.5	3.2
Pb(ppm)	11.5	3.8	8.9	6.7	18.3	7.6	2.0	4.0	5.2	8.7	2.6
Zn(ppm)	18	56	112	24	15	83	4	49	38	18	4
Ni(ppm)	979.1	975.7	1430.9	464.7	765.6,	1062.9	926.8	1430.0	2337.2	829.2	362.9
As(ppm)	>9999	77.4	709.4	>9999	6938.4	2233.2	>9999	467.5	570.4	1102.9	>9999
Cd(ppm)	0.1	< .1	0.5	0.1	0.1	0.2	< .1	0.4	0.3	0.2	< .1
Sb(ppm)	58.2	0.3	0.6	79.7	2.6	1.3	147.7	0.6	0.5	1.1	103.3
Bi(ppm)	18.7	0.3	0.9	23.9	19.5	0.9	231.4	0.6	4.7	1.9	13.0
Ag(ppm)	0.6	0.2	0.5	0.9	0.7	0.3	1.7	0.5	0.3	1.1	0.2
Au(ppm)	6.17	3	0.01	8.48	2.92	0.12	86.33	0.15	0.18	0.31	4.13
Hg(ppm)	0.01	0.01	0.02	0.18	0.64	0.23	0.09	0.01	0.01	< .01	0.21
Tl(ppm)	0.3	0.5	0.5	0.2	0.2	0.4	0.1	< .1	< .1	< .1	< .1
Se(ppm)	10.6	0.5	1.6	15.2	7.6	2.7	18.2	0.5	< .5	0.7	29.1

* Total iron as Fe_2O_3.

Table 4- Results of major oxide analyses of the samples collected during MTA-Italian Project studies.

Sample Nr →	7579	8368	8369	7541	7544	7545	7548	8375	8378	8426	8429	8432
SiO_2(%)	59.06	63.50	59.60	56.62	61.90	59.60	66.00	60.70	51.50	47.80	63.50	68.30
TiO_2(%)	0.82	0.93	0.94	0.35	0.49	0.98	0.83	0.51	0.31	3.00	1.14	0.87
Al_2O_3(%)	11.74	15.10	18.90	16.08	18.29	18.50	14.90	18.70	4.50	15.60	15.90	15.00
$Fe_2O_3^*$(%)	10.58	5.82	7.70	7.80	5.39	6.34	5.63	4.65	21.00	15.20	7.31	3.51
MnO(%)	0.08	0.21	0.10	0.11	0.12	0.10	0.08	0.05	-	0.19	0.10	0.02
MgO(%)	2.25	2.41	4.07	2.63	2.48	2.68	2.01	2.13	0.36	5.40	2.67	1.88
CaO(%)	5.12	6.66	1.15	9.28	2.43	1.81	2.25	1.34	0.54	7.14	2.21	2.30
Na_2O(%)	n.a	2.79	2.43	n.a	4.52	1.04	2.43	2.62	1.27	2.41	3.61	3.71
K_2O(%)	<0.02	0.10	3.42	0.13	2.32	4.03	1.88	3.80	1.68	1.31	2.32	2.44
P_2O_5(%)	0.29	0.40	0.23	0.69	0.26	0.19	0.21	0.09	0.17	0.51	0.31	0.12
LOI	n.a	0.90	2.10	n.a	2.50	2.50	1.60	4.70	19.80	1.80	1.10	2.00
SUM	98.14	98.80	100.80	98.08	100.88	97.95	97.85	99.80	98.60	100.60	100.10	100.60

Örnek No →	8433	8441	TR-Au-Z1	TR-M-9	8381	8414	8415	TR-M-10
SiO_2(%)	69.30	42.20	45.07	39.55	37.81	2.26	95.16	11.01
TiO_2(%)	0.85	5.04	0.26	0.24	0.18	0.09	0.03	0.15
Al_2O_3(%)	14.80	13.80	10.27	9.76	4.81	1.85	<1	<1
$Fe_2O_3^*$(%)	4.99	17.20	18.04	20.21	30.39	44.99	4.42	34.51
MnO(%)	0.05	0.14	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
MgO(%)	1.78	9.22	1.69	0.85	<0.50	0.89	<0.50	<0.50
CaO(%)	0.96	9.79	3.04	2.65	<1	3.49	<1	<1
Na_2O(%)	2.80	0.98	n.a	n.a	n.a	n.a	n.a	N.a
K_2O(%)	2.65	0.27	0.93	0.91	0.86	0.18	<0.02	0.2
P_2O_5(%)	0.16	0.42	0.39	0.58	0.07	0.11	0.03	<0.1
LOI	2.00	1.10	n.a	n.a	n.a	n.a	n.a	N.a
SUM	100.50	100.10	101.21	102.08	85.71	60.58	110.22	92.04

* Total iron as Fe_2O_3,- Below the dedection limit, n.a : not analysed.

Zeytinlik Area

SiO_2 contents of ore samples (ZT-1, ZT-4 and ZT-10) compiled from area are lower than 45% which are also lower than the mica schist's. On the other hand, ZT-5 sample has 61% SiO_2 value and similar to mica schists. Petrographical descriptions of ZT-5 sample also indicate mica schists. Al_2O_3 contents in ores and close to ore zones at ZT-1, ZT-4 and ZT-5 samples vary between 9-10%, but samples from mica schists (ZT-2, ZT-3 and ZT-6) exhibit more than 17% Al_2O_3 contents. ZT-10 ore sample has the lowest Al_2O_3 value with 2.83%. MgO contents of ore samples, except ZT-10 sample, vary between 1 to 4%. Mica schists have more the 1.84% MgO values. This indicates a 1 to 2% differences between ore samples and mica schists. Ore samples contain 2,5 - 3,8% CaO contents again except ZT-10 sample, while mica schists have 1 - 1,6% CaO values. P_2O_5 contents of ore samples are more than other samples. K_2O values of ore samples are less than 0.87%, while mica schist have higher contents.

Table 5- Results of trace element analyses of the samples collected during MTA-Italian Project studies.

Sample Nr →	7579	8368	8369	7541	7544	7545	7548	8375	8378	8426	8429	8432
V(ppm)	66.9	n.a	n.a	110.2	n.a	n.a	n.a	n.a	n.a	n.a	n.a	N.a
Co(ppm)	14	12	14	25.1	31	-	14	-	-	11	17	47
Ni(ppm)	45.5	37	60	200.9	90	10	43	13	-	24	43	71
Sn(ppm)	<16	-	-	<16	-	-	-	-	-	-	-	-
W(ppm)	851.5	n.a	n.a	16	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Mo(ppm)	7.7	n.a	n.a	<4	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Cu(ppm)	510.3	30	32	84	-	-	-	15	75	97	18	39
Pb(ppm)	<20	-	-	56.4	-	-	-	18	-	-	-	-
Zn(ppm)	43	31	164	575.9	234	116	138	76	-	102	109	63
As(ppm)	32826	-	-	225	-	-	-	105	5910	-	-	68
Sb(ppm)	20	n.a	n.a	<20	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Bi(ppm)	<20	n.a	n.a	<20	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Hg(ppm)	<0.1	n.a	n.a	<0.1	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Au(ppm)	0.34	n.a	n.a	0.01	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Ag(ppm)	<1.0	n.a	n.a	<1	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Ba(ppm)	78.8	85	556	103.9	483	1090	312	809	300	265	608	869
Rb(ppm)	n.a	-	131	-	100	136	84	136	98	51	86	68
Sr(ppm)	443.5	302	250	727.4	334	181	205	280	232	300	243	177
Li(ppm)	21.2	n.a	n.a	55.1	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Nb(ppm)	11.8	10	-	9.2	-	10	-	10	-	18	10	-
Zr(ppm)	192.4	228	199	123	185	239	235	200	124	230	371	263
Y(ppm)	36.1	33	33	32.6	28	47	44	39	-	30	33	24
Th(ppm)	n.a	-	-	n.a	-	-	-	-	27	-	-	-
U(ppm)	n.a	-	-	n.a	-	-	-	-	-	-	-	-
Cr(ppm)	69.1	46	67	54.8	73	100	88	80	-	34	94	72
Cd(ppm)	<2.0	n.a	n.a	4.7	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a

Sample Nr →	8433	8441	TR-Au-Z1	TR-M-9	8381	8414	8415	TR-M-10
V(ppm)	n.a	n.a	90.7	103.3	17.9	56.6	4.5	36.3
Co(ppm)	-	54	13.8	27.4	12.9	27.4	2.2	30.6
Ni(ppm)	18	94	56.2	42	6.1	25.3	<6	15.8
Sn(ppm)	-	-	<16	<16	17.8	16.4	20.8	<16
W(ppm)	n.a	n.a	1669.4	1050.2	454	<16	<16	<16
Mo(ppm)	n.a	n.a	20.9	21.1	<4	<4	<4	23.4
Cu(ppm)	60	57	75.1	72.8	3.4	5.1	4.1	3.9
Pb(ppm)	-	-	20	28.1	<20	<20	<20	<20
Zn(ppm)	75	231	59.3	60.9	28.5	63.2	10.4	60.9
As(ppm)	-	-	113000	150000	50000	50000	17000	287000
Sb(ppm)	n.a	n.a	89.3	115	90.3	113.5	32.1	137.5
Bi(ppm)	n.a	n.a	21.1	47	<20	<20	<20	38
Hg(ppm)	n.a	n.a	5	<0.1	5.1	4.8	0.3	<0.1
Au(ppm)	n.a	n.a	4.5	17	1.9	2.2	0.3	6.7
Ag(ppm)	n.a	n.a	<1	1	<1	<1	<1	<1
Ba(ppm)	872	140	236.7	244	308.2	599.7	58.8	735.9
Rb(ppm)	76	10	n.a	n.a	n.a	n.a	n.a	n.a
Sr(ppm)	180	105	347.9	302.2	95.9	395.7	9.3	120
Li(ppm)	n.a	n.a	7.8	17.1	<4	<4	<4	6.9
Nb(ppm)	-	22	3.9	5.3	6.3	<2	<2	2.7
Zr(ppm)	212	190	106.7	98.1	210.1	9.1	<2	15.6
Y(ppm)	21	15	21.2	22.7	3.7	2.8	<1	2.2
Th(ppm)	-	-	n.a	n.a	n.a	n.a	n.a	n.a
U(ppm)	-	-	n.a	n.a	n.a	n.a	n.a	n.a
Cr(ppm)	65	150	42	78.4	18.1	21.4	9.9	8.2
Cd(ppm)	n.a	n.a	<2	<2	<2	<2	<2	<2

- Below the dedection limit, n.a : not analysed.

Table 6- The symbols representing the samples on the graphics

Rock types	Description	Symbol	
		This study	Ital.Proj.
Amphibole bearing rocks	Amphibole schists and amphibolites	▲	△
Schists	All schist samples (except amphibole schists)	◆	◇
Ore samples	All ore samples	■	□
Gneiss	Biotite gneiss	-	○
Vein	Quartz vein	-	x
Prasinite	Meta volcanite	-	+

- Not observed in this study

SiO_2 contents of ore samples and amphibolites are lower than mica schists at MTA-Italian Project samples. TiO_2 values are high at amphibolites and Fe_2O_3 contents are also high at amphibolites, ore samples and meta volcanite (prasinite). Amphibolites contain higher amount of MgO. Major oxide analytical results of MTA-Italian Project samples are in concordance with this study.

At samples ZT-1 to ZT-6 in Table 3, higher amount of As, Sb, Bi, Au and Se point out ore zones. As contents of ore samples (ZT-1, ZT-4, ZT-5 and ZT-10) are higher than 7000 ppm. Mica schists have 77 - 2200 ppm As values. Sb, Bi and Se contents of ore samples are higher than mica schists.

When all samples collected from Zeytinlik area are interpreted, Ni contents exhibit heterogeneties. Ni contents of mica schists vary between 10 and 1463 ppm and are higher than ore samples. W value is high only with 4000 ppm at ZT-5 sample. On the other hand, channel samples (TR-Au-Z1 and TR-M-9) from MTA-Italian Project exhibit a little bit high W contents. At these samples, As values with 113000 ppm and 150000 ppm are very high.

At ore samples, Au contents vary 3 to 9 ppm. Only ZT-10 sample contain 86,33 ppm gold value. In connection with Au content, this sample has higher contents of Ag, Sb, and Bi but lower contents of Zn, Rb, Cs, Ga, Zr, Y, Th, U and Sc when compared with other samples. On the other hand, V, Co, W, Mo and Cu contents of this sample are higher than other ore samples but very close to mica schists.

At all major oxide versus SiO_2 diagrams, amphibole bearing rocks, schists and ore samples plot at different areas (Figure 2).

At TiO_2, Al_2O_3, MnO and MgO versus SiO_2 diagrams, major oxide contents of ore samples are lower than the contents of schists and amphibole bearing rocks. Total Fe_2O_3 and P_2O_5 values are similar both at ore samples and amphibole bearing rocks. No discrimination could be seen at rocks due to Na_2O and K_2O contents. TiO_2, MnO and MgO contents of amphibole bearing rocks are clearly higher than ore samples and schists. Total Fe_2O_3 contents of amphibole bearing rocks and ore samples look like very similar (Figure 2).

At a few samples collected from the rocks which are parallel to schistosity at Zeytinlik area, trace element contents are evaluated statistically e.g. Cluster analyses. According to this method three main association have been determined. First one is Cr-Ni association, second ore is rep-

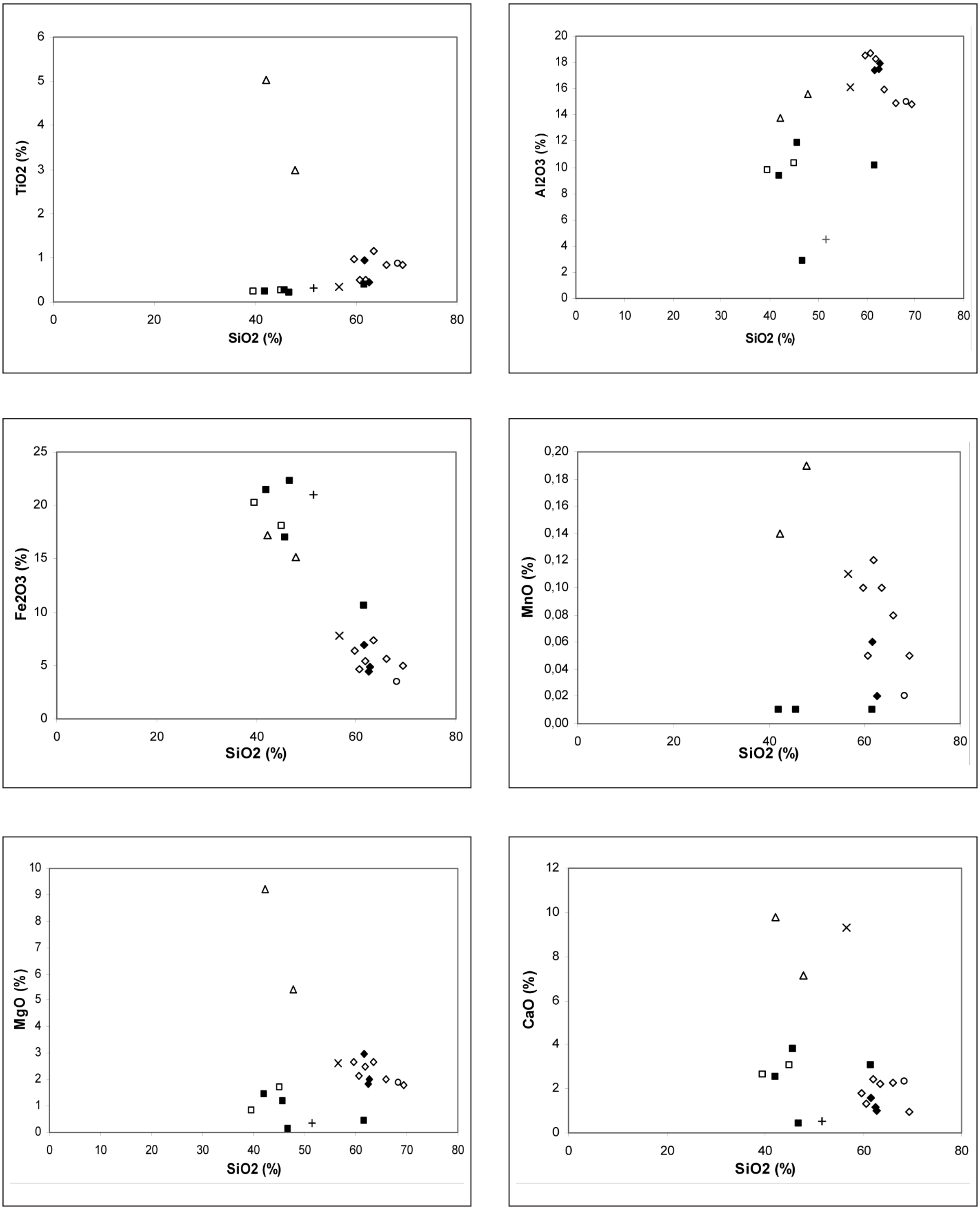


Figure 2- Harker diagrams (SiO_2 versus major oxides).

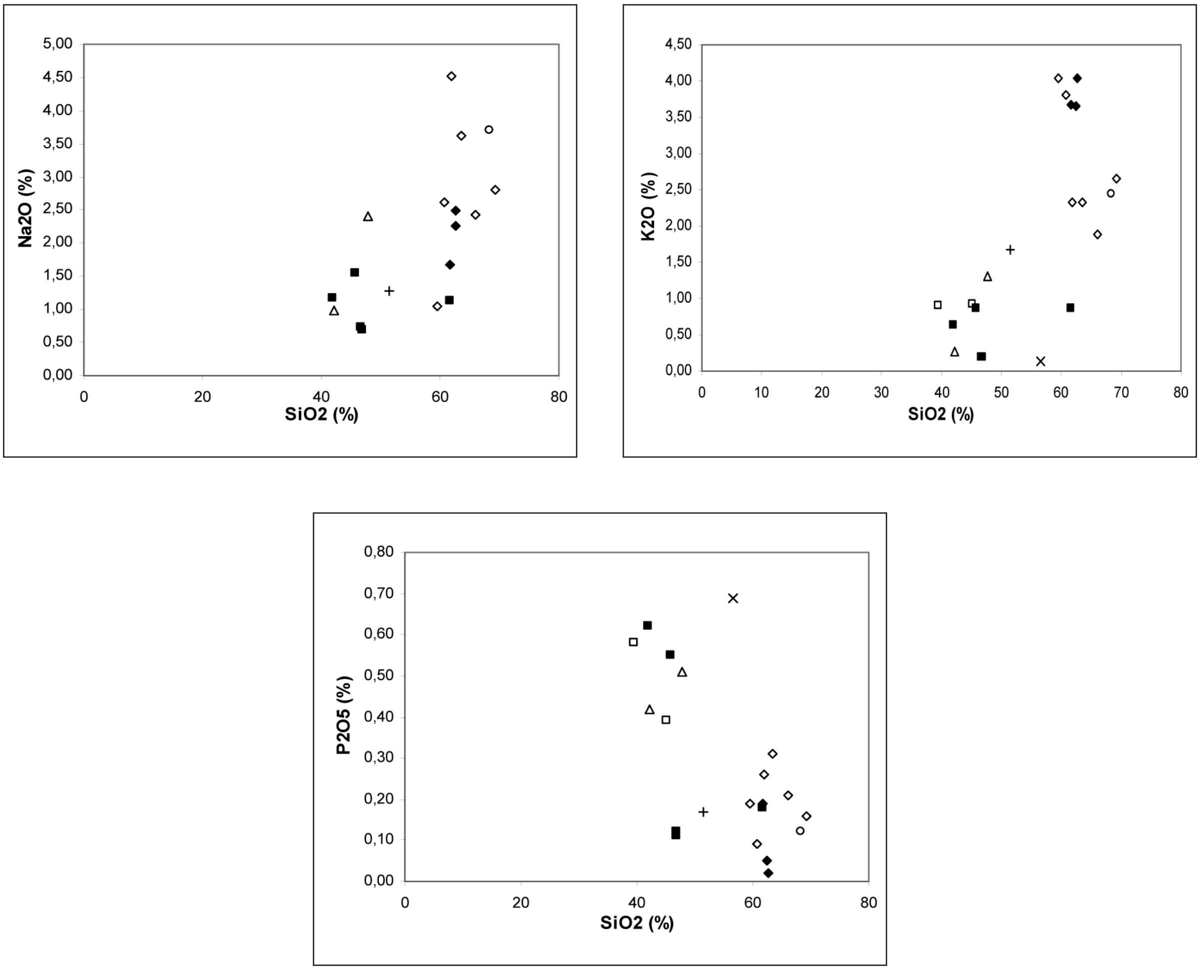


Figure 2- Continue

resented by U-V-Cu-Mo-Pb-Th-Ba association. Third association includes Au-Ag-Bi-Sb-Se elements (more detailed information, see Akıska 2003).

Kemer-Yılanlıkale Areas

All samples compiled from these areas are either ore-rich samples or channel samples. SiO_2 contents of analysed samples verify it. 95.16% SiO_2 content of sample 8415 points out arsenopyrite bearing quartz vein. On the other hand, 8414 and YK-2 samples contain only 2-4% SiO_2. These samples are rich in arsenopyrite and therefore SiO_2 contents are low. Except than 8415 sample which represents quartz vein, Fe_2O_3 content of all samples are high. SiO_2, Al_2O_3 and CaO contents of KM-1 sample are higher than other samples which can be interpreted that this sample represent host rock with ores. K_2O value of KM-1 sample is low. But with 21% of CaO content of this sample indicate an extraordinary composition of it. High content of CaO can be regarded to garnet and epidote minerals due to petrographical studies.

Due to trace element values, KM-1 sample shows special contents. V, Ni, Cu, Nb and Y and also possibly U and Th values are higher but W, Sb, Bi and Hg contents are lower than other samples. W content of 8381 sample is 454 ppm which point out presence of scheelite.

When arsenopyrite ore concentrations of TR-M-10 and YK-2 samples are compared to each other, except Ba and Sr contents, all trace element values are in concordance with each other. As is 287000 ppm at TR-M-10 sample and is also high at YK-2 sample. Au contents of all samples vary between 0,3 and 6,7 ppm.

Another characteristic feature of this area is that Sn contents, except than YK-2 sample, are higher than 16 ppm. Sb values are higher than 32,1 ppm which reachs up to 137 ppm with the KM-1 sample exception.

Rare Earth Element Analyses

The REE analytical results of all samples from Elmacıgediği, Zeytinlik, Kemer and Yılanlıkale areas are given at Table 7. Additionally the average contents of the crust, and basalt and shale are added to that table. Using all the data, the condrite normalized values are plotted into the diagram of Sun and Mc Donough (1989) in figure 3.

Table 7- Results of the rare earth element analyses at Elmacıgediği, Zeytinlik, Kemer and Yılanlıkale samples and average values of the rare earth elements in the crust, basalt and shale samples.

Sample Nr	EG-2a	EG-6	KM-1	YK-2	ZT-1	ZT-2	ZT-3	ZT-4	ZT-5	ZT-6	ZT-10
La	46.9	33.1	8	1.8	48.1	39.7	29.1	36.2	46.1	32.2	6.3
Ce	91.6	62.9	27.4	3.2	85.6	75.9	52.1	59.8	75	57.3	10.3
Pr	10.78	7.87	5.22	0.39	10.76	9.12	6.75	7.4	8.98	7.64	1.13
Nd	54.2	37	35.4	2	46.9	39	28	34.1	38.8	35.1	4.7
Sm	10	6.6	8.1	0.3	8.6	8.1	5.7	6.5	6.6	6.8	0.6
Eu	2.53	1.65	2.65	0.08	2.75	1.44	0.99	2.12	2.93	1.31	0.16
Gd	9.17	5.85	7.73	0.39	7.97	6.3	4.06	5.61	5.42	5.4	0.45
Tb	1.45	1.03	1.5	0.05	1.29	1.11	0.75	0.82	0.99	1.03	0.15
Dy	6.36	5.24	8.35	0.2	6.45	5.82	3.63	3.87	4.24	5.27	0.95
Ho	1.32	1.09	1.67	0.07	1.26	1.09	0.79	0.74	0.97	0.98	0.25
Er	3.53	3.38	4.8	0.13	3.65	3.39	2.4	1.93	2.77	2.77	0.71
Tm	0.54	0.5	0.71	<0.05*	0.5	0.54	0.39	0.32	0.41	0.44	0.13
Yb	3.99	3.27	4.93	0.15	3.56	3.4	2.57	2.3	2.94	3.05	0.8
Lu	0.52	0.47	0.62	0.03	0.56	0.56	0.41	0.4	0.47	0.4	0.12

	CRUST**	BASALT**	SHALE**
La	35	10	40
Ce	70	30	70
Pr	8	4	9
Nd	30	20	30
Sm	7	5	7
Eu	1,2	1,5	1,4
Gd	7	6	6
Tb	1	0,8	1
Dy	6	4	5
Ho	1,5	1	1,5
Er	3,5	3	3,5
Tm	0,5	0,5	0,6
Yb	3,5	2,5	3,5
Lu	0,6	0,5	0,6

* REE element values under the detection limits of the instrument are used in diagrams in order to provide the togetherness of all values.

** Krauskopf 1989, p,545 (In this book, the basalt values includes the basalt, diabase and gabbro values)

Table 8- The rock types of the samples in Table 7.

Samp. Nr	Location	Rock Types
EG-2a	Elmacıgediği	Garnet-amphibole schist-amphibolite contact
EG-6	Elmacıgediği	Amphibole schist
KM-1	Kemer	Ore (arsenopyrite)
YK-2	Yılanlıkale	Arsenopyrite ore (concentration)
ZT-1	Zeytinlik	Ore (arsenopyrite)
ZT-2	Zeytinlik	Biotite-muscovite-garnet-staurolite schist
ZT-3	Zeytinlik	Biotite-muscovite schist
ZT-4	Zeytinlik	Ore (arsenopyrite)
ZT-5	Zeytinlik	Ore (arsenopyrite)
ZT-6	Zeytinlik	Muscovite-biotite schist
ZT-10	Zeytinlik	Ore (arsenopyrite)

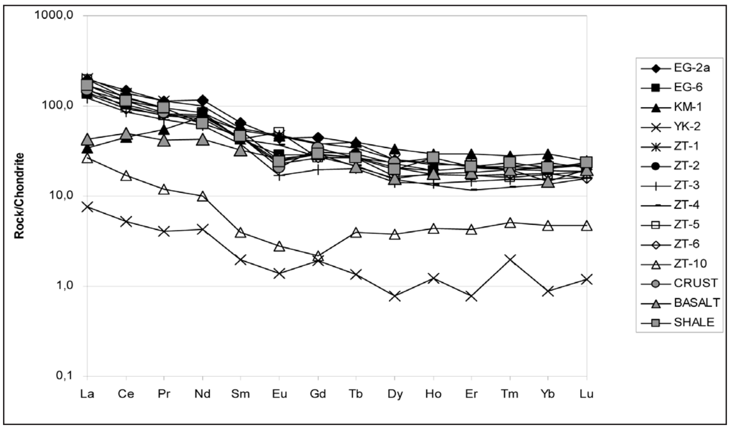


Figure 3- Chondrite normalized (Sun ve McDonough, 1989) spider diagrams of the samples in table 7.

According to these diagrams, the contents of all samples exhibit very close trends with crust and shale averages and very similar with basalt averages. Only YK-2 sample, which represents ore mineral concentrations, have another trend because of lack of silicate minerals. ZT-10 sample shows another trend which is poor in silicate minerals, but rich in iron ratio and gold (86 ppm) due to hydrothermal effects.

DISCUSSION AND CONCLUSIONS

Data, findings and results gained from investigations at Zeytinlik, Elmacıgediği, Yılanlıkale and Kemer areas are given below :

Due to field and laboratory studies, amphibolite and/or amphibole schists have been determined and ore zones are found either in these rocks or in their close vicinities in all areas. Arsenopyrite crystals are generally coarse grained and occur parallel to the schistosity. Scheelite sometimes accompany to arsenopyrites. Some amount of Sb, Bi and Ag enrichments are determined in the ore zones. Amphibolites at MTA-Italian Project are described as orthoamphibolites, i.e. magmatic in origin. This data is verified at our samples geochemically by high Ti, Cr and Ni contents. In all areas, both arsenopyrite ores parallel to schistosity and cutting across all the rocks have been observed. Depending upon all these data and concordance of ores with the schistosity, it can be postulated that mineralizations occured in association of various element incomes related to basic magmatism which comes to the basin during sedimentation. Basic solutions ceased with the time and an asidic stage with its solutions is dominated. All sedimentary and magmatic events occured synsedimentary and then metamorphosed. Further effects caused the mobilization of the ores. These effects could be the metamorphic stages and/or granitic intrusions. Trace element associations from Zeytinlik area could indicate basic magmatic rocks. Samples from Zeytinlik area are collected at zones which are parallel to schistosity. Cr-Ni associations are related to basic magmatic rocks, further U-V-Cu-Mo-Pb-Th-Ba association to asidic solution in comes to the basin. Final element association of Au-Ag-Bi-Sb-Se indicate mineralizations.

ACKNOWLEDGEMENTS

This study is a summary of the Master's Thesis of the first author at the Geological Engineering Department of Ankara University supervised by second and third authors. The authors acknowledge geological engineers Fahrettin Kayhan, Nevzat Karabalık and Dr.Ahmet Çağatay for their supports on the different stages of this study.

Manuscript received December 4, 2007

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PLATES

PLATE I

Figure 1 - Biotites including zircon inclusions in biotite-garnet schists (Bi: Biotite, Gr: Garnet, Zr: Zircon). Plane light.

Figure 2 - Strong green pleochroism exhibiting hornblendes in amphibolite (Hb: Hornblende, Gr: Garnet). Plane light.

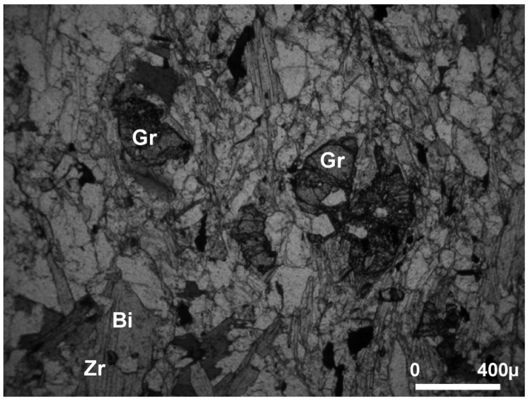
Figure 3- Biotite flakes and garnet porphyroblasts in mica schists (Bi: Biotite, Gr: Garnet). Plane light.

Figure 4 - Chloritization of biotites in mica schists. (Bi: Biotite, Op: Opaque minerals, Kl: Chlorite). Plane light.

Figure 5 - Titanite grains surrounded by hornblendes and epidotes in amphibolites (Hb: Hornblende, Ep: Epidote, Sf: Titanite). Crossed polars.

Figure 6 - Coarse-grained quartzs in mica schists (K: Quartz, Op: Opaque minerals, Sk: Scorodite). Crossed polars.

PLATE - I



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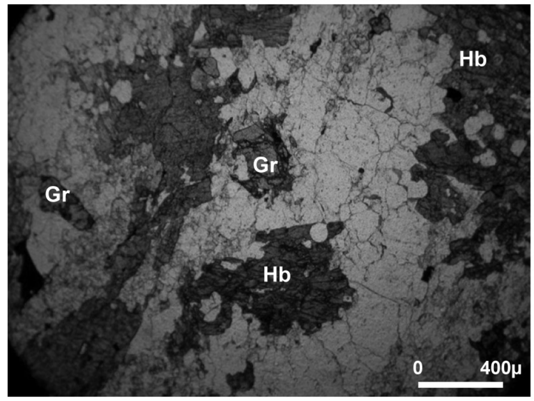

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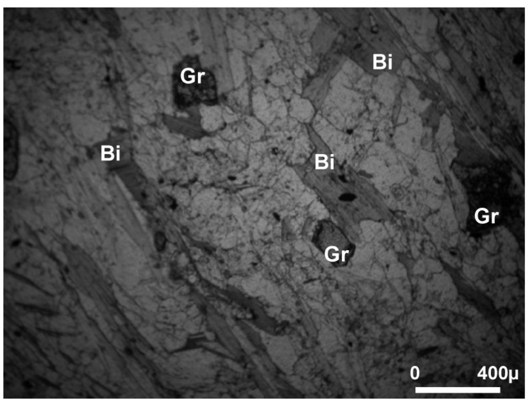

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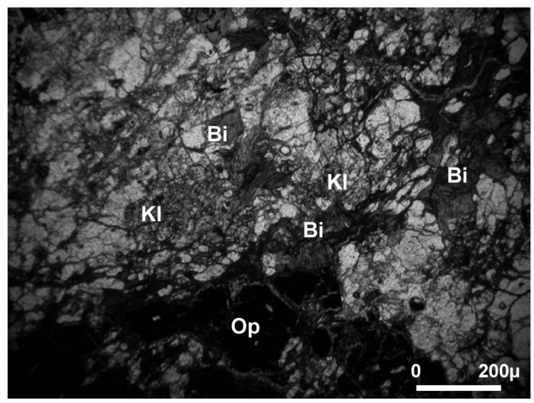

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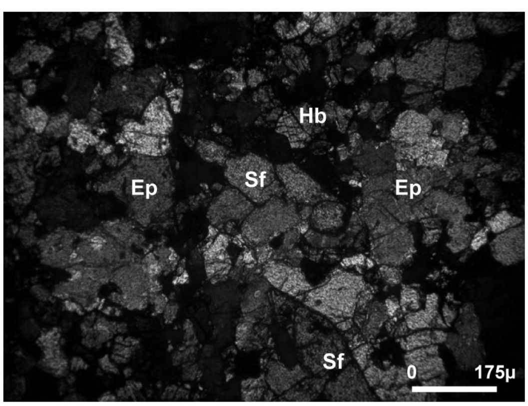

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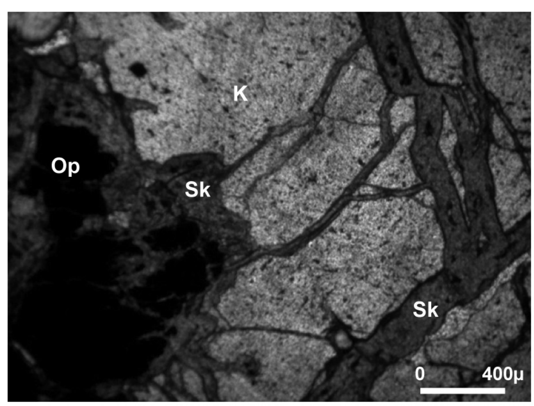

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PLATE II

Figure 1 - Scorodites occured along the cleavages and fractures of arsenopyrites. Plane light.

Figure 2 - Coarse-grained native gold grains in scorodites (Sk: Scorodite, Au: Gold). Plane light.

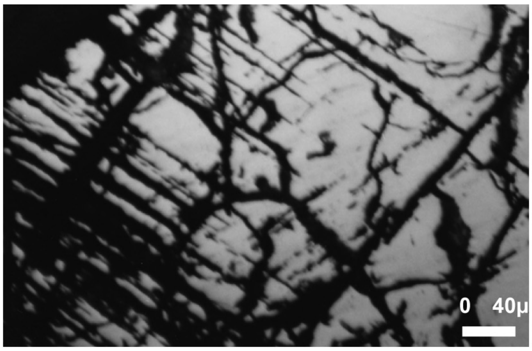
Figure 3 - Pyrite, chalcopyrite and arsenopyrite association (Py: Pyrite, Kpy: Chalcopyrite, Asp: Arsenopyrite). Plane light.

Figure 4 - Pyrite and marcasites formed after hexagonal pyrrhotite (Py: Pyrite, Ma: Marcasite). Plane light.

Figure 5 - Chalcopyrite surrounded by pyrite grain and relicts of arsenopyrite Kpy: Chalcopyrite, Py: Pyrite, Asp: Arsenopyrite). Plane light.

Figure 6 - Chalcopyrites locked with arsenopyrites. Chalcopyrites are altered to covelline and limonite along its fracture (Asp: Arsenopyrite, Ko: Covelline, Li: Limonite, Kpy: Chalcopyrite). Plane light.

PLATE - II



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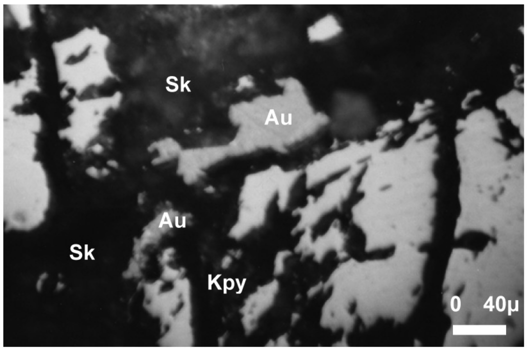

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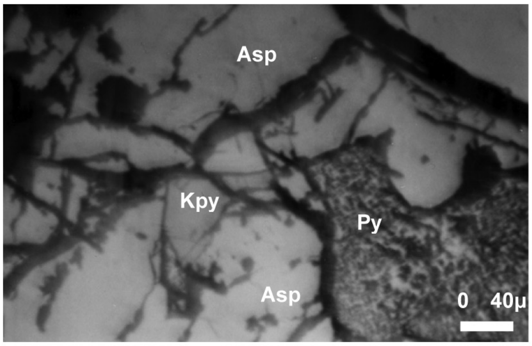

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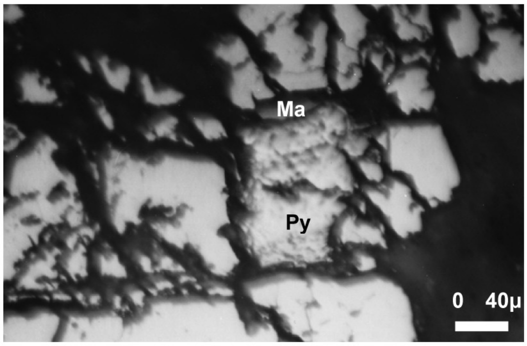

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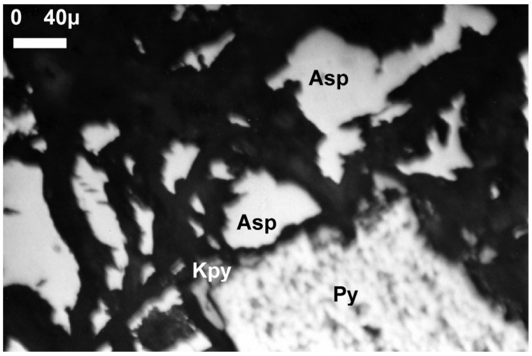

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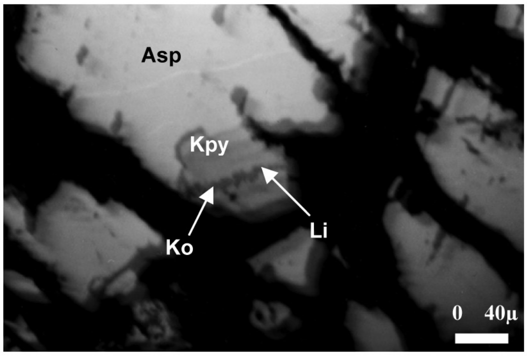

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ORIGIN OF MAGNESITE OCCURENCES IN SÜLEYMANİYE, MİHALLIÇIK, ESKİŞEHİR, TÜRKİYE

Asuman YILMAZ* and Mustafa KUŞCU*

In this study, the approaches on the origin of magnesite occurences which are developed related to altered ultramafic rocks in the peridotites of Tavşanlı Zone have been implemented with isotopic data in addition to geological and mineralogical data. Cryptocrystalline textured magnesites display two different type of formation as both individual veins at the fractures and cracks of ultramafic rocks and stockworks. In order to determine carbon source in magnesite composition and formation of magnesite, δC^{13} and δO^{18} isotope studies have been done. δC^{13} (PDB) values in magnesite vary between -2.71 and -7.69 ‰. On the other hand, δO^{18} (SMOW) values vary between 27.35 and 29.43 ‰. These isotopic data indicate that magnesites are formed as mixing of both CO_2 from atmospheric origin of carbon for magnesite occurrences is the result of mixing CO_2 from atmospheric origin and CO_2 released during decarbonization of organic rich sediments. Volcanogenic CO_2 are also effective in the formation.The mineralization of Süleymaniye magnesites probably occured after serpentinization of ultramafic rocks under near surface and low temperature conditions.

Key Words: Magnesite, isotope, Süleymaniye, Turkey

Mineral Res. Expl. Bull., 136, 17-28, 2008

PRESENCE OF *CRASSOSTREA GRYPHOIDES* (SCHLOTHEIM) FROM THE LOWER-MIDDLE MIOCENE SEQUENCE OF KAHRAMANMARAŞ BASIN (SE TURKEY); ITS TAXONOMY, PALEOECOLOGY AND PALEOGEOGRAPHY

İzzet HOŞGÖR*

ABSTRACT.- The Miocene rocks of the Salyan formation between the Salyan and Ahmetcik village in southeastern Turkey and northeastern Kahramanmaraş, contain Miocene bivalves and gastropods typical of the Tethys provence. The abundant and generally well-preserved bivalves are dominated by *Crassostrea gryphoides* (Schlotheim). The taxonomy, paleoecology and palaeogeography of the Neogene ostreid bivalve *Crassostrea gryphoides* (*Schlotheim*), and its paleogeographic effect the larval development from the Late Burdigalian-Early Langhian Salyan formation of the northwestern Kahramanmaraş Basin (southeastern Turkey) are discussed.

Key words: Bivalvia, *Crassostrea*, Early-Middle Miocene, paleogeography, taxonomy, Turkey.

INTRODUCTION

The Miocene rocks exposed in the north of the Kahramanmaraş Basin, southeastern Turkey, (Figure 1) contain a rich macro fauna, dominated by mollusc. With their large size and distinct shape, the bivalve genus *Crassostrea* form a conspicous element of this fauna, and is particularly well represented in Miocene succession. So far, presence of oysterids from the Kahramanmaraş Basin were briefly mentioned (Yılmaz et al., 1992; Baydar and Yergök, 1996). The aim of this study is to describe *Crassostrea gryphoides* (Schlotheim) from the Northwestern Kahramanmaraş Basin and to discuss its paleoecologic and paleogeographic significance.

During the Late Cretaceous-Tertiary period a number of sedimentary basins formed within the Tauride-Anatolide Platform. The most complete Miocene succession is exposed in the Kahramanmaraş Basin in the east Taurus Belt. The Miocene of the northern Kahramanmaraş Basin refers to the Salyan Formation (SW Çardak) and its unconformably overlays the Eocene units (sandstone and limestone) (Ericek Formation), Göksun ophiolithe (diabase, granite, volcanics and sedimentary units) and Malatya metamorp-

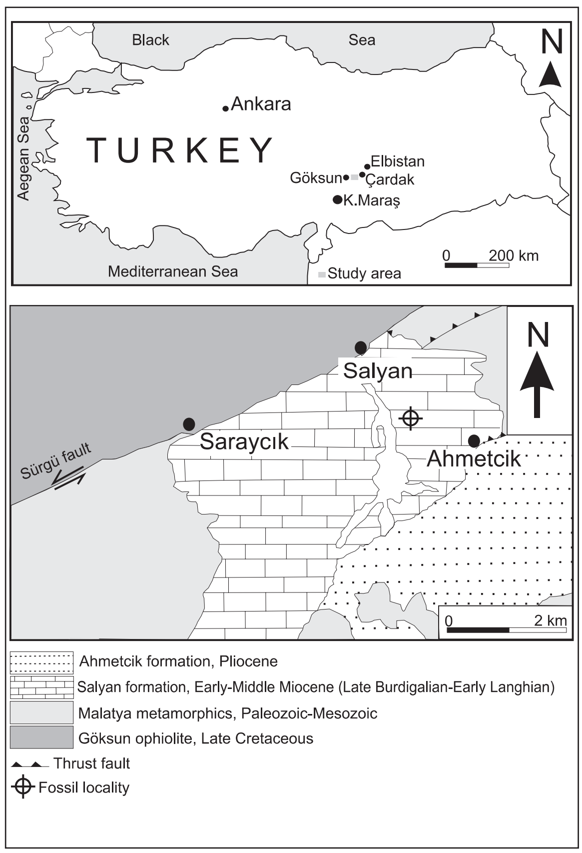

Figure 1- Geological map of the study area (Yılmaz et al., 1997).

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hics (marble and micaschist) (Figure 2). The Ahmetcik Formation (Pliocene) (conglomerate, marl, sandstone) is unconformably over the unit. The Salyan formation is characterized by thin marine and coastal plain carbonates with terrestrial conglomerates. The typical location of the unit in the area was around Salyan, Saraycık and Ahmetcik Valleys.

The formation, which was named for the first time in Tarhan (1982)'s study, starts with conglomerate at the base in the exposures between Salyan and Ahmetcik Valleys and continues with a sandstone, marl, shale and limestone (Figure 3). The limestones exposing around Salyan Valley, are sandy, bioclastic and characterized with

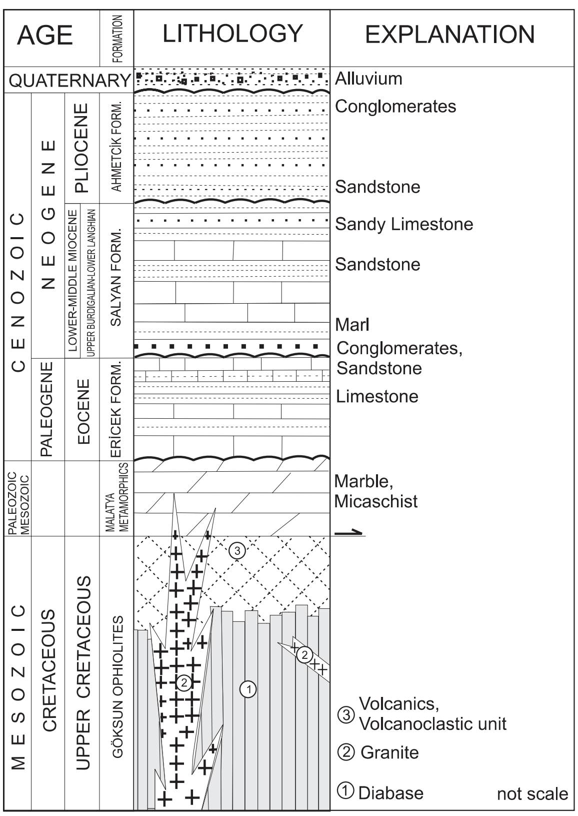


Figure 2- Stratigraphic column showing the relations of the Göksun ophiolite, Malatya metamorphites and sedimentary units (Yılmaz et al., 1997).

abundant macro (Figure 3) and micro fossils. It contains Early-Middle Miocene fauna. The crassosterids fossils are found associated with *Globigerinoides trilobus* (Reuss), *Praeorbulina transitoria* (Blow), *Praeorbulina sicana* (de Stafani), *Globorotalia obesa* (Bolli), *Globigerina* sp., *Miogypsina* sp., *Amphistegina* sp. (Yılmaz et al., 1992). According to Berggren et al. (1995), *Praeorbulina sicana* indicate M5a zone. According to this microfauna association, the Salyan Formation is Late Burdigalian-Early Langhian in age.

The geological evolution and the development of the marine Miocene of the Kahramanmaraş Basin were discussed by several authors (Gözübol and Gürpınar, 1980; Perinçek and Kozlu, 1983; Tarhan, 1984; Baydar, 1989; Yiğitbaş, 1989; Baydar and Yergök, 1996; Yılmaz et al., 1997).

MATERIAL

This study is based on an oyster material collected from the Early-Middle Miocene Salyan Formation, 28 m thick, exposed at Göksun area, northwestern Kahramanmaraş Basin (Figure 3). This section lies in L 34-d_4 quadrangle, and to the southeast of Ahmetcik village; in the coordinates of X_1: 11 008, Y_1:94 450 and X_2: 10 988, Y_2: 94 300. Oysters occur in great amount in greenish marls and sandy limestones. The material consists of poorly to moderately well-preserved internal moulds. *Crassostrea gryphoides* (Schlotheim) forms distinct shell beds, in the lower part of the Salyan Formation, just above a 0-3 m thick sandy-limestone. The associated macrofauna consists of bivalves (Figure 3). The abundant and generally well-preserved bivalves are dominated by *Crassostrea gryphoides* (Schlotheim) (68%). This lithologic units contains abundant veneroid (*Tellina* (P.) *sacyii* (Cossman and Peyrot), *Pitar* (P.) *rudis* (Poli), *Mactra corallina* (Linne)) and arcoid bivalves (*Anadara* (A.) *diluvii* (Lamarck)) that have both valves intact and the commissural plane oriented normal to the bedding plane, oysters are attached to other

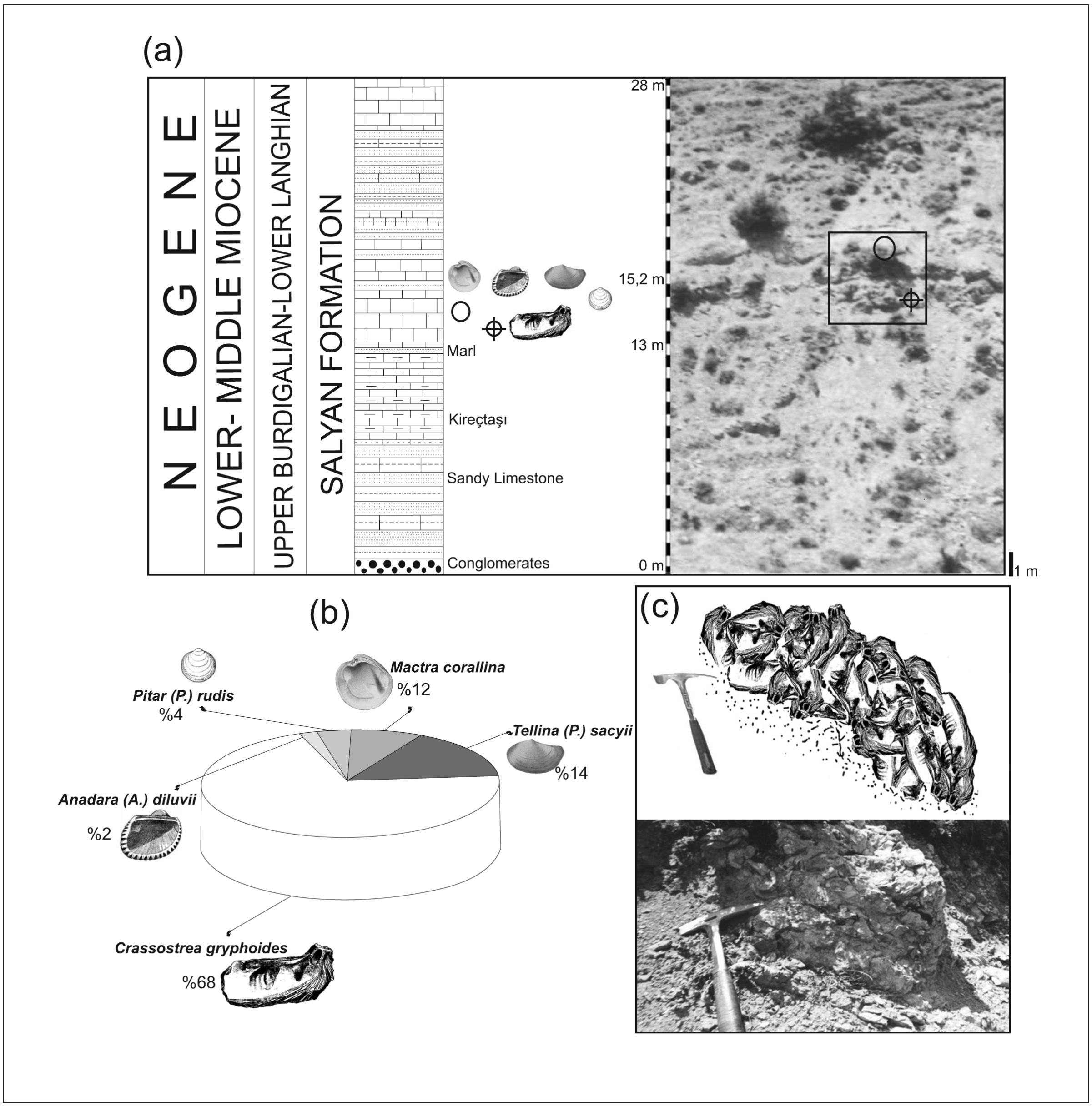


Figure 3- (a) Stratigraphic section from the Salyan Formation, (b) bivalves assemblage composition from the Salyan formation, (c) large and massive valves of *Crassostrea gryphoides* (Schlotheim).

oysters and consitıtute radially arranged, bouguet-like aggregates (Figure 3).

The specimens are housed in the collections of the Paleontology Laboratory of the University of Ankara, Turkey.

SYSTEMATIC PALEONTOLOGY

The descriptive terminology for the external and internal characters of the oyster shell follows that of Laurain (1980) and Bieler and Mikkelsen (2006).

Class : Bivalvia Linne, 1758
Subclass : Pteriomorphia Beurlen, 1944
Order : Pterioida Newell, 1965
Suborder : Ostreina Ferussac, 1822
Superfamily : Ostroidea Rafinesque, 1815
Family : Crassostreidae Scarlato and Starobogatov, 1979
Genus : *Crassostrea* Sacco, 1897

Type species: *Ostrea virginica* Gmelin, 1792

Diagnosis.- Shells are composed of two asymmetrical valves, joined at their hinges by ligament. Right valve flat in shape having relatively small hinge. Left valve larger in size, concave in shape, and has a large hinge. Outline high, slender-spatulate. Chambers common, with well-developed umbonal cavity in left valve. No chomata. Adductor muscle imprint close to postero-ventral margin. Outline crescentic or reniform, with fairly sharp corners in dorsal margin (Aqrabawi, 1993) (Figure 4).

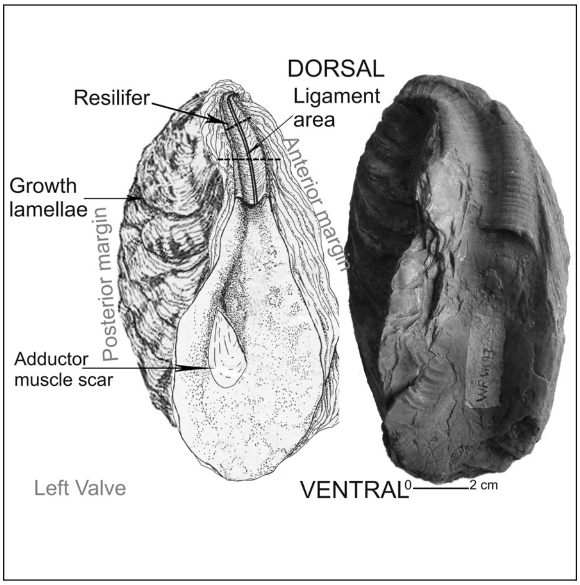


Figure 4- Internal and external morphological features of Crassostrea gryphoides (Schlotheim) (Laurain, 1980).

Crassostrea gryphoides (Schlotheim, 1813)
Plate 1, Figures 1-5.

1813 *Ostracides gryphoides* Schlotheim, p. 72.

1819 *Ostrea crassisima* Lamarck, p. 217.

1870 *Ostrea gingensis* Schlotheim, Hoernes, t. 2, p. 452, pl. 77, figs. 1-2; pl. 78. fig. 1; pl. 79. figs. 1-2; pl. 80. fig. 1.

1870 *Ostrea crassissima* Lamarck, Hoernes, p. 455, pl. 81, figs. 1-2; pl. 82. figs. 1-2; pl. 83. figs. 1-3.

1890 *Ostrea crassissima* Sowerby, Blanckenhorn, p. 21.

1897 *Ostrea* (*Crassostrea*) *crassissima* Lamarck, Sacco, pp. 15-16, pl. 4, figs. 1-3.

1904 *Ostrea gryphoides* Schlotheim var. *gingensis* Schlotheim, Dollfuss and Dautzenberg, p. 465, pl. 49, figs. 1-5.

1904 *Ostrea gryphoides* Schlotheim var. *crassissima* Lamarck, Dollfuss and Dautzenberg, p. 465, pl. 50, figs. 1-5.

1910 *Ostrea gingensis* Schlotheim, Schaffer, pp. 15-16, pl. 4, figs. 1-2; pl. 5, figs. 1-3.

1910 *Ostrea* (*Crassostrea*) *crassissima* Lamarck, Schaffer, pp. 19-20, pl. 8, figs. 1-2; pl. 9, figs. 1-2.

1914 *Gryphaea* (*Crassostrea*) *gingensis* (Schlotheim), Cossmann and Peyrot, pp. 391-393, pl. 21, figs. 16-18.

1933 *Gryphaea* (*Crassostrea*) *crassissima* (Lamarck), Pauca, p. 204, pl. 7, fig. 1-4.

1939 *Ostrea* (*Gryphea*) *gingensis* Schlotheim, Stchepinsky, p. 23, pl. 7, figs. 4-5; pl. 8, figs. 2-4; pl. 9, fig. 1.

1946 *Ostrea* (*Gryphea*) *gingensis* Schlotheim, Stchepinsky, p. 66, pl. 33, fig. 14.

1946 *Ostrea crassissima* Lamarck, Stchepinsky, p. 67, pl. 35, fig. 1.

1952 *Gryphaea gryphoides* Schlotheim, Lecointre, p. 30, pl. 13, figs. 1-5.

1954 *Ostrea gryphoides* Schlotheim, Korobkov, pp. 197-198, pl. 83, figs. 2-3.

1955 *Ostrea gryphoides* Schlotheim, Merklin and Nevesskaja, pp. 106-107, pl. 32, figs. 1-2.

1958 *Ostrea gryphoides* (Schlotheim), Azzaroli, p. 108, pl. 28, fig. 8.

1958 *Ostrea gryphoides* Schlotheim, Erünal-Erentöz, pp. 168-169, pl. 30, fig. 3; pl. 31, fig. 3.

1963 *Ostrea* (*Crassostrea*) *gingensis* (Schlotheim), Venzo and Pelosio, p. 165, pl. 53, figs.1-2.

1963 *Ostrea* (*Crassostrea*) *crassissima* (Lamarck), Venzo and Pelosio, p. 168, pl. 52, fig. 3; pl. 54, fig. 16.

1968 *Gryphaea* (*Crassostrea*) *gryphoides crassissima* (Lamarck), Iliescu et al., pp. 93-94, pl. 11, fig. 1

1968 *Gryphaea* (*Crassostrea*) *gingensis* (Schlotheim), Iliescu et al., p. 94, pl. 12, figs. 1-2; pl. 13, fig. 1.

1969 *Gryphaea* (*Crassostrea*) *gryphoides crassissima* (Lamarck), Dermitzakis, p. 380, pl. 69, figs. 1-2.

1971 *Crassostrea gryphoides* (Schlotheim), Freneix et al., p. 23, 27, pl. 6, figs. 1-4; pl. 7, figs. 1-3; pl. 8, figs. 1-5.

1974 *Crassostrea gryphoides* (Schlotheim), Freneix et al., p. 78, pl. 5, fig. 4.

1975 *Gryphaea* aff. *aginensis* Tournouer, Baldi and Steininger, pp. 341-342, pl.14, fig. 7.

1980 *Crassostrea gryphoides* (Schlotheim), Laurain, pp. 24-25, pl. 1, figs. 1-3.

1984 *Crassostrea gryphoides* (Schlotheim), Laurain, pp. 76-77, pl. 4, fig. 4.

1985 *Crassostrea* (*Crassostrea*) *gingensis* (Schlotheim), Moisescu, p. 30, pl. 2, fig. 1.

1985 *Crassostrea gryphoides* (Schlotheim), Tanar, p. 22, pl.1, figs. 1-3.

1993 *Crassostrea gryphoides* (Schlotheim), Nevesskaja, p. 62, pl. 9, figs.1-2; pl. 10, figs. 1-4.

1998 *Crassostrea gryphoides* (Schlotheim), Pfister and Wegmüller, p. 458, pl. 1, figs. 1-5; pl. 2, figs. 1-4.

2002 *Crassostrea gryphoides* (Schlotheim), Videt and Neraudeau, p. 153, pl. 1, fig. 3.

2003 *Crassostrea gryphoides* (Schlotheim), İslamoğlu and Taner, pp. 9, 10, pl. 3, fig. 1.

2005 *Crassostrea gryphoides* (Schlotheim), El-Hedeny, p. 720, pl. 1, figs. 1-7; pl. 2, figs. 3-5; pl. 4, figs. 7-9.

Figured Specimens.- Left valve, KMS. 04. SD01; Left valve, KMS. 04. SD04; Right valve, KMS. 04. SD05; Left valve, KMS. 04. SD11; Right valve, KMS. 04. SD12.

Description.- In general, *Crassostrea gryphoides* (Schlotheim), outline high, slender-spatulate. Chambers common with-developed umbonal cavity in the left valve. No chomata. Adductor muscle imprint close to postero-ventral margin, outline crescentic or reniform with fairly sharp corners in the dorsal margin. Shell, inequivalve, elongate, height much greater than length. Outline variable, usually straight or slightly curved. Shell becomes gradually broader toward the ventral margin; surface not smooth, strong fold ribs and growth lamellae. Growth and lenghty cylindiric ligament area in right valves. Nearly wide-length resilifer. Adductor muscle scar reniform or crescentic in some individuals. Left valve convex or moderately inflated; right valve slightly convex or flat. Chomata absent along the entire margin of both valves.

Horizons and Localities.- NE Göksun, Salyan Valley, limestone units in the centre of Salyan Fm.

*Dimensions.- (*Figure 5).

Discussion: Most of the Tethys or Paratethys, Miocene-Pliocene crassostrids have been assigned to *Ostrea crassissima* Lamarck, *Ostrea* (G.) *gingensis* Schlotheim, *Gryphea* (C.) *gingensis* (Schlotheim). In fact, these specimens are accepted as *Crassostrea gryphoides* (Schlotheim). According to literature (Cossman and Peyrot,1914; Erünal-Erentöz, 1958; Freneix et al., 1971; Laurain, 1980; Videt and Neraudeau, 2002; İslamoğlu and Taner, 2003) supporting its names.

Crassostrea virleti (Deshayes) is a very similiar species described from the Pliocene of the Madagascar (Freneix et al., 1971; p. 27-30, pl, I, fig. 1-4; pl. J, fig. 1-5). It is differented from

Specimen	Valve	H	L	L/H	lh	ll	lr	dlm	dlp
KMS.04.SD01	left	160	40	0,25	60	22	15	22	65
KMS.04.SD02	left	150	55	0,36	63	40	20	40	90
KMS.04.SD03	left	135	56	0,41	36	27	20	50	100
KMS.04.SD04	right	105	68	0,65	30	35	20	30	60
KMS.04.SD05	right	110	42	0,4	44	25	15	-	63
KMS.04.SD06	left	120	57	0,47	25	28	21	42	100
KMS.04.SD07	left	180	40	0,22	125	22	18	22	35
KMS.04.SD08	left	175	90	0,51	80	40	20	65	100
KMS.04.SD09	left	160	95	0,59	60	40	23	40	110
KMS.04.SD10	left	140	60	0,42	40	36	25	50	95
KMS.04.SD11	left	125	65	0,52	45	35	25	60	90
KMS.04.SD12	right	100	40	0,4	40	16	11	-	60

(mm)

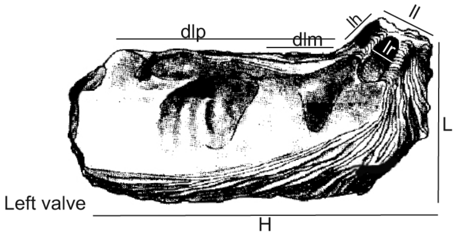


Figure 5- Measurements (H-height, L-length, lh-ligament high, ll-ligament length, lr-resilifer length, dlm-dimensions of between liga ment area and adductor muscle scar, dlp-dimensions of between ligament area and commissure shelf (likely pallial line)).

Crassostrea gryphoides by having fewer concentric growth lamellae and by the lack of a straight umbonal margin.

Crassostrea margaritacea (Lamarck) from the Miocene to Pliocene of the Africa coastal plain in Mediterranean (see Ranson, 1951; p. 8-9, text-fig. 6) is distinguished by its slender fold ribs, more convex anterior margin and rounded commissure shelf.

Crassostrea bersonensis (Matheron) shows similarities to forms regarded by Freneix et al., (1971), from the Aquitanian of Europe and Burdigalian of the Africa coasts. It is differented from *Crassostrea gryphoides* by having a slender and narrow ligament area and bigger valves.

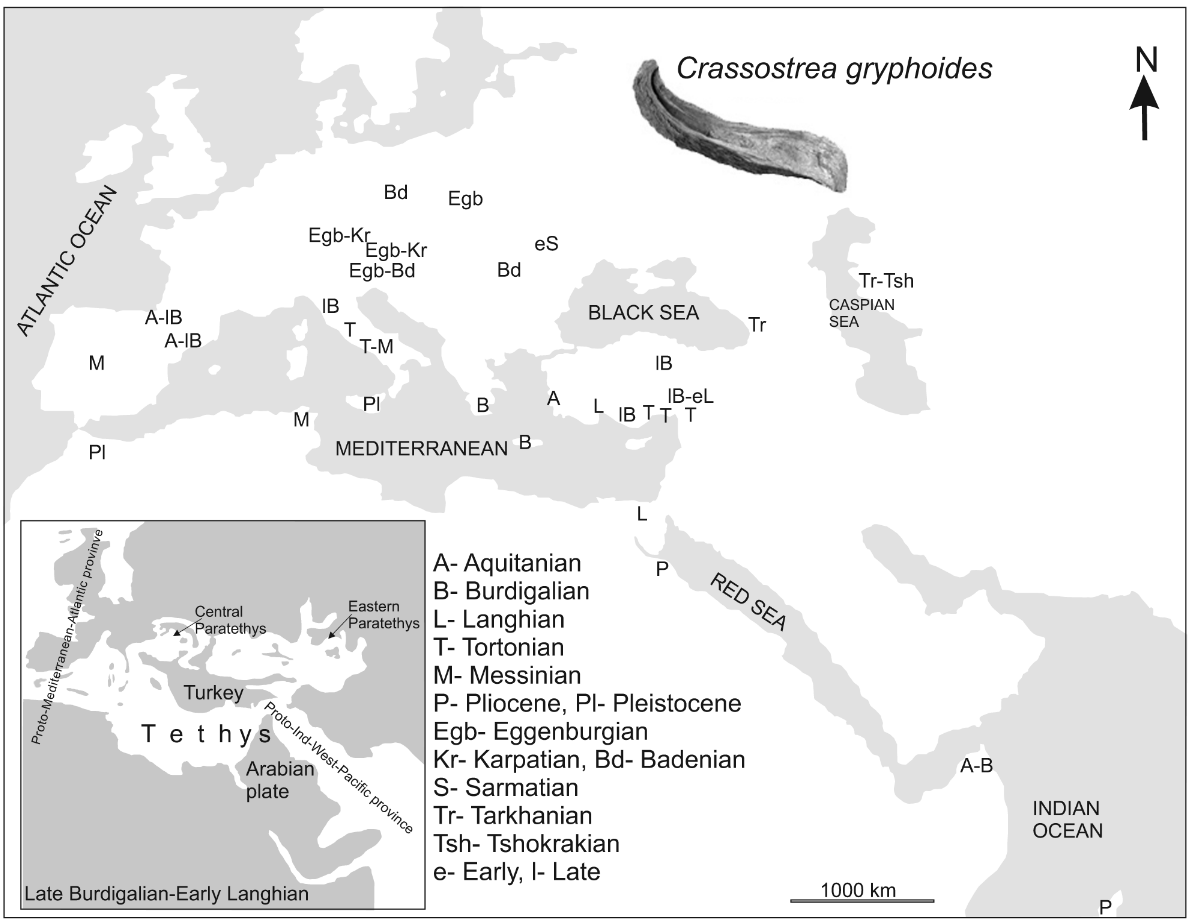
PALEOECOLOGY

Like their modern representatives, Miocene oysters lived nearshore in shallow, low-energy marine environment introduced with the onset of the Miocene transgression in southeast Anatolia. Oysters cement themselves onto the substrate by their left valves. Most cementing bivalves are found in shallow-water environments at depths less than 35 m. Modern oysters are typically found in estuaries, sounds, bays and tidal creeks from brackish water (5 ppt salinity) to normal marine water (35 ppt salinity) (İslamoğlu and Atabey, 1999; El-Hedeny, 2005). They are very tolerant organisms and able to withstand wide variations in temperature, salinity, suspented sediments, and dissolved oxygen. Throughout its range, the oyster occurs only in subtidal areas. Intertidal recent oysters typically have elongated and irregularly shaped shells (Hoffmann et al., 1978; El-Hedeny, 2005). When submerged by the tide, oysters feed by filtering phytoplankton from the water column. The morphology of oyster shell is strongly influenced by ecological factors particularly the nature of the substrate, degree of crowding and water turbulence. In addition, morphological features of oysters may change during their ontogenic evolution (Stenzel, 1971).

The Miocene oyster shells of the studied area are characterized by large and massive valves when compared with their recent represantatives. Bivalves living in warm and high energy environments tend to have thicker shells and more prominent growth lines in comparision to those living in cold and quiet water environments. However, oysters in fluctuating salinity grow faster than those under constant conditions (El-Hedeny, 2005). On the other hand, oysters show same growing rate both in tidal zone and continuously submerged region. Long exposure, however, reduces growth; those animals exposed 20% of the time grow twice as fast as those exposed 60% of the time. The Neogene *Crassostrea* oysters had large and thick shells, whereas their descendants, living *Crassostrea,* have comperatively smaller and thinner shells (Kirby, 2000).

PALEOGEOGRAPHIC DISTRIBUTION

Crassostrea gryphoides (Schlotheim) is a stratigraphically and geographically widely distributed species (Figure 6). In Turkey, it occurs in the Late Burdigalian of the Sivas and Karaman, Late Burdigalian-Early Langhian of the northwest Kahramanmaraş Basin (Salyan Formation), from the Aquitanian of the Denizli, from the Langhian of Antalya Basin, from the Tortonian of Kahta-Adıyaman and Tarsus-Mersin area (Kuzgun Formation) (Stchepinsky, 1939-1946; Erünal-Erentöz, 1958; Meriç, 1965; Tanar, 1985; İslamoğlu and Taner, 2003; İslamoğlu et al., 2005 and descriptions herein). In Tethys (Proto-Mediterranean Atlantic Region) provence, it is described from the Aquitanian to Pleistocene of Europe and Mediterranean coast, for example France (Aquitan Basin and Rhon Basin), Italy (Laguria Basin, Sicily Island, Vigoleno Basin, Alba Basin and Tuscany), Portugal (Umbra Basin), Spain (Sorbas Basin), Morocco, Algeria (Lalla Kouba Basin), Greece (Crete Island and Lakonia) (Sacco, 1897; Dolfuss and Dautzenberg, 1904; Cossman and Peyrot, 1914; Lecointre, 1952; Venzo and Pelosio, 1963; Dermitzakis, 1969; Freneix et al., 1974; Laurain, 1984; Videt and Neraudeau, 2002), the Burdigalian-Langhian of the eastern Mediterranean and the Near East, for example Syria and Egypt, morover from the Pliocene of Egypt (Red Sea coastal plain) (Blanckenhorn, 1890; Kora and Abdel-Fattah, 2000; El-Hedeny, 2005). It is well established that *Crassosstrea gryphoides* (Schlotheim) inhabited the western



Şekil 6- Crassostrea gryphoides (Schlotheim)'in paleocoğrafik yayılımı ve Erken-Orta Miyosen (Geç Burdigaliyen-Erken Langiyen) devrinin konumu (Rögl, 1998, 1999).

and central Mediterranean region during Pleistocene, a few areas with numerous and well-studied basins. In contrast, there are rare data about the Miocene to Pleistocene of the eastern Mediterranean and the Atlantic region (Figure 6).

During the Miocene (Eggenburgian to Sarmatian) *Crassostrea gryphoides* (Schlotheim) is found in the Central Paratethys, for example Austria (Vienna Basin), Hungary, Romania (Mera Basin), Poland, Switzerland (Bern Basin), Slovakia (Slaske Basin), Ukraine (Hoernes, 1870; Schaffer, 1910; Iliescu et al., 1968; Baldi and Steininger, 1975; Pfister and Wegmüller, 1998), the Tarchanian to Tschokrakian of Eastern Paratethys, for example, Georgia and Turkmenistan (Merklin and Nevesskaja, 1955; Nevesskaja, 1993).

In Proto-Indo-West-Pacific regions it occurs in the Early Miocene of Somalia and from the Pliocene of Madagascar (Azzaroli, 1958; Freneix et al., 1971).

Approximately 30 species of the Ostreidae, which make up the bulk of living oysters, are many recent oysterids possess teleplanic (long distance) larvae, capable of being transported over long distances (Malatesta and Zarlenga, 1986; Malchus, 1995; Foighil et al., 1998). Such larvae might have been also present in *Crassostrea virginica* and, along with external factors, such as climatic and palaeoceanographic conditions, controlled its wide distribution (Foighil and Taylor, 2000; Harzhauser et al., 2002, 2003). However, the actual and fossil distribution patterns of the aquatic gastropod genera that avian dispersal was an important dispersal mechanism in the geological past (Wesselingh et al., 1999).

The Early Miocene was characterised by warm climate and high sea-levels in the southeastern part of the Taurus Belt. Moreover, the Early Miocene period was characterised by a globally warm water faunas (Rögl, 1998 and 1999). During the Early Miocene the southeastern part of the Taurus belt was influenced by warm climatic conditions and the development of extensive shallow marine shelf areas in general study field, apparently favoured rapid and wide dispersal of taxa (Staesche, 1972; Steininger et al., 1985; Görür et al., 1998).

CONCLUSIONS

The Early-Middle Miocene oysters, *Crassostrea gryphoides* (Schlotheim), of Salyan Formation are characterized by large and massive valves. Paleoecologically, they were living in nearshore shallow, low-energy, lower salinity, warm climatical condition of marine environments. Paleogeographically, *Crassostrea gryphoides* (Schlotheim) is a stratigraphically and geographically widely distributed species. In the Proto-Mediterranean Atlantic area, it occurs in the Aquitanian to Pleistocene of the west and south Europe, west Africa coasts, and east Mediterranean area (Turkey); in the Early-Middle Miocene of the northern inland seas (Central and Eastern Paratethys). Moreover, in Indo-Pacific seas, the species in the Aquitanian to Pleiocene of the Red Seas coasts, Somalia and Madagascar.

ACKNOWLEDGEMENTS

This study is a part of the MSc Thesis fullfilled in the Geological Engineering Department of the Natural and Applied Science Instıtute of Ankara University. This study was carried out as a part of the Geodynamic Evolution of Eastern Tauride Project of the Mineral Research and Exploration General Directorate (MTA). The author is also grateful to Dr. Erkan Ekmekçi (MTA), to Dr. Yavuz Bedi (MTA), the chief of the Project, for his encouregements, to Dr. Halil Yusufoğlu (MTA), Birkan Alan (MTA) and Doğan Usta (MTA) for their helps during field studies, to Dr. Gerçek Saraç (MTA) for literature he provided and his valuable comments, and Dr. Yeşim İslamoğlu (MTA), Prof. Dr. Yavuz Okan, Prof. Dr. Ergun Gökten and Dr. Ireneusz Walaszczyk (Warsaw University, Poland) who reviewed the manuscript. Very special thanks go to Magdy Dr. M. El-Hedeny (Alexandria University, Egypt) for important paleoecological discussions and taphonomical reviews on oyster shells, and to Dr. Ercüment Sirel (Ankara University) for discussion on foraminiferal stratigraphy.

Manuscript received February 9, 2007

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PLATE

PLATE I

Figure 1 - Right valve, internal view, KMS. 04. SD12.

Figure 2 - Left valve, internal view, KMS. 04. SD04.

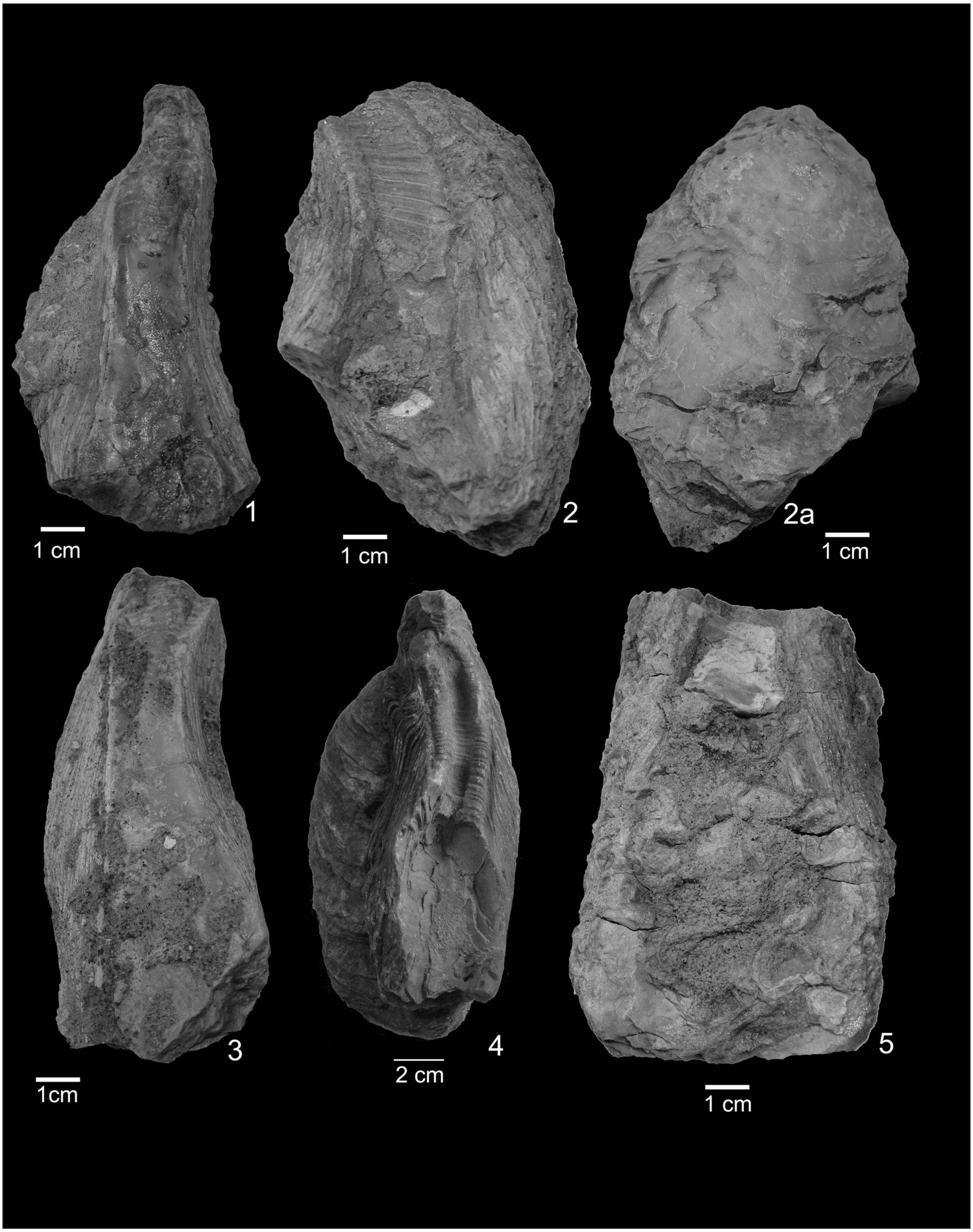
Figure 2a - Left valve, external view.

Figure 3 - Right valve, internal view, KMS. 04. SD05.

Figure 4 - Left valve, internal view, KMS. 04. SD01.

Figure 5 - Left valve, internal view, KMS. 04. SD11.

PLATE - I



BOS SAYFA

Mineral Res. Expl. Bull., 136, 29-47, 2008

TRACE FOSIL ASSOCIATIONS AND PALAEOENVIRONMENTAL INTERPRETATION OF THE LATE EOCENE UNITS (SW-THRACE)

Huriye DEMİRCAN*

ABSTRACT.- The Late Eocene deep marine fan sequence exposed in the northeast of the Saros Bay and around Korudağ, Keşan, Yenimuhacir regions consists of several facies associations such as middle and outer fan, slope, prodelta. From the study area, as a part of the observations, 4 measured sections involving Korudağ, Keşan, Yenimuhacir Formations were taken and the mid and outer fan facies association deposits were found to be more common than the others. The middle fan association was divided into two sub-associations: distribution channels and interchannel areas. 19 ichnogenus were identified in the deep sea fan deposits. From these ichnogenus: *Ophiomorpha* isp, *Ophiomorpha annulata, Ophiomorpha rudis, Thalassinoides* isp, *Planolites* isp, *Halopoa annulata, Rutichnius* isp, *Chondrites* isp, *Scolicia vertebralis, Scolicia strozzii, Scolicia prisca, Scolicia plana, Nereites irregularis, Helminthoidichnites* isp, *Helminthopsis* isp, *Cosmorhaphe* isp, and *Paleodictyon strozzi* helped to distinguish the mid fan-distal of the mid fan Korudağ Formation, *Ophiomorpha* isp, *Ophiomorpha annulata, Ophiomorpha rudis, Thalassinoides* isp, *Planolites* isp, *Halopoa annulata Zoophycos* isp, helped to distinguish inner fan Keşan formation and the *Lockeia* isp, ve *Planolites* isp. helped to distinguish the deltaic Yenimuhacir formation. The abundance and diversity of trace fossils found in the study area increase in the middle fan interchannel and channel margin sediments. On the other hand, in the outer fan and slope facies associations, the abundance and diversity of trace fossils are lower. Distribution and relative abundance of the trace fossils are compared with the interpretations of depositional environment and trace fossils associations were found to be related to the various parts of deep sea fan model.

Key words: Deep sea fan, Late Eocene, Trace Fossils, Thrace

INTRODUCTION

The research area is located northeast of the Saros bay and around Korudağ, Keşan, Yenimuhacir regions (Figure 1). There have been many published data which are related to especially oil and coal mining exploration around research area. The basin has different occurring between the area which has been showed by various geologist (Druit, 1961; Sfondrini, 1961; Saltık and Saka, 1972; Saltık, 1974; Önem, 1974; Doust and Arıkan 1974; Toker and Erkan 1985; Sümengen and Terlemez, 1991; Yaltırak, 1995; Demircan and Uchman, 2006). In this study the trace fossils in late Eocene deposits have been recognized and identified for the first time.

Trace fossils or ichnofossils are dwelling, feeding, crawling and other structures made by living organism in or on a substrate (Crimes et. al., 1981). According to Seilacher, (1964), 1967), the diversity of marine fossil groups related to water depth recurred throughout Phanerozoic time. Each assemblages was named after a characteristic trace fosil and they are, in order of increasing water depth: *Skolithos* zone (mainly litoral zone), *Cruziana zone,* (litoral zone to wave base), *Zoophycos* zone (wave base, turbidite depositional zone and slope), *Nereites* zone (deep water turbidite zone). Even though this classification seemed very useful, later studies showed that, trace fosil distribution is related to many factors, including substrate type, energy conditions, food availability, and preservation conditions, rather than bathymetry (Crimes, 1970, 1975; Frey and Howard, 1970). *Zoophycos* assemblage is questioned because of being in different marine environments but *Skolithos* and *Cruzina* assemblages are generally repre-

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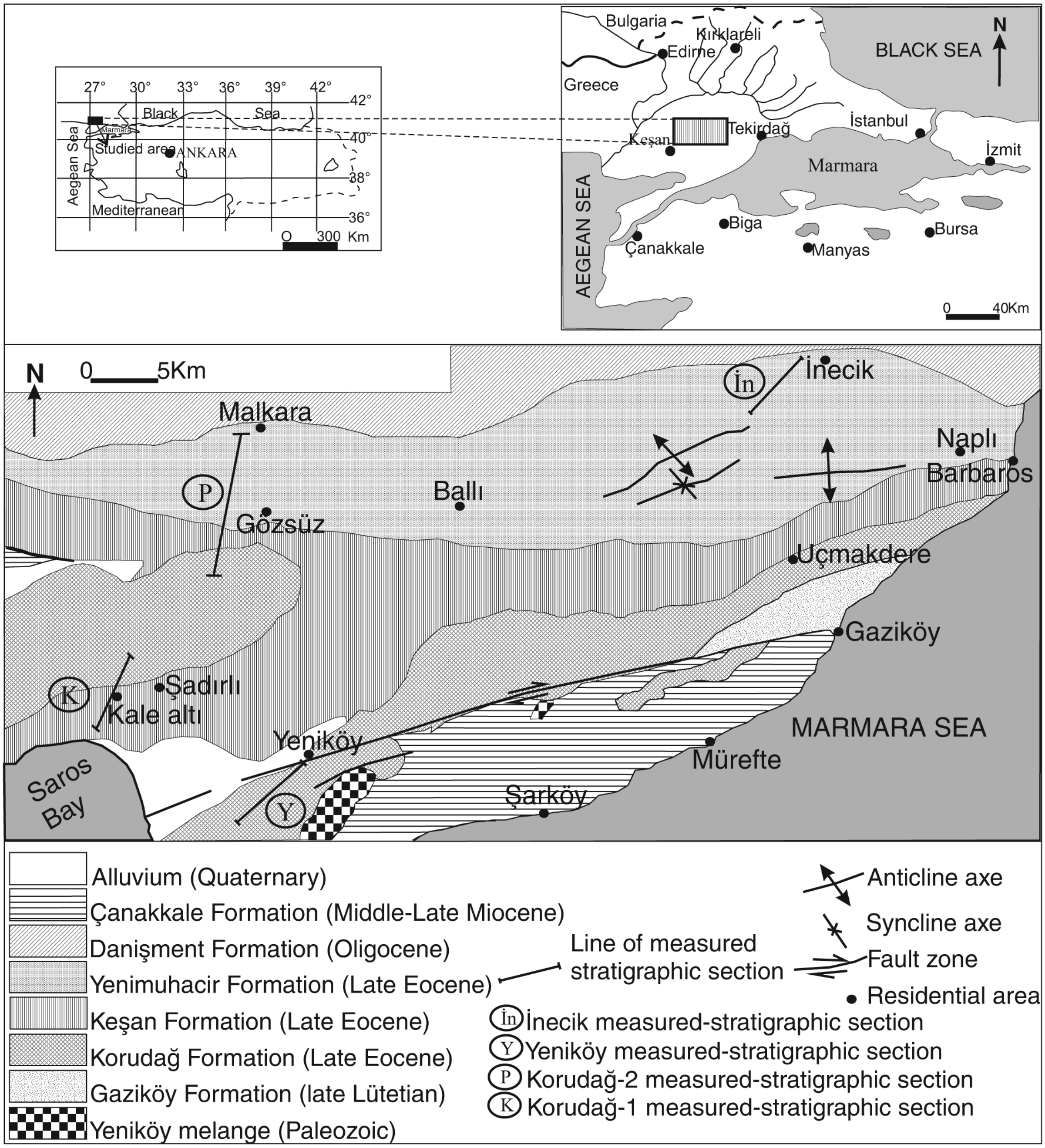


Figure 1- Location map (modified by Sümengen and Terlemez,1991)

sent the shallow marine on the other hand there is a common sense that *Nereites* assemblage indicates the deep marine environment (Seilacher, 1967; Crimes, 1970, 1975).

The aim of this study is to examine the ichnological properties of Late Eocene deep marine fan facies associations which are seen around Korudağ, Keşan and Yenimuhacir regions.

MATERIAL AND METHOD

The material for tis study, from the study area, as a part of the observations, 4 measured sections involving Late Eocene aged Korudağ, Keşan, Yenimuhacir formations were taken. The samples taking in the study area based on lithology changing. Identifications were made in the field from bedding surfaces, on parting surface and in vertical sections, and checked using collected material, photographs and sketches. Also, all specimens are taken in the field were correlated by literature (Table 1).

GEOLOGICAL SETTING

Considering Thrace Basin as a whole, the basement is mainly consists of Istranca massive metamorphites on the northeast of study area. Tertiary sediments which are not very thick are located on the south of bloc. However, Tertiary sediments more than 7000 m. thickness was measured on the southwest of the study area. The relation of Eocene and Miocene is very clear and all facies belonging to Eocene and Miocene are easily noticeable. Ergene Basin is in the middle section and mainly younger (?Pliocene) sediments are exposed in this region (Sümengen

Table 1- Position of the stratigrafic sections in the study area.

Quandrangle	The name of the stratlgrafic section	Start point (x,y) high (z)	End point (x, y) high (z)	Thickness (m.)
Bandırma G18-d1	Yeniköy	x 50 5000 y 45 01000 z 330 m	x 510900; y 4507000 z 290 m	460
ÇanakkaleG17-c1	Korudağ-1	x 48 2500 y 45 04600 z 90 m	x 481900 y 45 06500 z 300	310
Çanakkale G17-c1 (start point) Bandırma G18-a2 (end point)	Korudağ -2	x 48 1900; y 45 06500; z 300	x 51 1000; y 45 25800; z 270	335
BandırmaG18-b1 (start point) Bandırma G18-b2 (end point)	İnecik	x 52 4000 y 45 30320 z 200	x 542000 y 45 37000 z 50	250

and Terlemez 1991). The oldest unit in the area is the ophiolitic complex which forms the base of the basin called Yenikoy complex (Şentürk and Okay 1984). A series of Eocene-Oligocene (?) facies overlies the ofiolitic complex. These facies from bottom to top are; Late Lutetian age Gazikoy Formation, Late Eocene age Korudağ, Keşan, Yenimucahir Formations and Oligocene age Danişment Formation (Figure 2). There is an unconfirmity below Miocene age sediments. These sediments are called as Middle-Late Miocene Çanakkale Formation.

One of the most important tectonic structure in the study area is the N 70 E Saros gulf-Gazikoy Fault which is still active. This fault is a part of Northern Anatolian Fault System (Sümengen and et. al., 1987). Although, between Gaziköy and Saroz bay, at the northern parts of the fault was not considerably effected by tectonic processing, reverse and thrust faults are observed at the south (Sümengen and et. al., 1987).

SEDIMENTOLOGY

Four measured sections were taken at the investigated area (Yeniköy, Korudağ-1, Korudağ-2 and İnecik), and have been detailed in 4 main facies association as their litology changing. These are: prodelta, slope, middle and lower fan deposits.

Middle Fan Facies Association

Middle fan facies associations are common in the study area. They are seen as distributary channel fill and interchannel deposits at the Korudağ-1, Korudağ-2 measured sections (Figure 3, 4 Keşan formation).

a) Distributary channel fill deposits.- The channel deposits are characterized by coarse grained conglomerates at the base of the channel and continue thinning and fining upward. Trace fossils characterized by high energy are common.

b) Interchannel deposits.- They are represented by a sequence of thin bedded turbiditic sandstones with mudstones. Also, increase in the number of trace fossils and diversity is observed in these deposits.

Lower Fan Facies Association

It is a common facies association in the study area where it is seen at the Korudağ-1, Korudağ-2 and Yeniköy measured sections (Figure 5, Korudağ Formation). The unit is composed of thin bedded, fine grained sandstones with mudstone intercalations, and medium bedded, medium grained turbiditic sandstones. These two facies associations are observed to be vertically thickening and coarsening upward series that depend on grain size and bed thickness. Big and small scale loading, flute marks and groove marks are seen at the bottom of sandstone beds.

Slope Deposits

They represent a transition between Korudağ-1 and Korudağ-2 measured sections (Figure 3, 4 Keşan Formation). Sometimes, slump structure and shallower channel between middle fan and transitions levels are observed. Also, thicker sandstone beds include endichnial *Zoophycos* ichnospecies.

Prodeltaic deposits

They are observed at Korudağ-2 and Yeniköy measured sections (Figure 6, Yenimuhacır Formation). Generally, they consists of thin bedded, fine grained sandstone, alternated massive mudstone, and sandy, gravelly channel filled deposits. Sandstones are fine grained and, thin bedded with sharp contact at the bottom while ripple marks are observed on the bed surface. Bed thickness is laterally continuous and displays lenses form. Small scale cross beds and ripple lamination is common in sandstones, however, sandstone thickness is small scaled, and thickness continuously upwards. It also contains plant material and Bivalvia fraction.

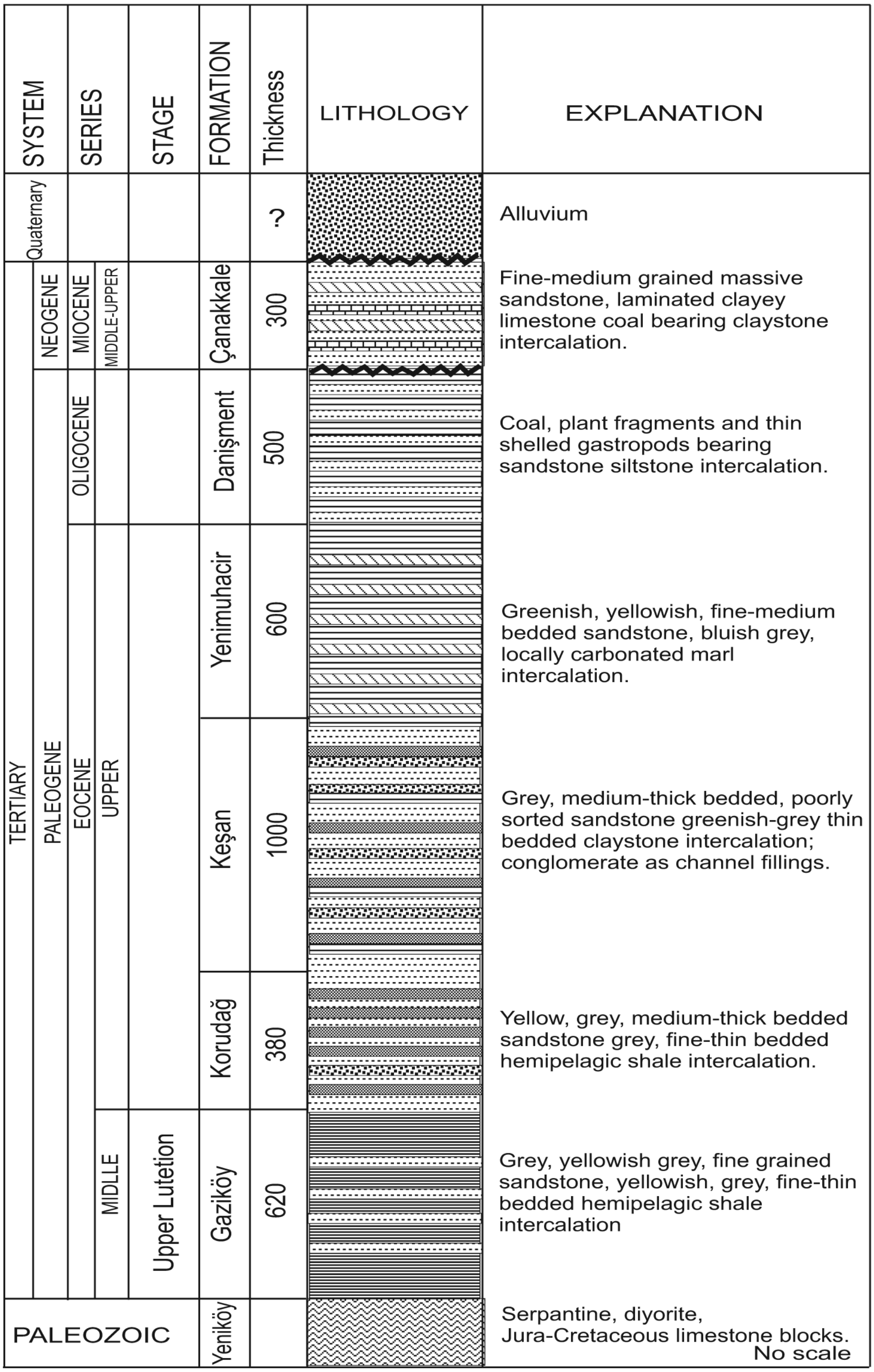


Figure 2- Generalized columnar section of the studied area (modified by Sümengen and Terlemez, 1991).

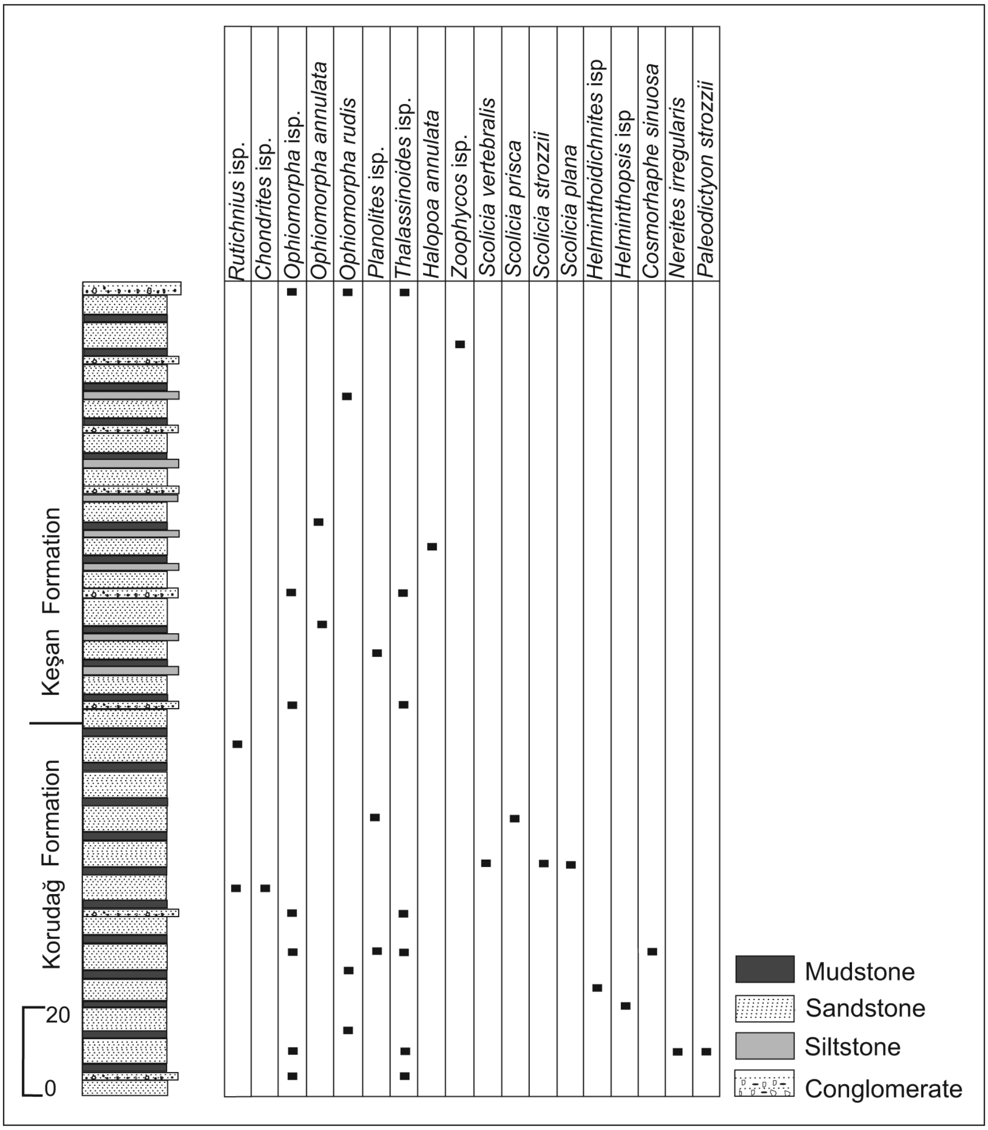


Figure 3- Korudağ-1 measured stratigrafic section

TRACE FOSSILS

From bottom to top, it is observed Late Eocene aged in Korudağ, Keşan, Yenimuhacır Formations. Most of trace fossils are middle fan, interchannel and outer fan deposits. Taxonomic description is prepared according to morphological groups distinguished by Hantzchel (1975), Ksiazkiewicz (1977), Seilacher (1977), Fillion and Pickerill (1990), Crimes and Crossley (1991) and Uchman (1998).

Simple and branched structure

This group embraces relatively small, rarely branched, horizontal or oblique burrows.

Planolites isp. (Plate 1, Figure 1).- *Planolites* isp., is straight, slightly curved and semi-relief,

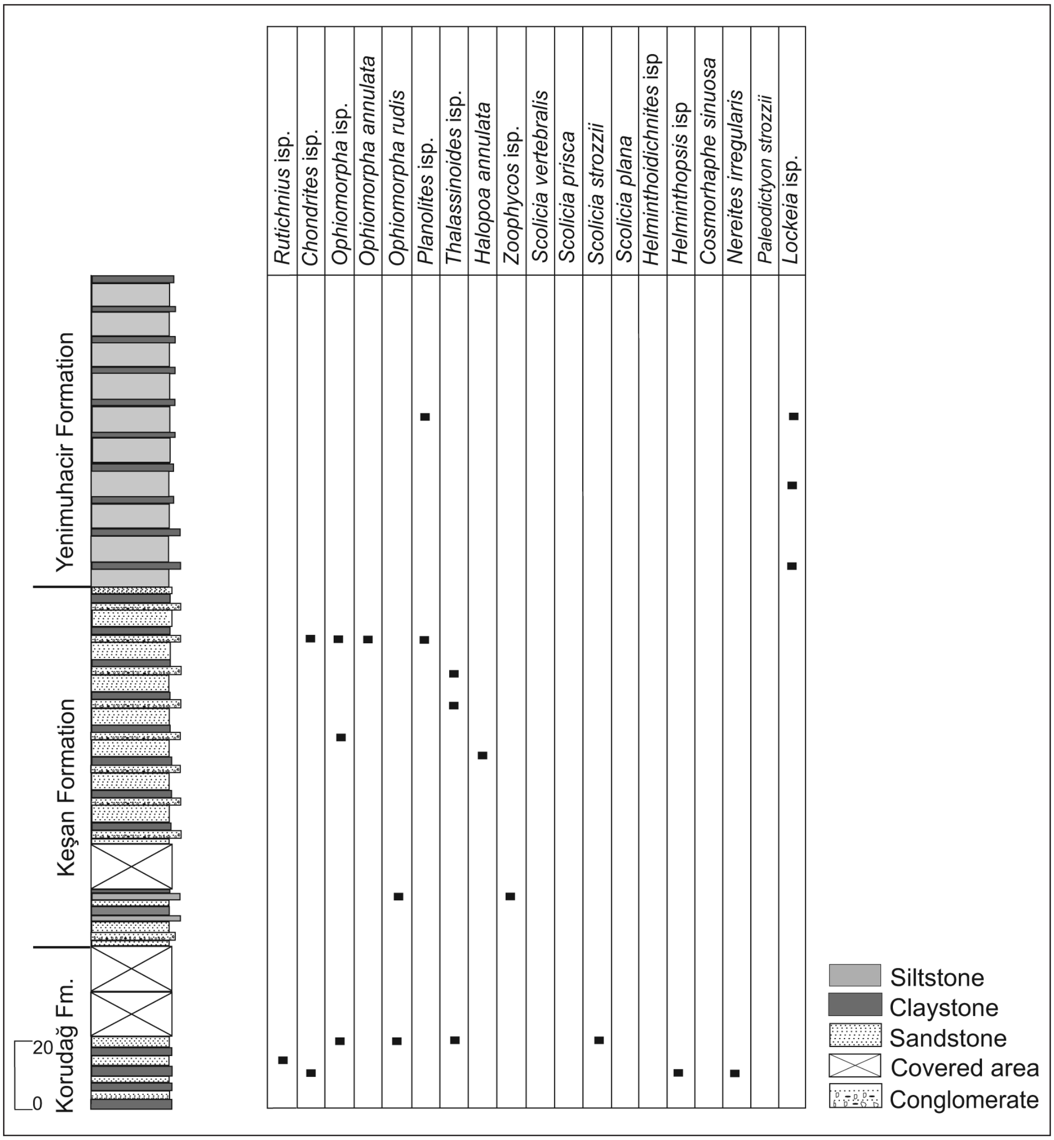


Figure 4- Korudağ-2 measured stratigrafic section

hypichial ridges. They are found as cylindrical tubes. The ridges are 2-4 mm wide. They are observed (İnecik, Korudağ-1 and Yeniköy measured sections) as facies breaking forms in the study area.

Planolites are common from Precambrian to today (Hantzschel, 1975).

Ophiomorpha isp.- They are observed in fine grained turbiditic sandstones as endichnial and hypichnial. Full relief, and wall structure is observed. The forms determined in the field (Korudağ-1, Korudağ-2 and Yeniköy measured sections) have 10 mm diameter and 49 mm length. *Ophiomorpha* is similar to *Thalassinoides* when it is in lateral or vertical forms (Kern and

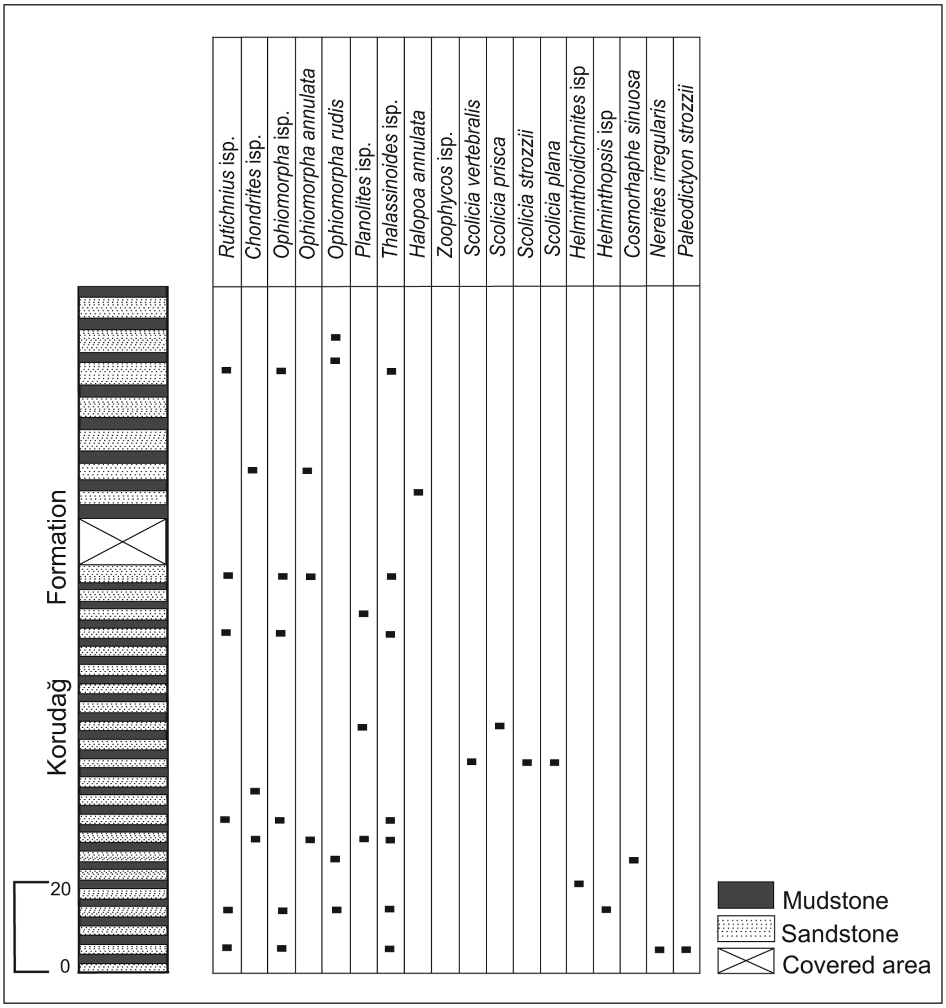


Figure 5- Yeniköy measured stratigrafic section

Warme, 1974). *Sabularia rudis* (Ksiazkiewicz, 1977) including the holotype, also strongly resembles *Ophiomorpha* (Uchman, 1991*a*) and may be regarded as a synonym of the latter. *Thalassinoides, Spongeliomorpha* and *Gyrolithes* are known to be the system of burrows formed by the same trace makers in different positions (Kennedy, 1967; Fürsich, 1973; Bromley and Frey, 1974).

Ophiomopha rudis (Ksiazkiewicz 1977) (Plate 1, Figure 2).- They are preserved as vertical to subvertical cylindrical, walled or unwalled, sand-filled, rarely branched tunnels (Korudağ-1, Korudağ-2 and Yeniköy measured sections). The diameters of the tubes are 2.5-2.6 mm and 34.5 cm. long.

Ophiomopha annulata (Ksiazkiewicz, 1977) (Plate 1, Figures 3, 4).- They embrace mainly horizontal and elongate pellets, cylindrical burrows. They are observed as exichnial cylindrical lined burrows (Korudağ-1, Korudağ-2 and Yeniköy measured sections). They are 2-4 mm in diameter.

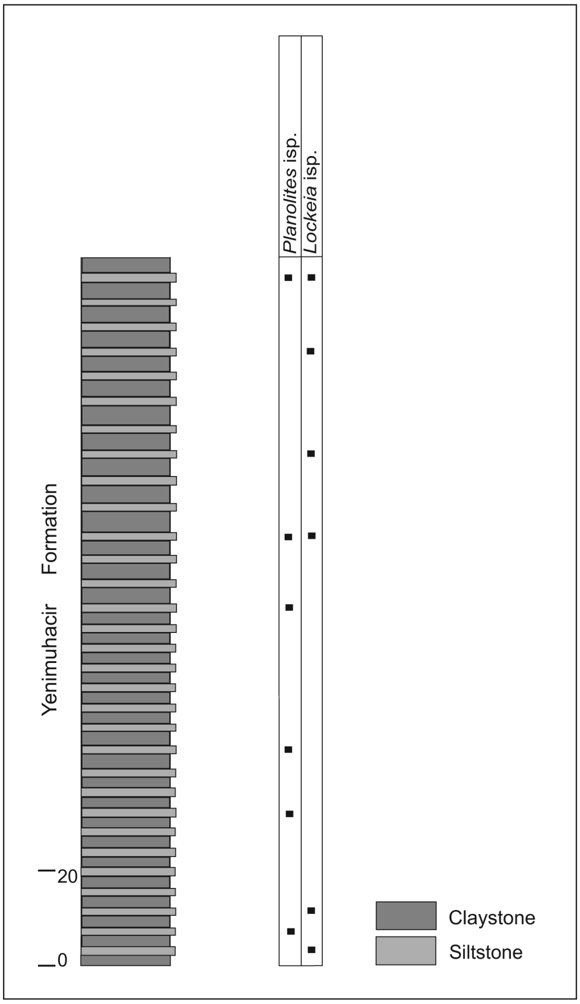


Figure 6- İnecik measured stratigrafic section

Thalassinoides Ehrenberg 1944 (Plate 1, figure 5).- They form the three-dimensional burrow system. They show branching from Y-shape to T-shape (Korudağ-1, Korudağ-2 and Yeniköy measured sections). They are typical to shallow-marine environments, and are formed by Crustaceans (Frey et. al., 1984). *Thalassinoides* is a facies breaking trace fossil. Origin and palaeoenvironmental meaning of *Thalassinoides* were summarized by Ekdale (1992). According to Föllmi and Grimm (1990) the *Thalassinoides* were formed by Crustaceans are produced burrow under anoxic conditions and can survive in turbidity currents.

Besides being widespread in Mesozoic and Cenozoic occurrences, *Thalassinoides* are common in Paleozoic shallow marine environments (Palmer, 1978; Archer and Maples, 1984; Sheehan and Schiefelbein, 1984; Stanistreet, 1989; Kulkov, 1991).

Halopoa annulata Uchman 1999 (Plate 1, Figure 6).- They are observed as straight, unbranched, and hypichnial traces (Korudağ-1 and Korudağ-2 measured sections). They don't have any secondary coming-out parts in the study area. The middle hand is 2 mm in diameter and contains 2-3 wrinkles. *Fucusopsis annulata* which contains *Halopoa* Torell (Uchman, 1998) was defined by Ksiazkiewicz (1970).

Chondrites isp. (Plate 2, Figure 1).- They appear in the form of small, branching, downward penetrating, and markedly flattened tunnels (Korudağ-1, Korudağ-2, and Yeniköy measured sections). The burrow is 0.5 mm in diameter.

Chondrites isp, is a feeding trace of an unknown trace maker. This trace fossil has a high degree of branching, and at the same time, this kind of fossil is probably constructed by endobentic deposit feeding (Bromley and Ekdale, 1984). *Chondrites* occurs independent from facies (Crimes, 1977) and significantly it is formed hypichially, and under anaerobic conditions as a chemo symbiotic organism (Bromley and Ekdale, 1984).

Rutichnus isp. (Plate 2, Figure 2).- They are branching, walled, meniscate traces. A branched structure can be produced by a deposit feeder, backing up or reversing as horizontal or oblique (Korudağ-1, Korudağ-2 and Yeniköy measured sections).

It mainly indicates shallow marine deposits (D' Alessandro et. al., 1987).

Circular structure

Lockeia isp. James 1879.- Generally, It is almond shaped or heart shaped outline with, smooth margin, preserved commonly as hypichnial mounds (İnecik measured section). Lockeia isp. is commonly interpreted as Bivalve resting trace (Seilacher, and Seilacher 1994) occuring from Cambrian to the recent, and seen nonmarine and deltaic environment.

Spreiten structure

This group consists of typically helicoidal lining and three dimensional spreite structures (Hantzschel, 1975).

Zoophycos Massalongo 1855 (Plate 2, Figure 3).- It is observed as spreiten structures which are endichnial to epichnial in fine grained turbiditic sandstone (Korudağ-1 and Korudağ-2 measured sections). The spreite lamellae are 1-5 mm wide and consists of numerous small, more or less 'U' or 'J' shaped protrusive burrows. The structure is bordered by a marginal tunnel, which is 5 mm wide. Different ichnogenera and/or species have been defined as *Zoophycos* (Hantzschel, 1975). Recently, many special studies have been made about the members of Zoophycos group (Bromley, 1991; Wetzel, 1992; Gaillard and Olivero, 1993; Olivero, 1994; Uchman and Demircan, 1999). There is a real necessity to re-observe this group.

Zoophycos is generally accepted as the traces left by unknown deposit feeding organisms. Organisms producing these traces can be sipunculoids (Wetzel and Werner, 1981), polychaete annelid, artropod (Ekdale and Lewis, 1991*a*, and *b*) and hemicordates. According to Kotake (1989, 1991*a*), *Zoophycos* are formed by surface ingestors of organic detritus, but still the organisms which are forming these traces are unclear.

Winding and meandering structure

This term was used firstly by Hantzschel (1975). These bilobate and trilobate tube forms were formed by echinoid burrows in Mesozoic and Senozoic (Smith and Crimes, 1983). All members of this group were included in the ichnogenus *Scolicia* by Seilacher (1986).

Scolicia vertebralis Ksiazkiewicz 1970 (Plate 2, Figure 4, 5).- They are observed as epichnial two or three lobed, winding and meandering traces in medium-grained turbiditic sandstones (Korudağ-1 and Yeniköy measured sections). The furrow is very narrow 10 mm in width, and 5 mm in depth. The side lobes consist of asymmetric ribs that are 1.5 mm in width. They are less common than *Scolia plana* and *Scolicia prisca* (Ksiazkiewicz 1970, 1977).

Scolicia prisca De Quatrafages 1849 (Plate 2, Figure 6).- They are observed as epichnial, three lobed, winding trace fossils in medium-grained turbiditic sandstones (Korudağ-1 and Yeniköy measured sections). The furrow is 10 mm in width and 3.5 mm in depth. The median lobe is the lower ridge on the floor of the furrow. It is 6 mm in width. The side lobes have assymetric ribs. The ribs are nearly 2 mm in width.

The parallel strings structure is formed by drainage of spatangoid echinoids. The asymmetric thicker ribs on both sides are remnants of backfill menisci. This ichnotaxon is generally observed in the middle part of turbidites at the transition from sandstone to mudstone. The lower part of the burrow is preserved. The upper part, making up backfill structures, remains usually at the top of the shaley levels of the turbidites (Ksiazkiewicz 1970, 1977).

Scolicia strozzii (Savi and Meneghini 1850) (Plate 3, Figure 1).- They are observed as hypichnical, having bilobate ridge with median groove in fine grained turbiditic sandstone (Korudağ-1, Korudağ-2 and Yeniköy measured sections). The ridge is 13 mm in width, and 1.5-2 mm in height. The median groove is narrow and shallow.

This ichnotaxon is a cast of the furrow formed after erosion of the *Scolicia* burrow. Height, depth of the median ridge, and wide of the trace depend on small differences in depth of burrowing, depth and strength of erosion, and properties of substrate. If the burrow is cut by erosion in the central part, its cast gets higher and wider, the sides of the ridge become gentler, and the median groove seems to be narrower. If erosion cuts the base of the burrow, its cast gets lower, the median groove becomes shallow and wide, and the prominent part of the ridge becomes narrow. However, some differences in burrow shapes depend on biological factors. Preservation factors seem to dominate the shape of the ridge. In the past, such criteria were used for distinguishing taxa of *Taphrhelminthopsis.*

Ksiazkiewicz (1977) differentiated these forms by their meandering structures; 1) gently winding, usually single *Taphrhelminthopsis vagans*, 2) usually gregariously occurring *Taphrhelminthopsis auricularis,* and 3) tightly meandering *Taphrhelminthoida.* The first form corresponds to locomotion activity (repichnia), and the latter to feeding activity (pascichnia) (e.g. Ksiazkiewicz, 1977; plate 17, figure2: Crimes, 1977; plate 6b). However, some transitional forms occur among them *Scolicia prisca* and *Subphyllochorda* (*Scolicia* isp.) commonly display meanders, which may be preserved as *Taphrhelminthopsis* or *Taphrhelminthoida* (=*Scolicia strazzii*). The tendency to meandering depends on the nutrient content of the substrate. Thus, differentiating between meandering and non-meandering forms is problematic at the species level.

Scolicia strozzii was produced at shallow tiers as indicated by the co-occurrence of *Paleodictyon strozzii*. Its Mesozoic-Cenozoic producers (*spantangoid echinoids*) can not be excluded. The Paleozoic forms are probably casts of washed out burrows of *Cruziana* and *Curvolithus*. There are no diagnostic features, which allow Paleozoic and past Paleozoic forms.

Scolicia plana Ksiazkiewicz 1970.- They are three lobed, winding and meandering, and hypichnial trace fossil in fine-grained turbiditic sandstone (Korudağ-1 and Yeniköy measured sections). The furrow is 9 mm in width, and side lobes are covered with ribs which are 1.5 mm in width. The narrow side lobes are 2.6 mm in width.

They are typical for Mesozoic and Cenozoic deposits (Ksiazkiewicz, 1977).

Nereites irregularis (Schafhäutl 1851) (Plate 3, Figure 2).- They are observed as meandering to winding, epichnial and/or endichnial trace fossils in fine-grained turbiditic sandstone. (Korudağ-1, Korudağ-2 and Yeniköy measured sections). The thickness of meander formed by *Nereites* is 3.5-4 mm. The list of ichnotaxa including Nereites was offered by Uchman (1995).

Nereites ırregularis was observed in deep sea environments in the begining of the Mesozoic (Yang, 1986) to Miocene (Uchman, 1995) and ?Quaternary (Ekdale and Lewis, 1991*b*)

Helminthoidichnites isp. (Plate 3, Figure 3).- They are traces having irregular winding with rarely ridges on both parting surfaces and on the upper parting surface or grooves on the lower parting surface (Korudağ-1 and Yeniköy measured sections). They are similar to *Gordia*, but *Helminthoidichnites* displays only occasional loops, whereas Gordio Emmons' (1844) loops are the most characteristic feature. However, these trace fossils were produced by the same tracemarker. They were probably been produced by insect larvae (Hoffman, 1990). *Helminthoidichnites* spreads form marine to nonmarine environment.

Helminthopsis Heer 1877 (Plate 3, Figure 4).- They are observed as hypichnial, convex, loosely meandering, smooth, string-like, no branched forms in fine-grained turbiditic sandstone (Korudağ-1, Korudağ-2 and Yeniköy measured sections). The string is 3.5-4 mm in width. Examination of the type material related to *Helminthopsis* has revealed that the type species *Helminthopsis magna* is in fact *Taphrhelminthopsis* Sacco, and that *Helminthopsis labyrintica* (Heer, 1877) is identical to *Spirocosmorhaphe* Seilacher. These types of traces are probably produced by polychaetes or pripulid (Ksiazkiewicz, 1977; Fillón and Pickerill, 1990).

Helminthopsis occurs in the time interval ranging between the Cambrian (Crimes, 1987) to the Recent (Swinbanks and Murray, 1981; Wetzel, 1983*a, b*).

Cosmorhaphe sinuosa (Azpeitia Moros 1933) (Plate 3, Figure 5).- It is a hypichnial, convex, meandering string in fine-grained turbiditic sandstone (Korudağ-1 and Yeniköy measured sections). It is preserved in semi-relief. The string is 2 mm in width. The meanders are 10-15 mm in width.

Cosmorhaphe isp. is a graphoglyptid burrow, common in flysch deposits since the Ordovician (Häntzschel, 1975). Fossil forms have been present since the Cambrian (Narbonne et al., 1987).

Networks

Paleodictyon (Glenodictyum) strozzii Meneghini, 1850 (Plate 3, Figure 6).- They form a hypichnial semi-relief, network in fine-grained turbiditic sandstone (Korudağ-1, Korudağ-2 and Yeniköy measured sections). The net is 2-5 mm in size and 1 mm in string diameter. The nets forming the trace are quite regular.

ENVIRONMENTAL DISTRIBUTION OF TRACE FOSSILS

From the study area, 4 measured sections involving Korudağ, Keşan, Yenimuhacir formations were taken. Although Korudağ and Keşan formations have various trace fossils, Yenimuhacır formation has rarely. Environmental distribution of trace fossils depending on facies association in the measured sections are shown in table 2, 3, 4. Ichnogenus and/or species were tried to be given as environmental indicators forming the ichnofacies. Generally simple structures show shallow water trace fossils while mixing, meandering and network structures indicate deep water trace fossils.

DISCUSSION

Working on distribution of trace fossils in the submarine fan and evaluating the submarine through the different part of submarine is more accurate than evaluating it through their preservation factor and source. (Crimes et. al, 1981). For example; since main channel fill of inner fan and distributary channel of the mid fan deposits is mostly conglomerate, trace fossils were not observed. Shallow water trace fossils such as *Ophiomorpha* isp, *Thalassinoides* isp. which occur in vertical and horizontal position at the coarse sandy level and especially loose meandering forms of the trace fossils which is eroded by turbidity current, do not have the chance to preserve of their vertical and horizontal forms. (Crimes, 1977; Crimes et. al., 1981: McCann and Pickerill, 1988). The facies that have the most trace fossils and diversity are mostly middle fan interchannel and fan fridge deposits. In these deposits, especially meandering, network and radial trace fossils which are parallel to the bedding, show abundance and diversity. At the same time, these forms indicate deep water (Crimes et. al., 1981).

Demircan and Toker (2003) in their submarine fan research around Adana, Southern Turkey observed that the diversity of the organisms at the inner fan is sparse and not many traces were observed at this part on the other hand, in the middle fan this diversity increases and the highest level of the organisms were observed at the outer fan.

Sander and Hessler (1969) indicated the variations in ichnofauna in modern seas which

Table 2- Environmental distribution of trace fossils in Korudağ Formation

shows higher diversity on the continental slope than the shelf shows a gradual decrease with depths under 2000 m.

Boreen and James (1995) explained that deeper part of the shelf facies in Tertiary limestone in Southeast Avustralia has *Scolicia* isp, *Planolites* isp, and *Helminthopsis* isp forms, and especially *Scolicia* isp, is common.

According to Howell et. al., (1996), at shoreface deposits which is very common at the Hammer group in England, Ophiomorpha isp. forms are abundant.

Distribution of the trace fossils, which were observed at the submarine fan deposits at the outcrops of Korudağ, Keşan and Yenimuhacir Formations, in the study area, change according

Table 3- Environmental distribution of trace fossils in Keşan formation

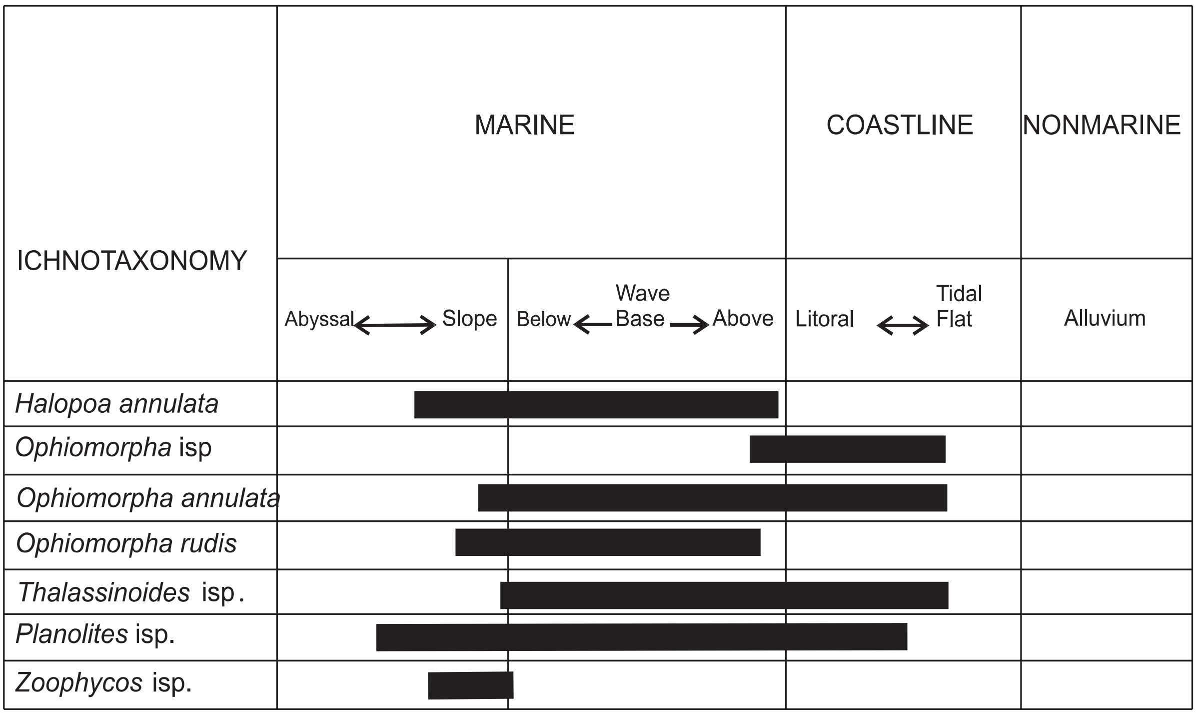
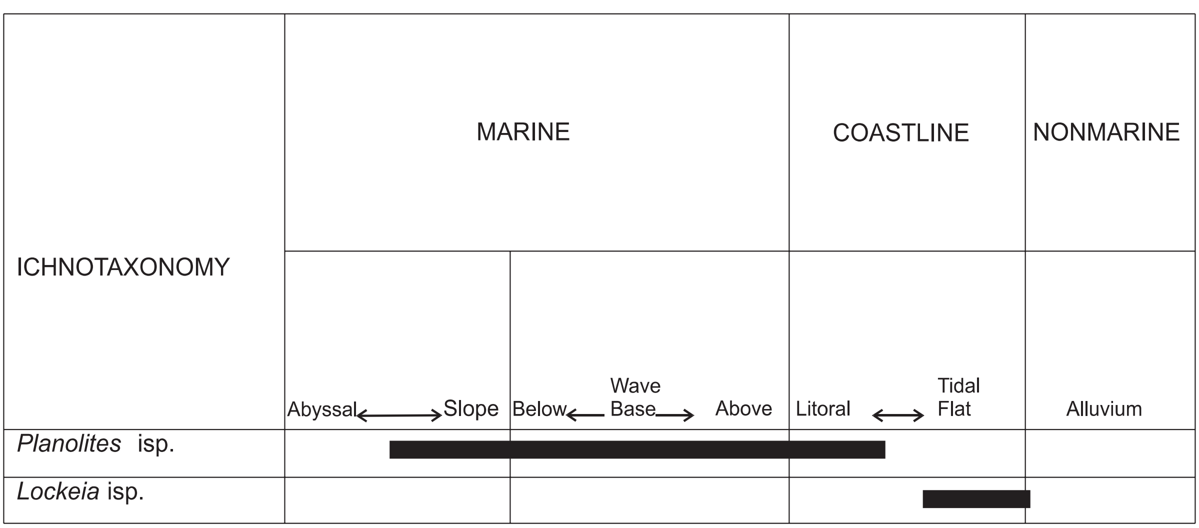


Table 4- Environmental distribution of trace fossils in Yenimuhacır formation



to their position in the fan system. In the research area Keşan Formation which was formed in the slope deposits, the facies breaking forms observes. Addition to facies breaking forms, it contains shallow trace fossils such as *Ophiomorpha* isp. and *Thalassinoides* isp. The unit also contains crawling trace fossils (*Scolicia* isp, etc.) which are common. In the deposits which are belong to Korudağ formation, has especially meandering, network and radial trace fossils. These forms indicate deep water. Although Korudağ and Keşan formations have various trace fossils, Yenimuhacır formation has rarely. At the same time, at the study area, lateral and vertical distribution of the trace fossils at the middle fan is higher than the ones abundant in the outer fan.

RESULTS

Five groups (simple and branched structures, circular structure, spreiten structure, winding and meandering structures and networks) and 19 ichnofossils (*Ophiomorpha* isp, *Ophiomorpha annulata, Ophiomorpha rudis, Thalassinoides* isp, *Planolites* isp, *Halopoa annulata, Rutichnius* isp, *Chondrites* isp, *Scolicia vertebralis, Scolicia strozzii, Scolicia prisca, Scolicia plana, Nereites irregularis, Helminthopsis* isp, *Cosmorhaphe* isp, *Helminthoidichnites* isp, *Paleodictyon strozzii Zoophycos* isp, *Lockeia* isp,) depending on their morphology at northeastern of Saros bay and around Korudağ, Keşan, Yenimuhacir regions in Late Eocene deposits were identified. As a result, inner fan is represented by Keşan formation which is composed of simple structures (*Ophiomorpha* isp, *Ophiomorpha annulata, Ophiomorpha rudis, Thalassinoides* isp, *Planolites* isp, *Halopoa annulata, Zoophycos* isp,), while Korudağ formation is characterized as a middle fan and distal of middle fan which has lamell and meandering structures (*Ophiomorpha* isp, *Ophiomorpha annulata, Ophiomorpha rudis, Thalassinoides* isp, *Planolites* isp, *Halopoa annulata, Rutichnius* isp, *Chondrites* isp, *Scolicia vertebralis, Scolicia strozzii, Scolicia prisca, Scolicia plana, Nereites irregularis, Helminthoidichnites* isp, *Helminthopsis* isp, *Cosmorhaphe* isp, and *Paleodictyon strozzi*), and Yenimuhacır formation shows deltaic features which has simple and circular structure (*Lockeia* isp., *Planolites* isp.,). It indicates Cruziana ichnofacies which is represented by normal salinity, temperature varies seasonally. According to the data, inner fan has normal salinity; temperature varies seasonally, contains high oxygen, bottom is stable except during the storms and is represented by *Skolithos-Cruziana* ichnofacies and eutrophic conditions. The middle fan has low oxygen, except the turbidite sedimantation the conditions are same as the inner fan and is represented by mixed ichnoassemblages *Skolithos-Cruziana* ichnofacies and *Nereites* ichnofacies which show eutrophic-oligotrophic conditions. Outer fan is described by high diversity in ichnofossils, low or no oxygen, turbidite sedimentation and totally oligotrophic conditions in *Nereites* ichnofacies.

ACKNOWLEDGEMENTS

This paper is supported by the MTA General Directorate Natural History Museum Project no: 16B45 and European Union Scholarship (Synthesis Program-Austria Natural History Museum, 2004).

Manuscript received January 9, 2008

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PLATES

PLATE I

Figure 1- *Planolites* isp.
Endichnial full-relief in fine grained sandstone.
İnecik (Delta)-Korudağ-1 (Middle fan)- Yeniköy (Outer fan).

Figure 2- *Ophiomorpha rudis*
Endichnial full-relief in medium-fine grained sandstone.
Korudağ-1 (Slope)- Korudağ-2 (Middle fan-Outer fan)
Yeniköy (Outer fan).

Figure 3- *Ophiomorpha annulata*
Exichnial semi-relief in medium-fine grained sandstone.
Korudağ-1 (Slope)- Korudağ-2 (Middle fan-Outer fan)
Yeniköy (Outer fan).

Figure 4- *Ophiomorpha annulata*
Exichnial semi-relief in medium-fine grained sandstone.
Korudağ-1 (Slope)- Korudağ-2 (Middle fan-Outer fan)
Yeniköy (Outer fan).

Figure 5- *Thallasinoides* isp.
Exichnial semi-relief in medium grained sandstone.
Korudağ-1 (Slope)-Korudağ-2 (Middle fan-Outer fan)
Yeniköy (Fan fridge).

Figure 6- *Halopoa annulata*
Hypichnial semi-relief in medium grained sandstone.
Korudağ-1 (Slope)-Korudağ-2 (Middle fan).

PLATE - I

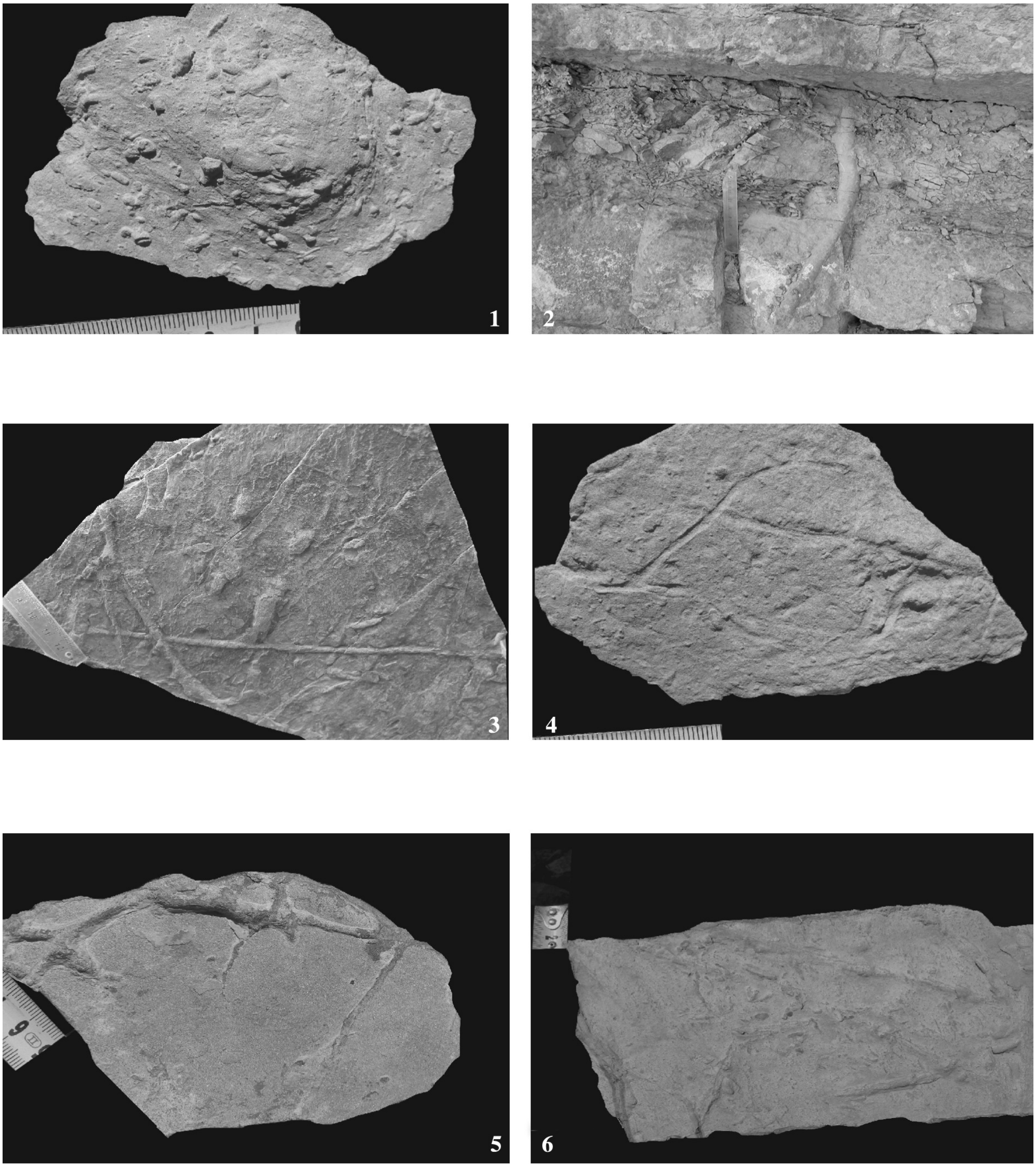


PLATE II

Figure 1- *Chondrites* isp.
Endichnial full-relief in medium-fine grained sandstone.
Korudağ-1 (Slope-Outer fan)-Korudağ-2 (Middle fan-Outer fan)
Yeniköy (Outer fan).

Figure 2- *Rutichnius* isp.
Hypichnial full-relief in medium grained sandstone.
Korudağ-1 (Slope-Outer fan)-Korudağ-2 (Middle fan-Outer fan)
Yeniköy (Outer fan).

Figure 3- *Zoophycos* isp.
Endichnial semi-relief in medium-fine grained sandstone.
Korudağ-1 (Slope)-Korudağ-2 (Middle fan)

Figure 4- *Scolicia vertebralis.*
Exichnial semi-relief in fine grained sandstone.
Korudağ-1 (Distal of Middle fan-Outer fan)-Yeniköy (Outer fan).

Figure 5- *Scolicia vertebralis.*
Exichnial semi-relief in fine grained sandstone.
Korudağ-1 (Distal of Middle fan-Outer fan)-Yeniköy (Outer fan).

Figure 6- *Scolicia prisca.*
Exichnial full-relief in fine grained sandstone.
Korudağ-1 (Distal of Middle fan-Outer fan)-Yeniköy (Outer fan).

PLATE - II

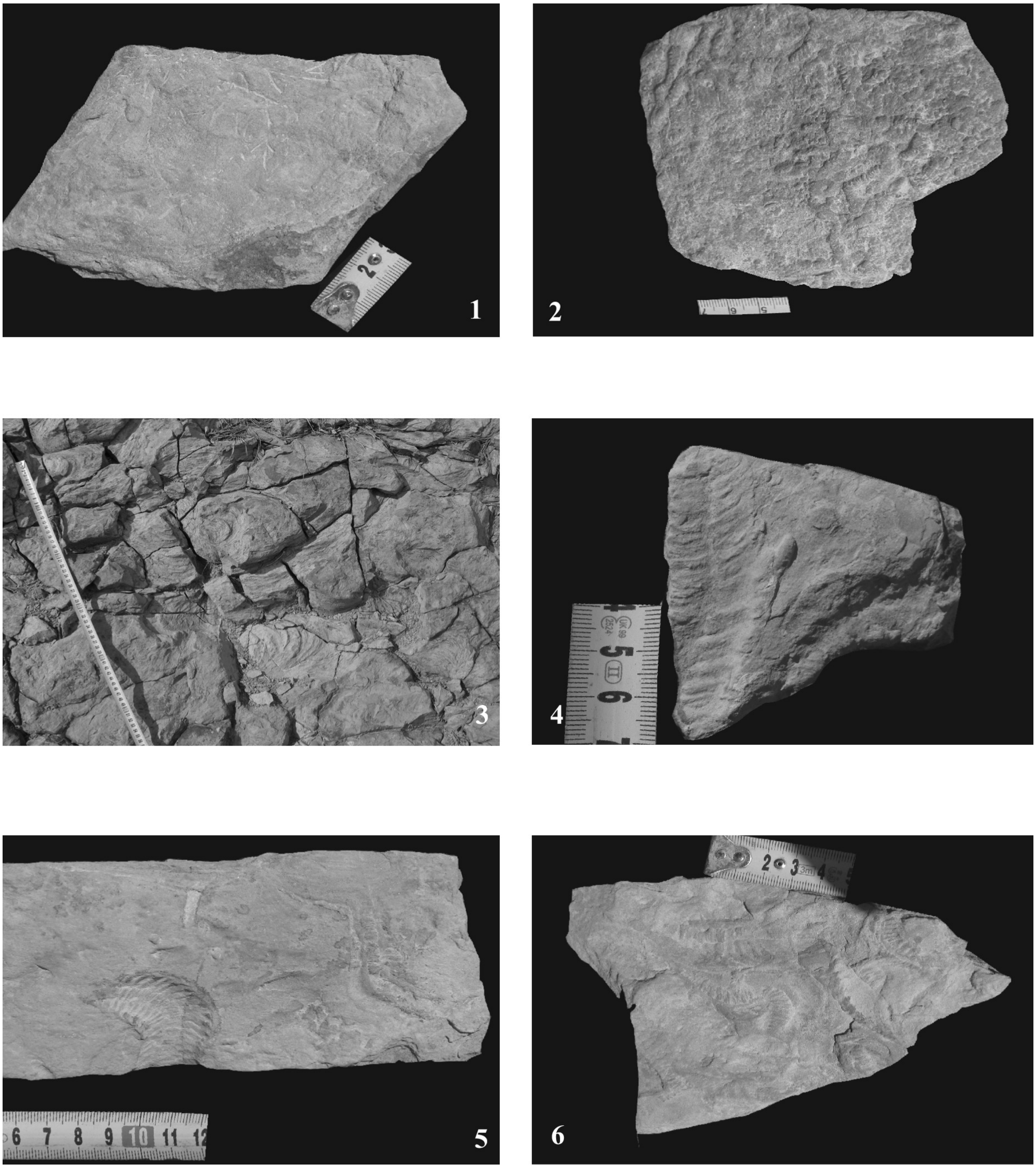


PLATE III

Figure 1- *Scolicia strozzii.*
Hypichnial semi-relief in fine grained sandstone.
Korudağ-1 (Distal of Middle fan-Outer fan)-Korudağ-2 (Middle-Outer fan)
Yeniköy (Outer fan).

Figure 2- *Nereites irregularis.*
Epichnial semi-relief in fine grained sandstone.
Korudağ-1 (Distal of Middle fan -Outer fan)-Korudağ-2 (Middle-Outer fan)
Yeniköy (Outer fan).

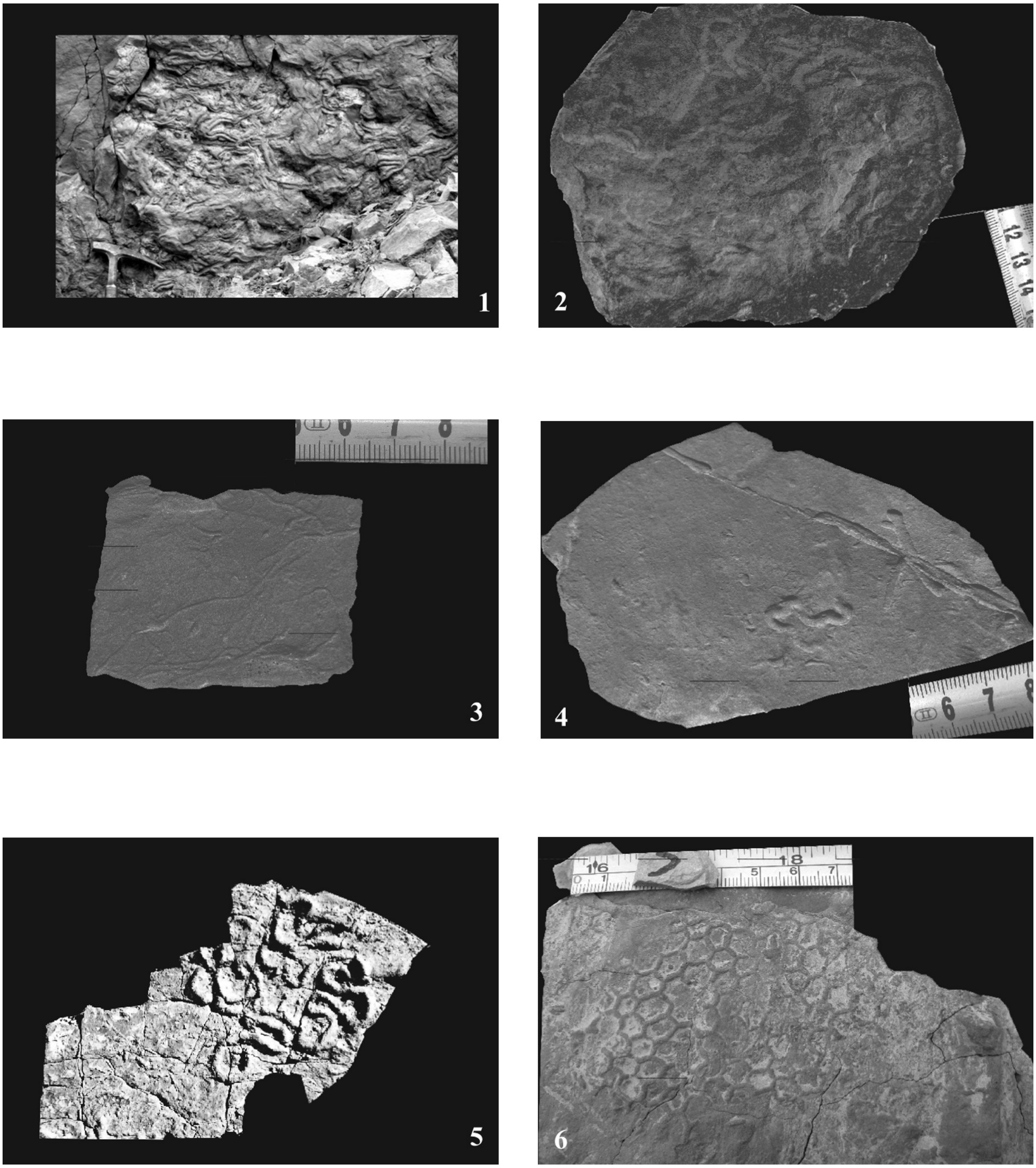
Figure 3- *Helminthoidichnites* isp.
Hypichnial semi-relief in fine grained sandstone.
Korudağ-1 (Distal of Middle fan-Outer fan)-Yeniköy (Outer fan).

Figure 4- *Helminthopsis* isp.
Hypichnial semi-relief in fine grained sandstone.
Korudağ-1 (Distal of Middle fan -Outer fan)-Korudağ-2 (Middle-Outer fan)
Yeniköy (Outer fan).

Figure 5- *Cosmorhaphe sinuosa.*
Hypichnial semi-relief in fine grained sandstone.
Korudağ-1 (Distal of Middle fan-Outer fan)-Yeniköy (Outer fan).

Figure 6- *Paleodictyon strozzii.*
Hypichnial semi-relief in fine grained sandstone.
Korudağ-1 (Distal of Middle fan -Outer fan)-Korudağ-2 (Middle-Outer fan)
Yeniköy (Outer fan).

PLATE - III



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FORAMINIFER AND OSTRACOD FAUNAS OF THE SUBMARINE HILL HARMANTAŞI LOCALITY (GULF OF SAROS, NORTHERN AEGEAN SEA) AND THE IMPACT OF THE UNDERWATER SPRINGS ON THE FAUNA

Engin MERİÇ**, Niyazi AVŞAR***, Atike NAZİK***, Cemal TUNOĞLU****, Baki YOKEŞ*****, İpek F. BARUT******, Fulya YÜCESOY-ERYILMAZ*******, Beril TUĞRUL*******,* Muhittin GÖRMÜŞ*********, M. Salim ÖNCEL**********, Hacı ORAK***********, Erol KAM************ and Feyza DİNÇER***

ABSTRACT.- A total of 46 sediment samples collected from Harmantaşı locality (Gulf of Saros, Northern Aegean Sea) were analysed for its Foraminifer and Ostracod content. 68 genera and 111 species of benthic formaninifera were identified. 99 of the species have calcerous tests, and agglutinant types were represented with only 12 species. 20 genera and 27 species of ostarcods were found. Physicochemical parameters such as depth, temperature, dissolved oxygen, pH and salinity we measured to reveal the underwater topography of the region. Several underwater springs were detected around the fault lines. Taxonomical differences as well as morphological abnormalities were observed in the the foraminiferal species found close to these springs. Water samples were collected from the springs and near stations. Heavy metal and trace elements analyses of these water samples revealed that there is no antropogenic pollution around the locality, but the submarine springs are the major source of the heavy metals and trace elements in sea water. Radioactivity of the sea water samples were found to be above the WHO limits. The aim of this study is to figure out the possible reasons of the morphological abnormalities observed in foraminiferal tests.