Mineral Res. Expl. Bull.. 113, 1-14 .1991

PALEOCENE-EOCENE SEDIMENTS INTERBEDDED WITH VOLCANICS WITHIN THE LYCIAN NAPPES : FARALYA FORMATION

Mustafa ŞENEL*

ABSTRACT. - The presumably allochthonous structural units in the Southwestern Turkey between the Menderes massif and Beydağları autochthon are known as the Lycian nappes. Some of these units particularly beneath the ophiolite nappe end up with the Faralya formation of Paleocene-Lutetian age. The striking feature of this formation which includes micrile, clayey micrite, claystone, sandstone and conglomerate, is the presence of basic volcanite interbeds of Eocene age, This volcanite bearing formation exhibits a strong similarity to those of the other formations in Southwestern Turkey most of which include similar basic volcanites. Eocene basic volcaniles are also known in the Akseki autochthon to the south of Seydişehir (Geyikdağ unit in broad sense). Similar extensive lateral movements (Eocene mountain building processes) developed over the Faralya formation are seen over the volcanite bearing formations to the south of Menderes massif as well as to the north of Isparta angle and the Akseki autochthon. These features indicate that the area between the Menderes massif and Akseki autochthon (Geyikdağ unit) reflects common basinal characters in terms of depositional conditions, volcanism and the traces of Eocene mountain building process.

INTRODUCTION

The Lycian nappes are known as a NE-lrending allochthonous complex between the Menderes massif and Beydağları autochthon, SE Anatolia and made up of a great number of structural units related to the Lower Langhian overthrusting. Some structural units, particularly lying beneath the ophiolite nappe, as parts of the Lycian nappes widespreadly occurring in the southwest and becoming narrower towards north end with the Paleocene-Eocene flysch-like sediments (Fig. 1). These sediments, termed flysch by many investigators who have studied the Lycian nappes begin with the Datça flysch (Orombelli and others, 1967) and extend northeasterly as thin and narrow outcrops locally widening along the tectonic contacts in the uppermost levels of some structural units in the Teke Taurids. Some volcanic rocks are also known to be found within these sediments (Fig. 2) that exhibit various lithologies and successions within the region (Yılmaz, 1966; Bassaget, 1966; Richard, 1967) Graciansky, (1968, 1972) recognized the presence of some blocks (flysch with blocks) with varying ages and lithology within the Paleocene-Lower Eocene sediments overlying the cherty limestones of the Haticeana series. These sediments arc called the Alakaya formation by Erkman and others (1982), the Camialanı tectonic unit by Bölükbaşı (1987).

This paper dealing with part of a research carried out in Fethiye-Çameli-Elmalı area summarizes the stratigraphic and structural features of the Paleocene-Eocene sediments described as the Faralya formation.

FARALYA FORMATION

Definition, name and distribution. - The Paleocene-Eocene flysch-like sediments that begin with red micritcs locally containing thin interbeds of basic volcanics are called the Faralya formation. This unit could be observed in the uppermost section of the structural units lying beneath the ophiolite nappe, west of Teke peninsula.

Type sections. - This unit exhibits type sections at the locality of Avian Pınarı, near Faralya village, and Küre Çeşme and Uzunca Yayla, east of Boyalı Mahallesi (Fig. 3).

Lithology. - The Faralya formation that exhibits various lilhologic sequences at different places, begins with planktonic foraminifera-bearing, red and pink colored micrites which are seen as thickly bedded from a distance, although they show, to medium lamination (Fig. 3, 4). These micrites locally containing nodule and bands of red chert arc overlain by alternating clayey limestone, marl, and claystone, all of which indicating the same characteristics of micritcs. The formation be-

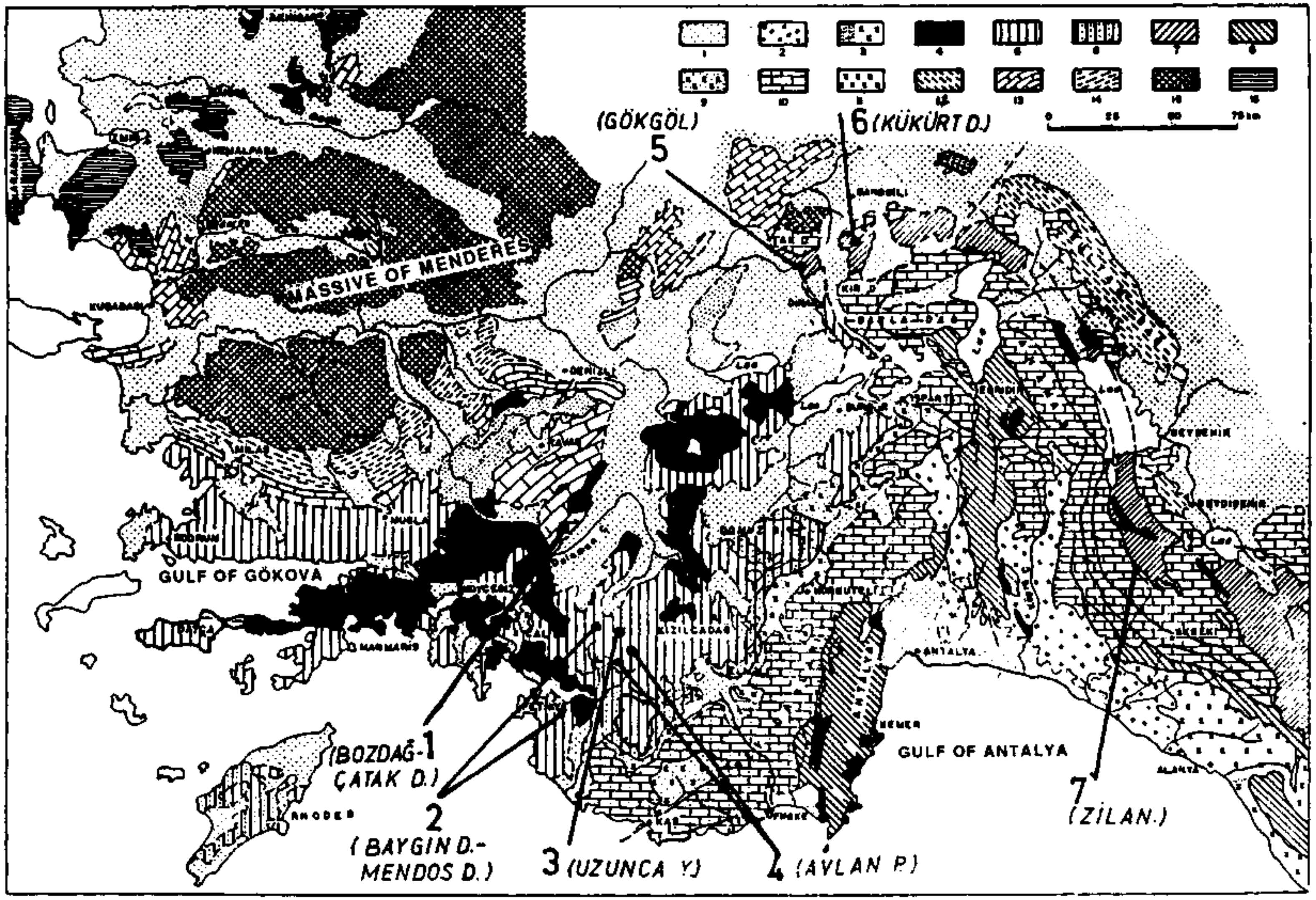


Fig. 1 - Structural scheme of the western Taurus. 1- Plio-Quaternary; 2- Antalya Miocene basin; 3- Tavas-Burdur and Torbalı-Kemalpaşa post-tectonic molasse basin (Oligocene-Burdigalian); 4- Ophiolite nappe; 5, 6- Lycian nappes (5: Radiolarite and carbonate units, 6: Yavuz unit); 7- Beyşehir-Hoyran-Hadim nappes; 8- Antalya nappes; 9- Beydağları Lower-Middle Miocene; 10- Carbonate platform (Mesozoic-Paleocene); 11- Alanya massif; 12- Series of Seydişehir Paleozoic and Sultan Dağları; 13- Mesozoic marbles; 14- Upper Paleozoic micaschists; 15a- Gneiss; 15b- Sandıklı porphyroids (Paleozoic); 16-Northern Menderes metamorphic series.

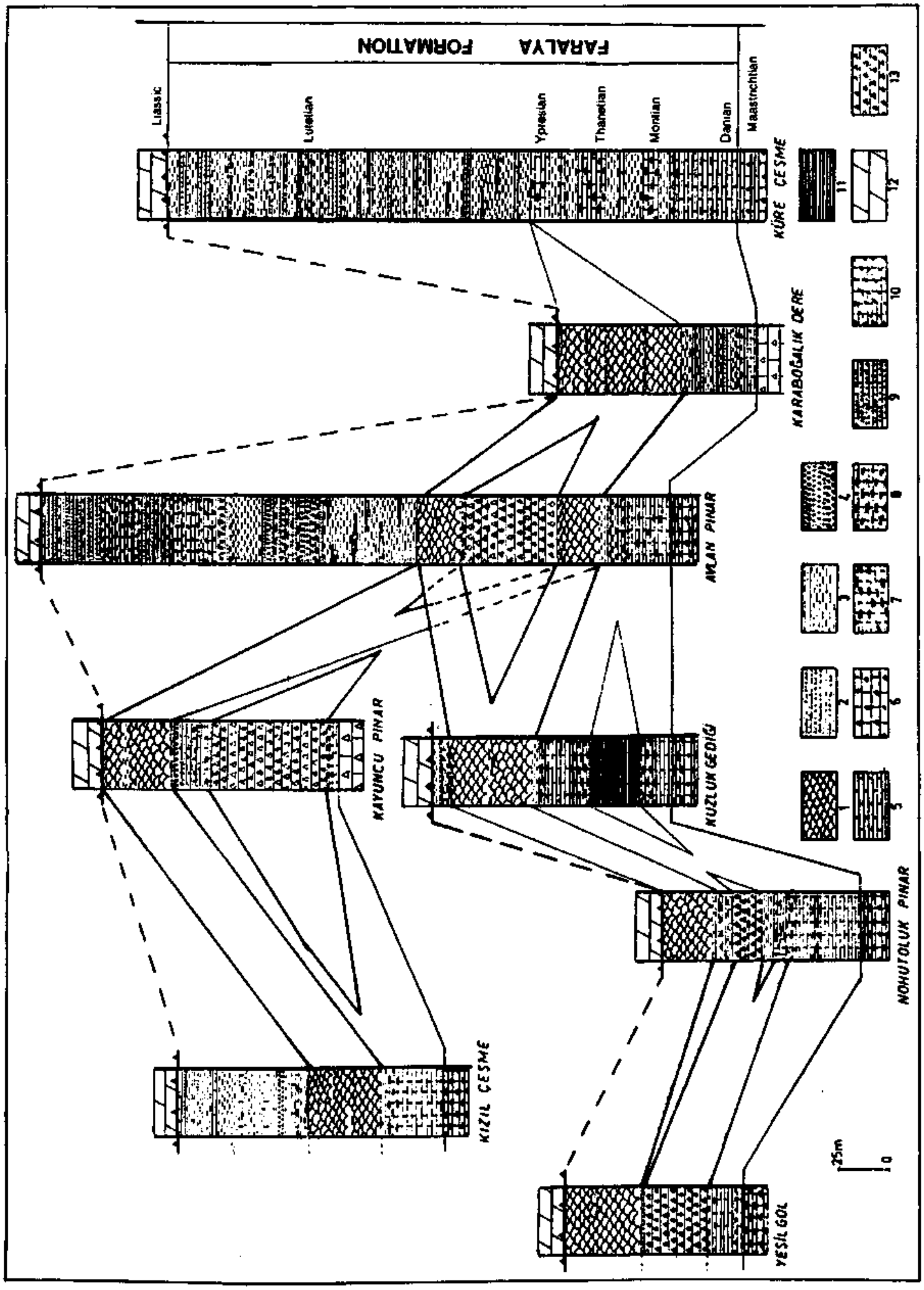


Fig. 2 - Stratigraphic columnar sections of the Faralya formation. 1- Pillow lava; 2- Sandstone; 3- Claystone and siltstone; 4- Conglomerate; 5- Pelagic limestone; 6- Brecciated limestone; 7- Cherty pelagic limestone; 8- Clayey limestone; 9- Sandy limestone; 10- Conglomeratic limestone; 11- Bedded chert; 12- Dolomite; 13- Breccia.

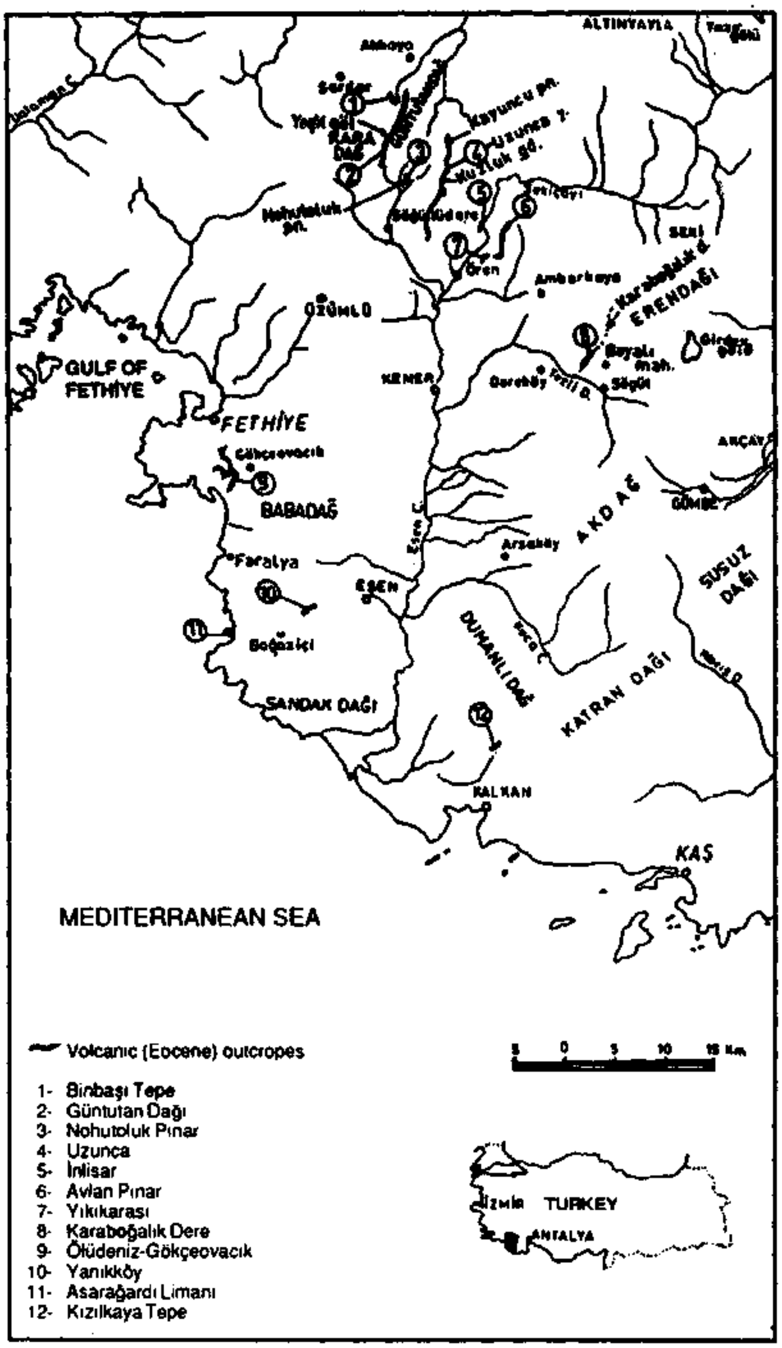


Fig. 3 - Cross-section illustrating basic volcanic outcrops within the Faralya formation.

ginning with brecciated, sandy, and clayey limestone and claystone, occurring rarely (Fig. 3, 5, 6 and 7), grades upward into conglomeratic limestone, breccia, sandy limestone, clayey limestone, marl, micritic limestone, sandstone, conglomerate, and siltstonc and claystone interbedded with basic pillow lavas. The siltstone and claystone, the most common lithologies of the formation, are thinly bedded and are reddish brown, wine, red, pink, dirty yellow, green and greenish gray colored at various horizons.

The breccias found as interbeds within the above lithologies are thick to medium bedded and greenish gray, dirty yellow, dirty white and light brown colored. This breccia unit which could be identified as a member locally show flow struc-

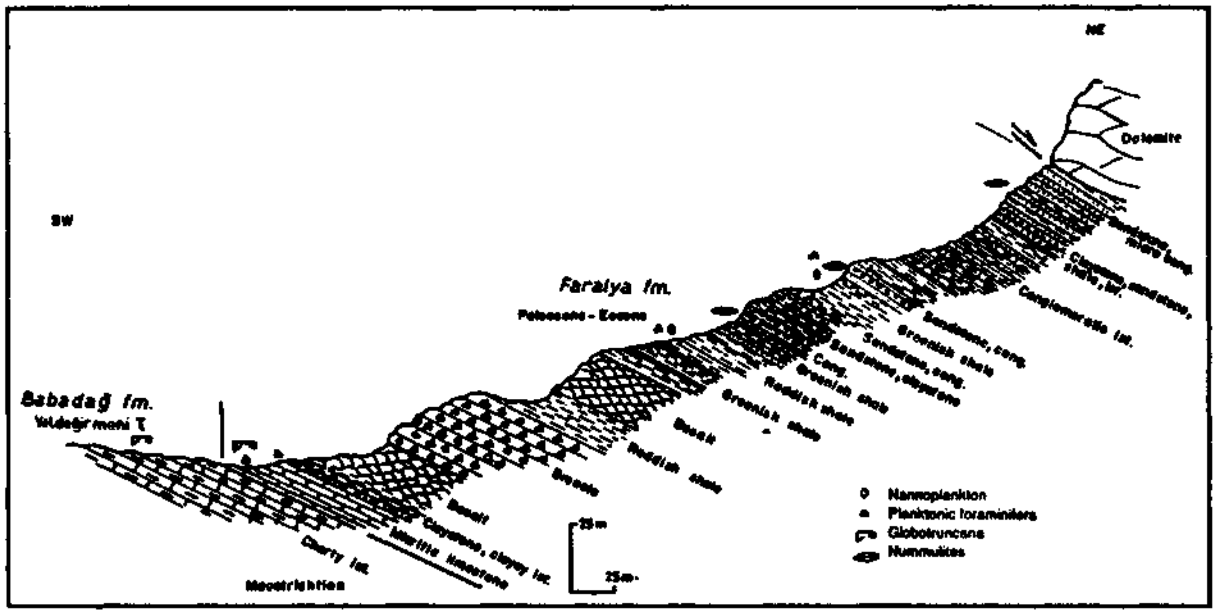


Fig. 4 - Cross-section illustrating outcrop of the Faralya formation from Avlan Pınarı.

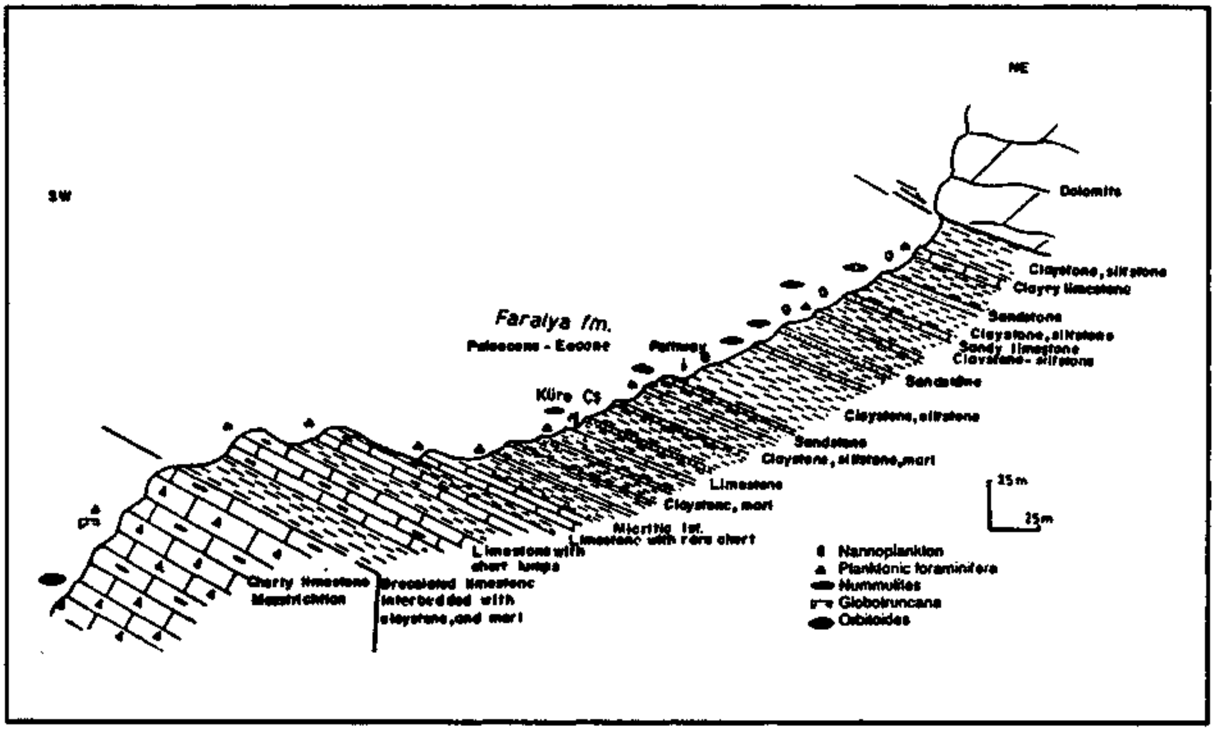


Fig. 5 - Cross-section illustrating outcrop of the Faralya formation from Küre Çeşme.

ture (flute casts) on the lower bedding planes and have angular fragments, displaying medium to poor sorting and local grading. The cherty limestone rarely contains fragments of some rock units such as diabase, gabbro and peridotite. It is locally as much as 50 m. thick and pinches out laterally as discontinuous outcrops for a long distance. As seen from the Avian Pınarı section, it is found between two basic volcanic flows, although it generally lies between the red micrites and basic volcanics (Fig. 4).

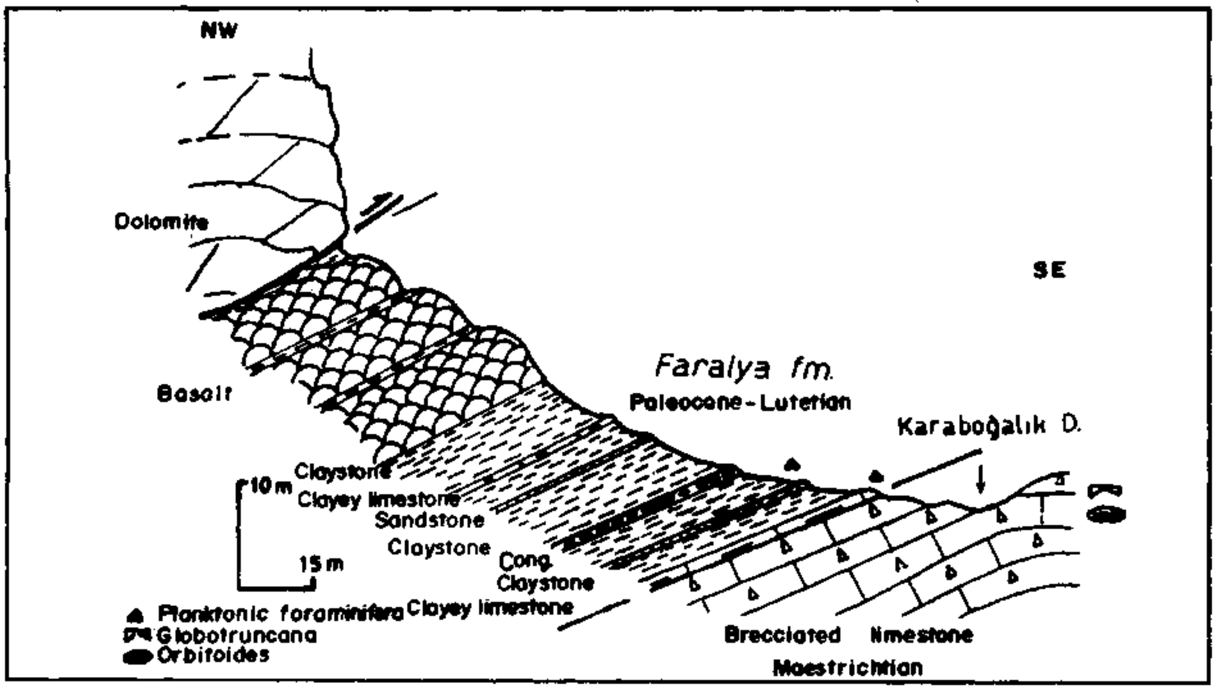


Fig. 6 - Cross-section illustrating outcrop of the Faralya formation from Karaboğalık Dere.

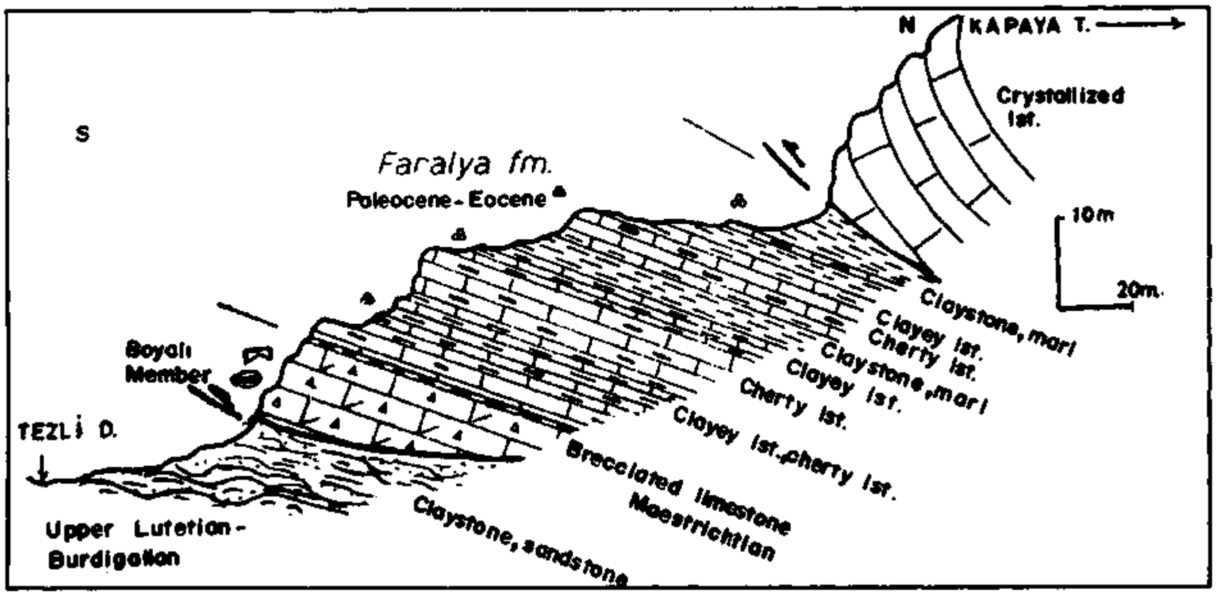


Fig. 7 - Cross-section illustrating outcrop of the Faralya formation from south of Kayaaya Tepe.

The interbeds of the brecciated limestone, sandy limestone, clayey limestone, and micritic limestone arc mostly seen as thin lenses, and bands at different levels of the siltstonc, and claystone. They are rarely up to 10 m. thick. The sandstone interbeds have the same features as those of the above mentioned lithologies. However, the uppermost section of the formation is composed of sandstone that is up to 30 m. thick near Avian Pınarı (Fig. 4). This greenish gray colored sandstone is thin to medium bedded. It contains thin lenses and bands ofsiltstone, and claystone. It has been intensively fractured and crushed, due to overthrusting of dolomite. It rarely contains thin horizons of conglomerate. The same section also displays alternating of clayslonc, and conglomeratic limestone, with a total thickness of more than 40 m. (Fig. 4). These lithologies formed boudinage structure arising from intense deformation.

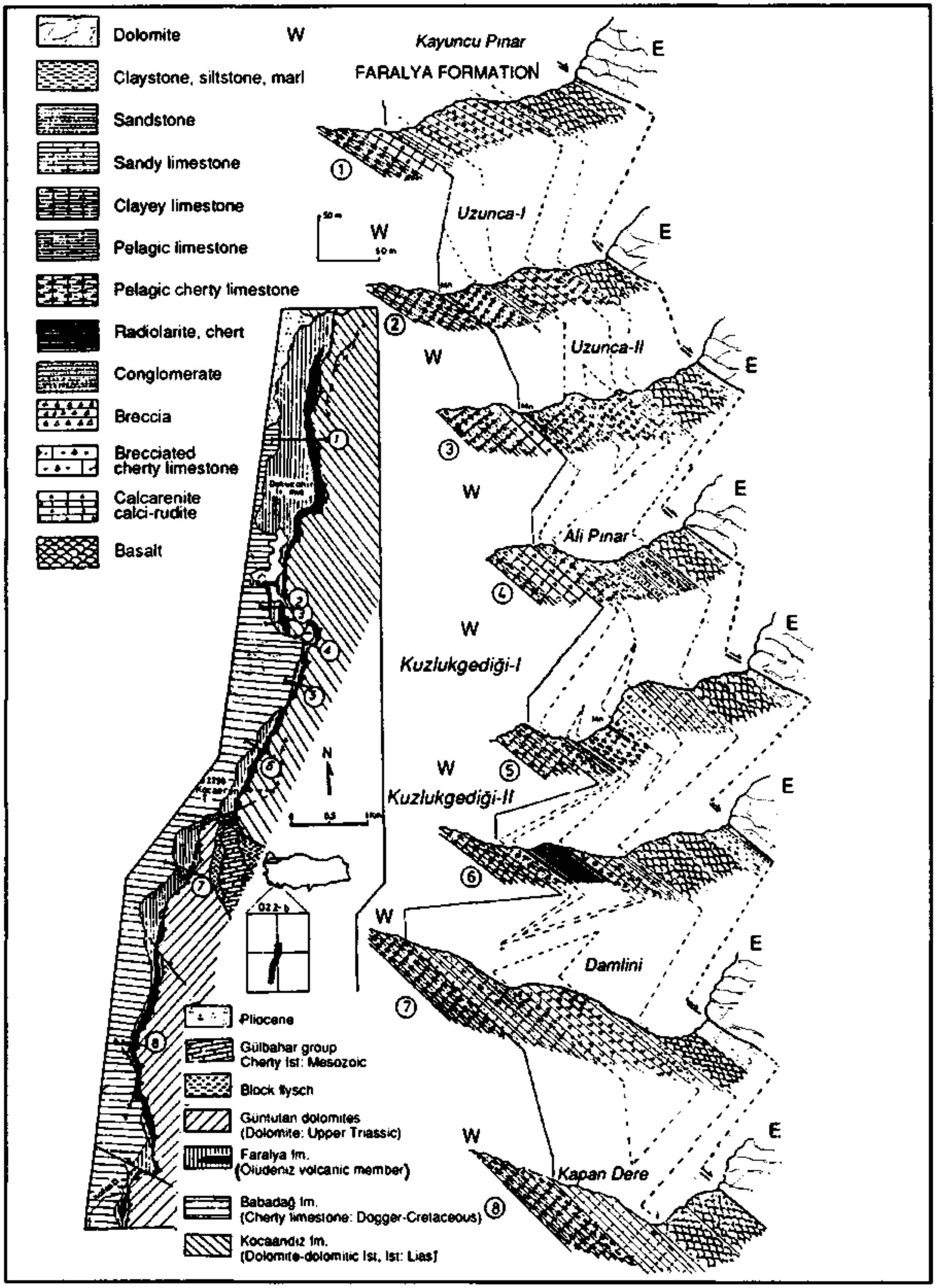


Fig. 8 - Geologic map showing the Faralya formation from Uzunca Yayla and, its southern part and cross-sections illustrating lateral lithologic variations throughout the unit.

The radiolarite and chert of the formation are observed only at the locality of Kuzluk Gediği, south of Uzunca Yayla (Fig. 8). These rocks overlying the red cherty micrites are thin to medium bedded; are reddish brown, and red colored. Cherts, about 25 m thick, grade laterally and vertically into the red cherty micrites.

The pillow lavas interslratified with the Faralya formation is named the Ölüdeniz volcanite member.

Ölüdeniz volcanite member

These basic volcanics named as "Ölüdeniz volcanile member" are best exposed along the road of Gökçeovacık-Oliidcniz, south of Fethiye and are seen as thin layers beneath the tectonic contacts where the Faralya formation is exposed (Fig. 3). They vary in thickness from 25 to 50 m. within the formation. These volcanics that commonly overlie the red micrites and breccias are pillow structured and reddish brown, brown and dark brown colored. The pillows range in length from 20 cm. to 1 m. They include thin lenses of green, and red colored claystone. Some red miqrites and clayey micrites can be found between the pillow lavas. Fractures and gas vesicles are filled with calcitc. The Ölüdeniz volcanics are fractured and crushed, due to the overlying dolomite overthrust, and as a result, they formed cataclastic texture.

These volcanics, namely spilite, spililized basalt, and olivine basalt display intersertal and ophilic textures. Plagioclascs found as phenoerysts are mostly albitized and locally sericitized. Augite (Ti-bearing) crystals are conspicuous between the laths of plagioclase. Olivine crystals occur mostly as carbonate and limonite pseudomorphs.

A total number of 13 rock samples collected from 3 different sections where the Ölüdeniz volcanics are exposed were analyzed for total rock chemistry (Table 1). When the analytical data is plotted using the diagrams of Zanettin (1984), and Peccerillo and Taylor (1976) (Fig. 9, and 10) in order to confirm the pctrographic descriptions, it is apparently shown

Table 1 - Major oxide compositions of the Ölüdeniz volcanite member within the Faralya formation

	K.1	*K.2*	*K.3*	*K.4*	*772A*	*772B*	*772C*	*803A*	*803B*	*803C*	*803E*	*803F*	*803G*
SiO_2	45.7	50.0	48.9	50.0	45.6	48.0	46.8	47.4	45.1	45.7	48.6	47.0	47.7
Al_2O_3	16.1	15.9	15.5	15.0	14.7	15.5	15.5	13.6	13.3	13.0	14.5	13.8	13.5
Fe_2O_3	8.7	5.7	8.0	5.8	7.9	5.7	5.9	6.4	7.7	8.2	6.2	6.5	6.7
FeO	1.65	3.75	3.00	2.75	3.54	3.50	4.64	3.26	3.62	3.10	4.40	4.58	3.90
MnO	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
MgO	2.60	6.60	6.25	5.00	5.55	6.36	5.88	6.35	6.16	6.12	6.00	5.67	6.12
CaO	8.15	6.55	7.15	8.75	5.95	8.17	10.12	9.17	9.12	9.62	8.07	8.57	8.90
Na_2O	6.45	5.70	4.75	4.75	4.55	4.48	3.32	4.75	4.60	4.80	4.72	5.05	4.68
K_2O	0.80	0.50	1.10	1.10	2.00	0.85	1.30	0.60	0.70	0.80	0.90	0.80	0.70
TiO_2	1.8	1.8	2.0	1.3	2.2	1.2	1.1	1.4	1.4	1.4	1.5	1.5	1.4
P_2O_5	0.3	0.2	0.3	0.2	0.4	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.2
CO_2	2.90	0.28	0.41	1.78	0.50	1.00	1.25	1.52	1.77	1.77	0.75	0.75	1.52
H_2O	3.68	1.88	1.40	1.76	1.20	0.70	1.18	2.02	1.12	1.70	0.90	0.84	1.20

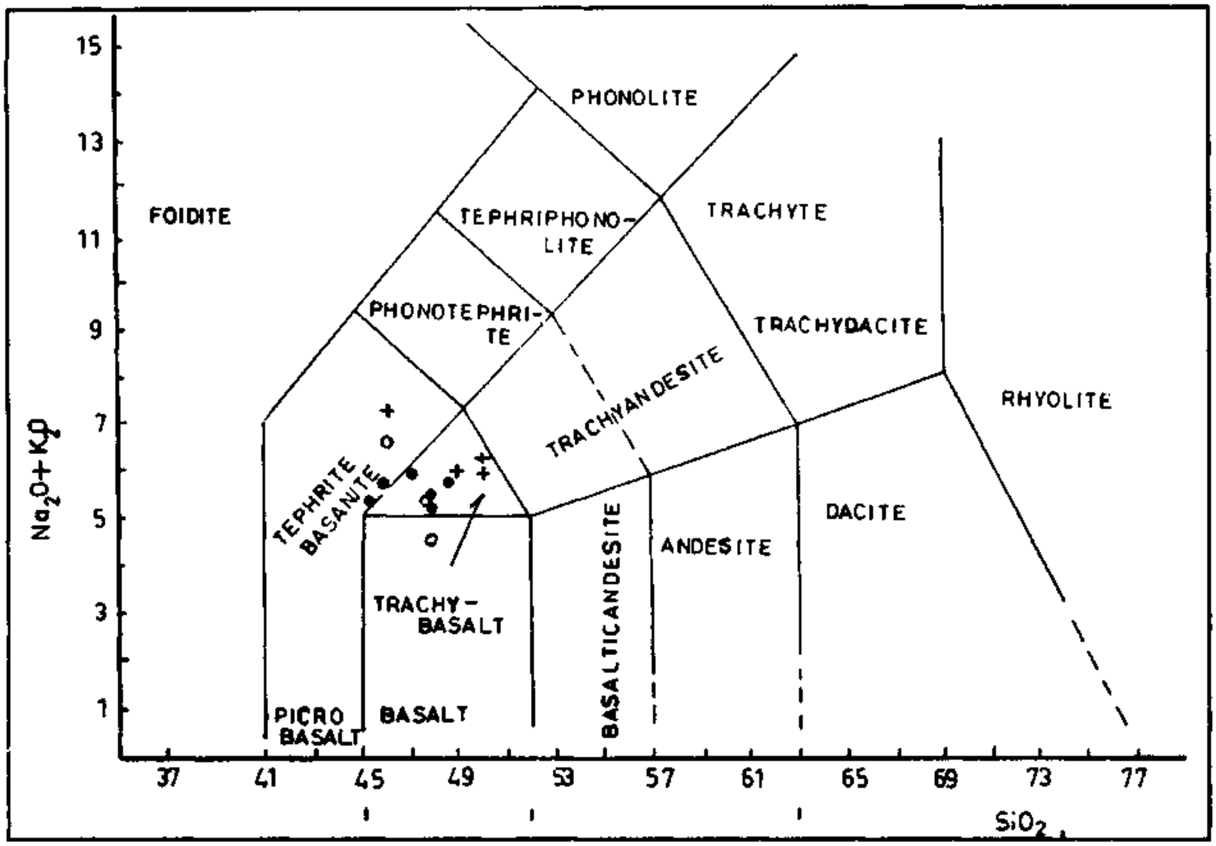


Fig. 9 - Nomenclature of volcanic rocks within the Faralya formation according to the diagram given by Zanettin (1984).

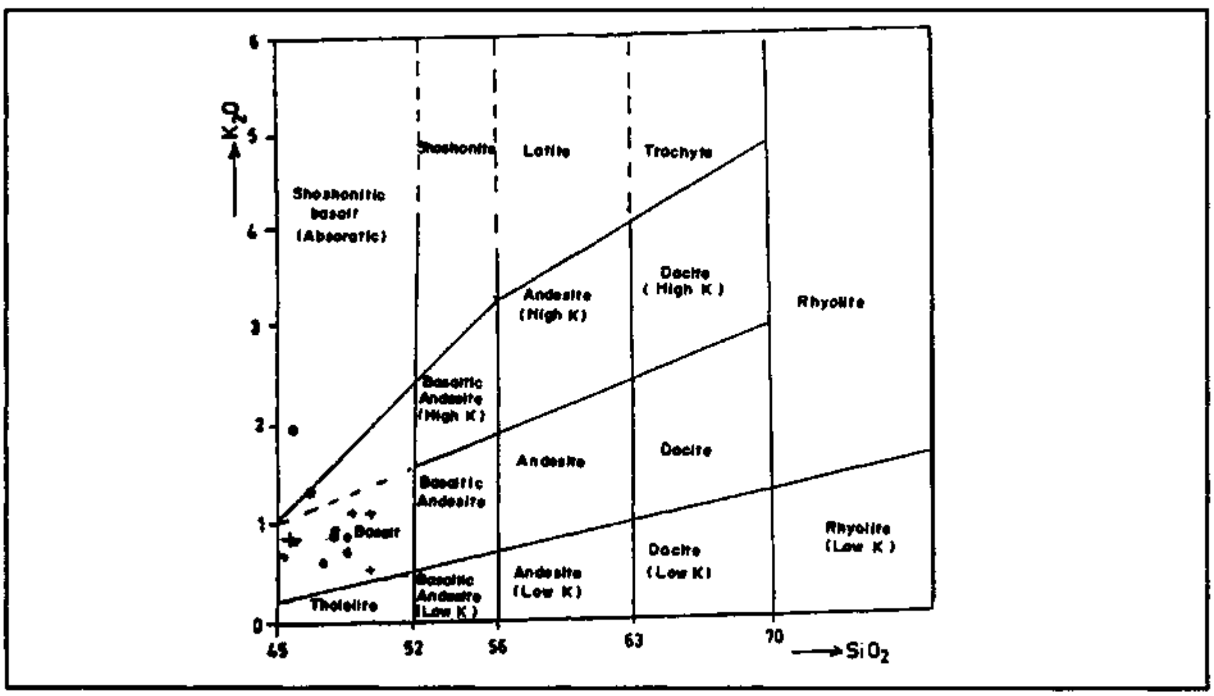


Fig. 10 - Nomenclature of basic volcanic rocks within the Faralya formation, according to the diagram given by Peccerillo and Taylor (1976).

that the total rock chemistry of the samples plots in trachybasalt field of the diagram given by Zanettin (1984), but in the basalt Held of Peccerillo and Taylor (1976). The concentration in the trachybasalt field in the diagram given by Zanettin (1984) may be attributed to the fact that the Ölüdeniz volcanics have been extensively spilitized. Having regard to the SiO_2 alkali (Na_2O+K_2O) contents of the discrimination lines given by McDonald and Katsuno (1964). and Kuna (1960), they show an alkaline character (Fig. 11).

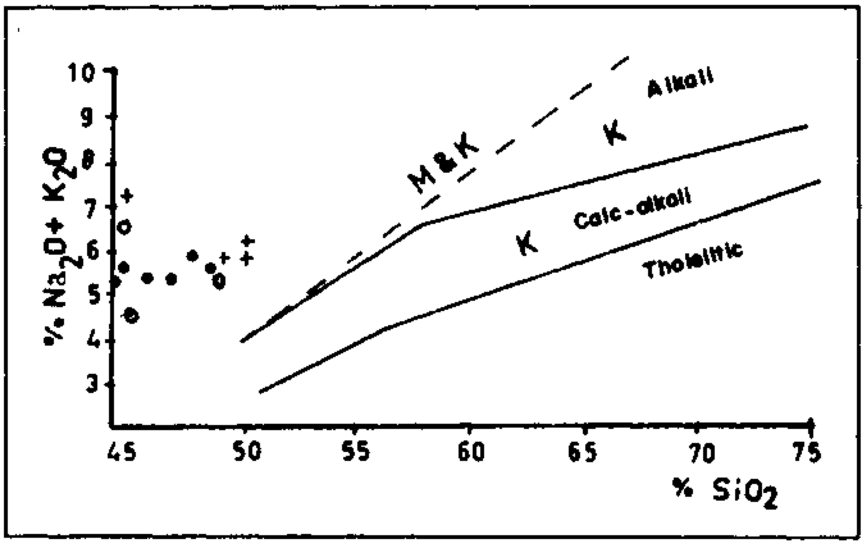


Fig. 11 - Alkali-silica diagram of volcanic rocks within the Faralya formation.

The observations reveal that no olistoliths arc found within the Faralya formation. However, a small block of serpentinized peridotite was observed immediately beneath the dolomite overthrust near Ali Pınar, south of Uzunca Yayla. Whether it is an olistolith or not, is debated. The presence of sonic exotic blocks is not uncommon, particularly in the uppermost levels of the formation, due to emplacement of nappes on to them.

The red micrites that make up the lowermost portion of the formation has some manganese occurrences. The common feature of all manganese occurrences is that they are overlain by a volcanic interbed. Locally, enrichments in F2O3 and MnO are found within the Ölüdeniz volcanics. A sample collected from such a level observed along the road of Gökçeovacık-Ölüdeniz yielded the following total-rock (major oxides) analytical results; 41.2 % SiO_2, 12.9 % Al_2O_3, 19 % Fe_2O_3 (total), 6.55 % = CaO. 4.07 % = MgO. 2.8 % = MnO, 3.15 % = Na_2O, 1.6 % = K_2O.1 % = TiO_2, 0.5 % = P_2O_5, 0.5 % = CO_2, 2.08 % = H_2O and FeO (trace amount). The contents of Fe_2O_3 and MnO(19 % and 2.8 %, respectively). The mangenese occurrences hosted by the Faralya formation were investigated in detail by Çelebi and others (1989).

Some pyrite chalcopyrite occurrences arc found particularly within the volcanics of the Faralya formation near Karaboğalık Dere, northwest of Boyalı Mahallesi and surrounding areas. These occurrences developed within the alteration zones parallel or subparallel to bedding planes.

Thickness and lateral changes. - The thickness of the Faralya formation was measured to be about 280 m. near Küre Çeşme (Fig. 5) and about 290 m. near Avian Pınarı (Fig. 4). It is considerably variable elsewhere in the area, due to emplacement of nappes. The lilhologics of the formation grade into one another, laterally and vertically. This variation is best documented near Uzunca Yayla and its southern part (Fig. 8).

Contact relations. - The formation conformably overlies the brecciated limestone, and cherty limestone of Maestrichlian age, where the structural units of the Lycian Nappes lie beneath the ophiolite nappe. However, it may be conspicuous by its thin skinned parts and abrasion surfaces on top of cherty limestones, and brecciated limestones. It differs markedly from the overlying formation in lilhology. The structural units that make up the Lycian Nappes are tecionically overlain particularly by dolomites.

Fossil content and age - Numerous samples were collected in order to determine the age span of the unit. Fossils identified in the samples taken from red micrites and adjacent horizons are as follows;

Globorataliu cf. *pusilla* Boli.
Globorotalia cf. *triloculinoide* Plummer,
Globorotalia cf. *aequa* Cush.-Renz.
Globorataliac f. *angulala* (White).
Globarotalia cf. *nex.* Martin,
Globorotalia sp.,
Globigerina sp.,
Anomalina sp.,
Discocyclina sp.,
Hasligerina sp..
Quinqucloculina sp.,
Textularidae,
Rotaliidae,
Lithothamnium sp.,
Bryozoa,

Orbitoides and Globotruncuna (allocluhonous) fossils were also determined. Conversely, the uppermost levels that are made up of volcanics contain the following fossils;

Sphaerogypsina globus Rcuss,
Discocyelina sp..
Nu*nmulites* sp..
Alveolina sp.,
Lochartia sp.,
Eorupertia sp.,
Asterigerina sp.,
Operculina sp.,
Anomalina sp.,
Quinquelaculina sp.,
Cuvillerina sp.,
Lithothainnium sp.,
Globorotalia sp.,
Globigerina sp.,
Rotaliidae,
Textularidae and
Pelecypoda.

In addition to those, fossils identified in some claystone samples are as follows;

Sphenolithus radians Deflandre,
Discoaster lodensis Bramlette-Riedel,
Discoaster sublodoensis Bramlette-Sullivan,
Chiasmolithus grandis (Bramlette-Riedel),
Cyclococcolilhina gammalion (Bramlette-Sullivan),
Cyclococcolithina formosa (Kamptner).
H*elicopotosphaena sp.*

Based on the above fossil assemblage, a Paleocene-Lutetian age is assigned to the Faralya formation.

Environmental interpretation. - On the basis of lithologic features and fossil content, it is suggested that the formation was deposited in a deep sea environment. The presence of turbidite beds, complete or parts missing indicate that turbiditic current were effective in the environment. On the other hand the presence of benthonse foraminifera, algac etc. show that shelf environment was not very for off also. Breccias found within the unit appear to represent submarine fan that developed along an active tectonic line. Basic volcanics are interbedded with Eocene sediments. Turbidity currents, volcanic activities, and the presence of breccias reflect that the depositional environment was tectonically active.

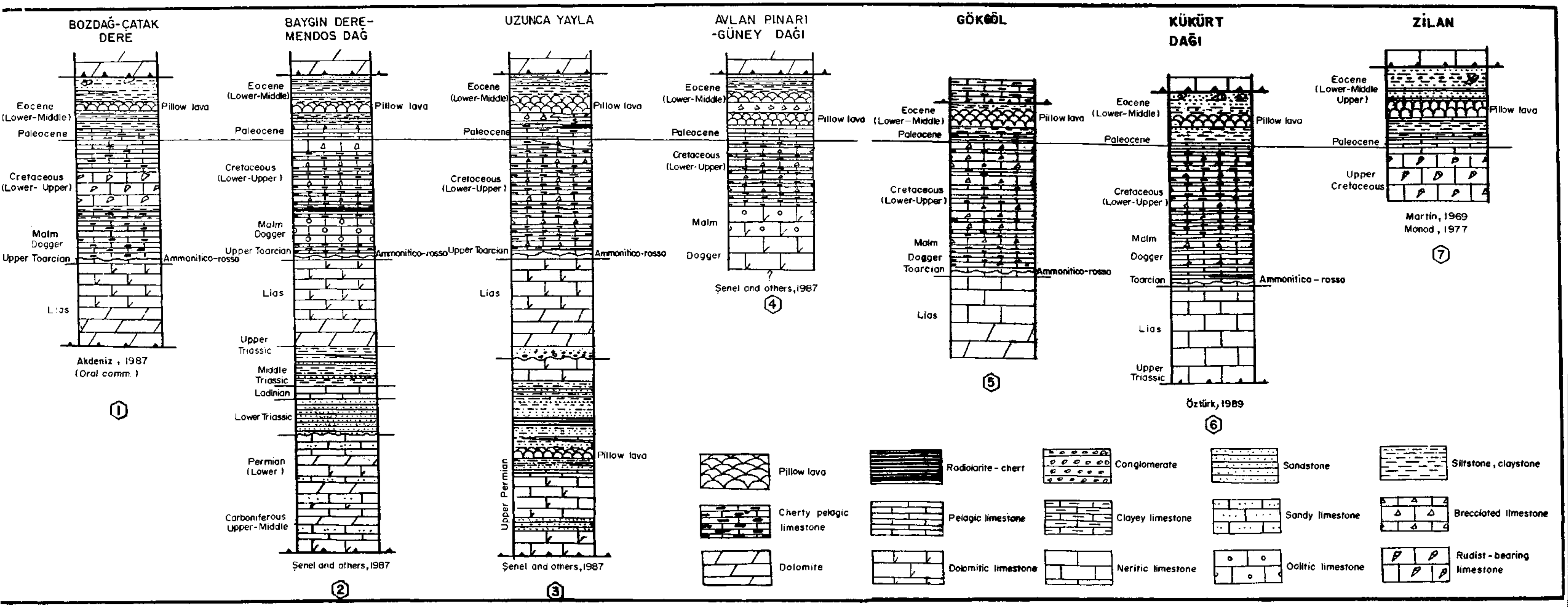
Correlation. - The Faralya formation shows similarity to the Datça flysch (Orombelli and others. 1967) to the west, with respect to lithologic features. The Palcocene-Lower Eocene rock units belonging to the southern cover of Mendcres massif are closely correctable with particularly the lower part of the Faralya formation (Bernoulli and others, 1974; Dün, 1975; Akat and others, 1975; Çağlayan and others, 1980; Konak and others, 1987). Akdeniz (1989, pers. comm.) reports that some basic volcanic rocks are found within this unit. Poisson (1977) reports another sequence equivalent to the Faralya formation from the Çatak Dere section measured within a structural unit named the Bozdağ massif. However, recent observations from the Çatak Dere section (Akdeniz, 1987, pers. comm.) indicated the presence of volcanics which have not been described by Poisson (1977) (Fig. 12-1). Some sediments and basic volcanics, that are identical to those found in the Faralya formation were observed within the structural unit named the Gökgöl unit (Gutnic, 1977), northwest of Dinar (Fig. 12-5). These volcanics were previously incorporated in the lowermost part of the Denizpınarı unit and considered to be Upper Triassic-Lias in age by Gutnic (1977). Various rock units similar to those of the Faralya formation and Eocene basic volcanic rocks are exposed within the Kükürtdağ group to the east of Dinar (Öztürk, 1989) and near Sultandağları (Öztürk, 1987, pers. comm.). The volcanics of the Eocene Zilan flysch (Table 2) described from the Akseki autochthon to the south of Seydişehir (Martin, 1969; Monod, 1977) show similarity to those found in the Faralya formation (Fig. 12-8).

Table 2 - Major oxide compositions of the volcanics within the Zilan flysch (Monod, 1977)

	Zi 02	Zi 03	Zi 04	Zi 06	Zi 07
SiO_2	43.50	40.10	44.80	47.20	45.80
Al_2O_3	15.80	16.10	17.90	16.00	17.55
Fe_2O_3	10.15	08.64	09.01	09.25	09.43
MnO	00.18	00.19	00.16	00.42	00.24
MgO	06.40	04.32	06.79	05.97	05.97
CaO	08.42	14.23	10.28	11.66	08.68
Na_2O	05.35	04.01	03.96	02.94	04.20
K_2O	00.32	00.76	00.47	00.38	00.37
TiO_2	01.31	00.95	01.33	01.03	01.54
P.F.	08.49	09.10	05.63	03.60	06.60

DISCUSSION AND CONCLUSION

It is put in evidence that at least a part of some units which had been defined as "intervening en echelon complex" and considered to be derived from the northern part of the Menderes massif by Graciansky (1968; 1972) should have been originally derived from an area between the Menderes massif and Beydağları autochthon (Poisson, 1977; Erkman and others, 1982). The structural and straligraphic features of the newly described Faralya formation provide a result that justifies this view.



ig. 12 - Stratigraphic columnar sections illustrating structural units that terminate with the Faralya formation from western Taurus.

The Faralya formation has the same environmental characteristics as flysch series that occurred more or less contemporaneously with it and constitute the uppermost portions of the southern cover, paraautochthons of the Menderes massif, and the structural units to the north of Isparta angle. The most striking similar ity between the Faralya formation and closely correlatable formations which extend from Datça peninsula to Akseki autochthon (in broad sense, Geyikdağ unit, Özgül, 1976) to the south of Seydişehir is that large scale lateral movements (Eocene orogeny) occurred over all these formations.

These formations that have the same environmental characteristics include equivalent basic volcanics and bear traces of similar orogenic movements reflect the presence of a common basin which existed as extending from the southern part of the Menderes massif, through the north of Isparta angle to the north of Geyikdağ unit during the Paleocene-Eocene.

ACKNOWLEDGEMENTS

The writer thanks to Dr. Sefer Örçen, Özcan Aksoy, Meral Erkan and Hatice Kaymakçı for paleontological determinations, Dr. Necati Akdeniz, Dr. Neşat Konak and Dr. Esat Melih Öztürk for providing information on the region.

Manuscript received May 4,1990

REFERENCES

Akal, U.; Öztürk, Z ; Öztürk. E.M. and Çağlayan, A . 1975. Menderes Masifi güneyi-SW Toros kuşağı ilişkisi : MTA Rep., 5488 (unpublished), Ankara.

Bassaget J.P., 1966, Conunbution a l'etude de la region au Sud du Massif du Menderes entre Fethiye et Sandras Dağ (province de Muğla, Turquie): These Univ. Grenoble 102 p.

Bemoulli, D.; Graeiansky, P Ch and Monod, O., 1974, The extension of the lycian nappes (SW Turkey) into the Southeastern Aegeun Islands Eclog. Geol. Helv . 67/1. 39-90.

Bölükbaşı. S., 1987, Elmalı (Antalya)-Acıgöl-Burdur Gölü (Burdur) Korkuteli (Antalya) arasında kalan alanın Elmalı naplarının jeolojisi: TPAO Rep 2415 (unpublished). Ankara.

Çağlayan, A.Öztürk, E.M.Öztürk, Z., Sav, H. and Akat, U.,1980, Menderes Masifi güneyine ait bulgular ve yapısal yorum; TMMOB Jeo. Müh.Od. Jeo. Müh. 10.9-18

Çelebi. A.; İşbaşarır, O.. Katipoğlu. B. and Turkmen, H.. 1989, Yeşilova (Burdur), Çameli (Denizli), Elmalı (Antalya). Fethiye (Muğla) ve çevresi Manganez prospeksiyonu: MTA Rep., 8834 (unpublished), Ankara.

Dürr, S., 1975. Über alter und geotektonische stellung des. Menderes kristallins/SW-Anotolien und seine aegu ivalente inder miueren, Aegaeis; Habilitauonsschrift, Marburg/Lahn, 107 p.

Erkman, B.; Meşhur, M ; Gül, MA.; Alkan. H ; Öztaş, Y. and Akpınar M., 1982, Fethiye-Köyceğiz-Tefenni-Elmalı-Kalkan arasında kalan alanın jeolojisi: Türkiye Sixth Petrol Kong , 23-31, Ankara.

Gutnic. M., 1977, Geologic du Taurus Pisidien au Nord'd Isparta (Turquie): Trav, Lab. Geol. Hist., Univ. Paris x1. 130 p., Orsay.

Graciansky, P. Ch., 1968, Teke yarımadası (Likya) Toroslarının üst üste gelmiş ünitelerinin stratigrafisi ve Dinaro Toroslar'daki yeri: MTA Bull. 71.73-92.

______, 1972, Recherches geologiques dans le Taurus Lycie occıdental These Univ. 762 p. Paris-sud.sud. Orsay.

Konak, N.; Hepşen, N.; Öztürk, E.M., Öztürk Z.; Çakmakoğlu, A.; Göktüş, F; Sarıkaya, H.; Armağan, F.; Çatal, E. and Serdaroğlu, M., 1987, Menderes Masifinin G-GD sundaki Mesozoyik istiflerinin karşılaştırmalı sıratigrafi ve konumları: Türkiye Jeoloji Kurultayı Bildiri Özleri 5, Ankara

Kuna, H.. 1960, High-alumina basalt: Journal of Petrology, I.121-145.

Martin, C., 1969. Aksekikuzeyindekibir kısım Torosların stratigrafik ve tektonik incelenmesi: MTA Bull., 72, 158-175.

McDonald, G.A and Katsuno, J.. 1964, Chemical composiuon of Hawaiian: Lavas Journal of petrology, 5, 82-133.

Monod, O., 1977, Recherches geologiques dans le Taurus occidental au sud Beyşehir (Turguie):These Univ., Paris-sud, Orsay, 442 p.

Orombelli, G.; Lozey, G.P. and Rossi, L.A., 1967, Preliminary notes on the geology of the Datça peninsula (SW Turkey): Acc.naz Lincei, Rend, 8. vol 42, 830-841.

Özgül, N., 1976. Torosların bazı temel jeolojik özellikleri: Türkiye Jeol. Kur. Bull., 19/1, 65-77.

Öztürk. E.M., 1989, Balçıkhisar-Karadilli (Afyon) Dereköy (Isparta) dolayının jeolojisi: Doktora Tezi, İÜ Fen Bilimleri Ens. 319 s, Istanbul.

Peccerillo, A. and Taylor, S.R., 1976, Geochemistry of Eocene calcalkaline volkanic rocks from Kastamonu area, Northern Turkey: Contrib. Mineral. Petrol.. 58,63-81.

Poisson, A., 1977, Recherches gdologiques dans les Taurides occidentales (Turquie): These Univ., Paris-sud (Orsay), 795 p.

Richard, F., 1967, Etude geologique de la fenetre de Göcek-Aygır dağ (Taurus Lycien occidental, Turquie): These 3e cycle, Fac. Sc. Grenoble. 116p.

Şenel, M.; Akdeniz, N.; Özdemir, T. and Öztürk, E.M., 1987. Teke Torosları: Jeoloji Etütleri Projesi MTA Orta Anadolu II. Bölge Müd. Bölge Yayınları 15,91-96, Konya.

Yılmaz, İ., 1966, Etude geologique de la region cotiere comprise entre Dalaman çay et Innice Ovası (Province de Muğla, Turquie): 3 e cycle, Fac. Sc. Grenoble, 75 p.

Zanettin, B., 1984, Prosed new chemical classification of volcanic rocks: Episodes, 7/4,19-20.

Mineral Res. Expl. Bull., 113, 15-29 ,1991

STRATIGRAPHY OF EOCENE SEDIMENTS IN THE SOUTHWEST THRACE**

Muhsin SÜMENGEN* and İsmail TERLEMEZ*

ABSTRACT. - The area concerned is situated in the Gelibolu peninsula, north of the Saros bay and northwest of the Marmara sea sediments of Upper Cretaceous to Miocene age, having a variety of fades crop out SW of Thrace. During the present survey, the goal was to examine the stratigraphic features of the Eocene sediments in the region. The Tertiary basin is underlain by an ophiotitic complex emplaced prior to Maastrichtian and limestone of Maastrichtian to Paleocenc age. The base of the limestone is not exposed within the region. The Tertiary transgression began in the Early Eocene in the Gelibolu peninsula. Massive mudstones, sandstone sequences that become thicker and coarser upward, and channel fill sediments are the first products of this transgression (Karaağaç limanı formation). This sequence is overlain by deltaic sediments beginning with massive mudstones and becoming thicker and coarser upward (Koyun limanı formation). These sediments are conformably and transitionally overlain by interbedded mudstone and sandstone, cut by channel fill deposits (Rcitepe formation). This formation was formed by meandering rivers. The sea that progressed inward to the Gelibolu peninsula during the Early Eocene began to become shallower again at the beginning of Lutetian and as a result, the region as a whole became a positive area during the Middle Lutetian. During the Late Lutetian, a new transgression occurred in the entire region. The first product of this transgression was a limestone (Soğucak formation). This limestone which was deposited in a shallow sea environment is locally intercalated with sandstone and conglomerate. The sea became deeper from the beginning of Upper Eocene. Firstly, turbiditic sandstone, and mudstone, interbedded hemipelagic mudstone (Gaziköy formation) with tuff, and carbonate mudstone and massive mudstone (Burgaz formation) were deposited. These units are products of flat basins. These are, in turn, overlain by sequences consisting of siltstone, mudstone, and conglomerate, which become thick bedded and coarser upward (Korudağ formation) and fining upward sequences (Keşan formation). These are submarine fan deposits of turbiditic origin. The basin became shallower again towards the end of Upper Eocene. During this period, rock units made up of mudstone, siltstone, sandstone, and conglomerate were deposited. This sequence deposited in a deltaic environment has been named differently, the Kanlıbent formation in the Gelibolu peninsula and the Yenimuhacir formation between Keşan and Tekirdağ, due to its diverse local features. The basin as a whole became a continent during the Oligocene (?) and alluvial deposits that consist of mudstone, sandstone, and conglomerate formed (Armuttepe formation).

INTRODUCTION

The study area is located between Enez-Keşan-Tekirdağ and Şarköy, southwest of Thrace and northwest of Gelibolu peninsula (Fig. 1).

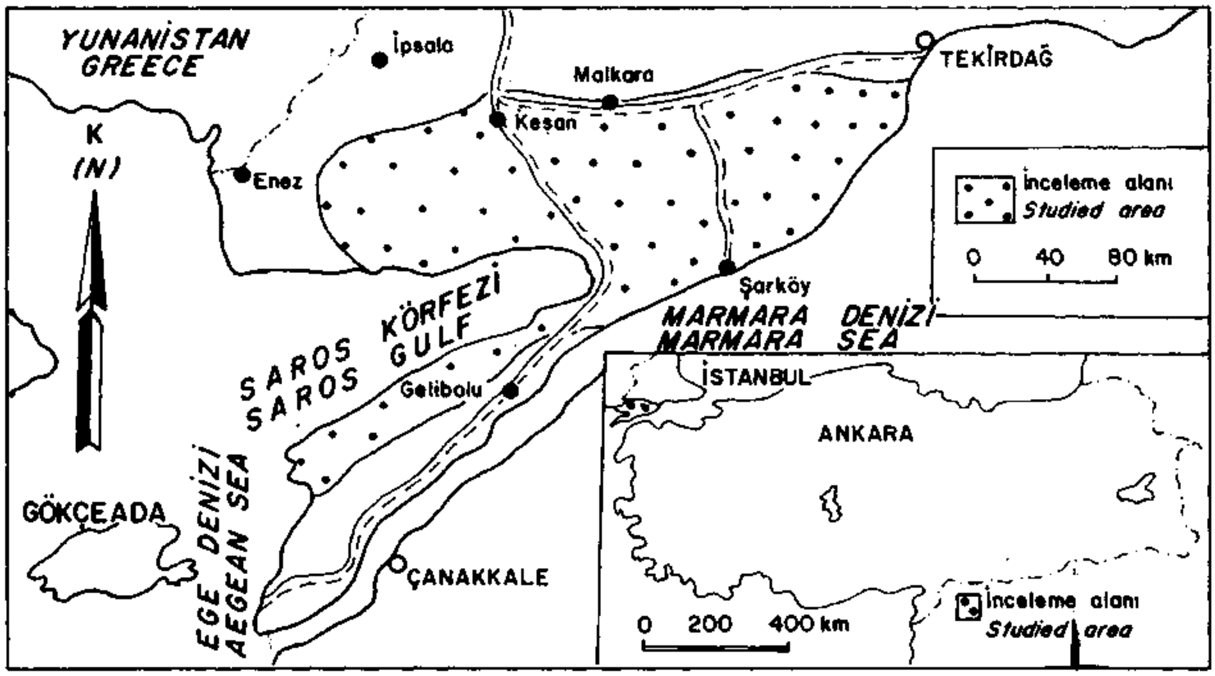


Fig. 1 - Location map.

The purpose of this paper was to introduce stratigraphic properties of the Eocene sediments that crop out in the southwestern Thrace. In the study area. Tertiary rock units belonging to distinct facies are exposed, exceeding 7000 m. in total thickness. The detailed, reliable and complete stratigraphic positions of these rock units for regional integrity have not previously been defined. Also, some formation names are not suitable with rules of stratigraphic nomenclature. A study was carried out within the framework of a project titled "Thrace Tertiary Project" in 1979 and 1982 in order to make up for this type of gaps in the region. This paper deals with a part of this project. Air photographs and 1:25 000 scale topographic maps were utilized during these studies. Rock units in the study area were differentiated and mapped on the basis of facies. Later, macro tectonic features was studied and measured stratigraphic sections were defined. In addition, some collected samples were examined pctrographically and paleontologically. With regard to these features and studies of earlier workers, formations were named. For interpretation of depositional environments of rock units, available data and conclusions drawn by Bourna (1962), Allen (1964, and 1970), Mutti and Ricci Lucci (1972, 1974, and 1978), Ricci Lucci (1975), Wilson (1975), Mutti (1977), Walker (1978), Guido Ghibuudo (1980, and 1981) and Stewart (1981) were evaluated.

A number of studies dealing with the southwestern part of Thrace were conducted, the vast majority of wich have focused on economic potential of the area (petroleum and coal). Druit (1961), Turkse Shell (1969), Kellog (1973), Önem (1974), Saltık and Saka (1972, and 1973) and Saltık (1974) investigated the area for exploration of petroleum. In addition, Lebküchner (1974) investigated the northern part of the study area for ccal. The studies by these workers lack at least one or more of the above mentioned points. The present writers alm to complete this type of gaps to some extent.

GENERAL GEOLOGIC SETTING OF THE REGION

With regard to Thrace as a whole, one can say that the rnetamorphics making up the Istranca massif in the northeastern part of the region form the basement. Tertiary sediments are not very thick and are exposed immediately south of the massif. Conversely, Tertiary sediments with a total thickness of more than 7000 m. occur in the southwestern pan of Thrace including the study area. The relations of the Eocene Miocene rock units and all facies are observed throughout this region. Inner parts (Ergene basin) are wholly covered by younger deposits (Pliocene?)

The oldest exposed unit within the study area which is located in the southwestern part of Thrace is an ophiolitic melange (Fig. 2). This unit also constitutes the basement of the Tertiary basin in the region. The ophiolitic melange comprise rock types such as serpentinite, phyllite, diorite metadolerite, metachert, glaucophanc schist, spilite, recrystallized limestone, altered porphyntic dacite and graphite schist conclusively suggesting varying environments (Şenrtürk and Okay, 1983). Blocks that make up this unit, named as the Yeniköy melange, are a non-matrix assemblage. These blocks display traces of deformation at their contacts. A melange with these properties is likely to correspond to a melange developped within a subduction zone. The emplacement age of this melange is probably pre-Maasirichtian (Şentürk and Okay, 1983).

The relation of the Upper Cretaceous-Paleocene limestones exposed adjacent to the southern coast of Saros bay, Gelibolu peninsula with the basement is unknown (Fig. 2,3). These limestones are also observed near Yeniköy on the Gelibolu-Şarköy highway. They are wine, green and greenish gray and thin to medium bedded and are usually pelagic limestones.

The Eocene-Oligocene (?) rock units, main lilhologies of the Tertiary basin form various facies. The Miocene sediments unconformably rest upon the underlying units. From the base upwards, the sequence consists of interbedded siltstone, claystone, and conglomerate, 500 m. thick, interbedded sandstone, less abundant siltstone, and claystone, 150 to 250 m. thick, interbedded siltstone, claystone, and sandstone, 90 m. thick, and interbedded sandy limestone, siltstone, sandstone, and oolitic limestone, 220 m. thick. This sequence is named the Çanakkale formation and is Middle-Upper Miocene in age.

The Upper Miocene unit is the youngest formed lithology after actual deposits in the study area. This unit consists of alternating siltstone, sandstone and conglomerate, about 300 m. thick and is named the Conkbayırı formation.

The N70E-trending Saros bay-Gaziköy fault, the most prominent tectonic element of the region, that has been continuing its activity in the present day passes through the central part of the study area. This fault coincides with the western extension of the North Anatolian Fault (NAF) (Fig. 2). The northern parts of the Gelibolu peninsula were more intensely affected relative to the southern parts by tectonic movements. The northern parts include folds with low attitudes parallel to the trend of the peninsula. Fractures are poorly developped. In general, the central part of the peninsula where Paleogene and Neogene are in contact, the units are overturned southwards. This may be attributed to the presence of the North Anatolian Fault passing through the north of the peninsula and Saros bay graben. While, in general, the northern parts of this fault were

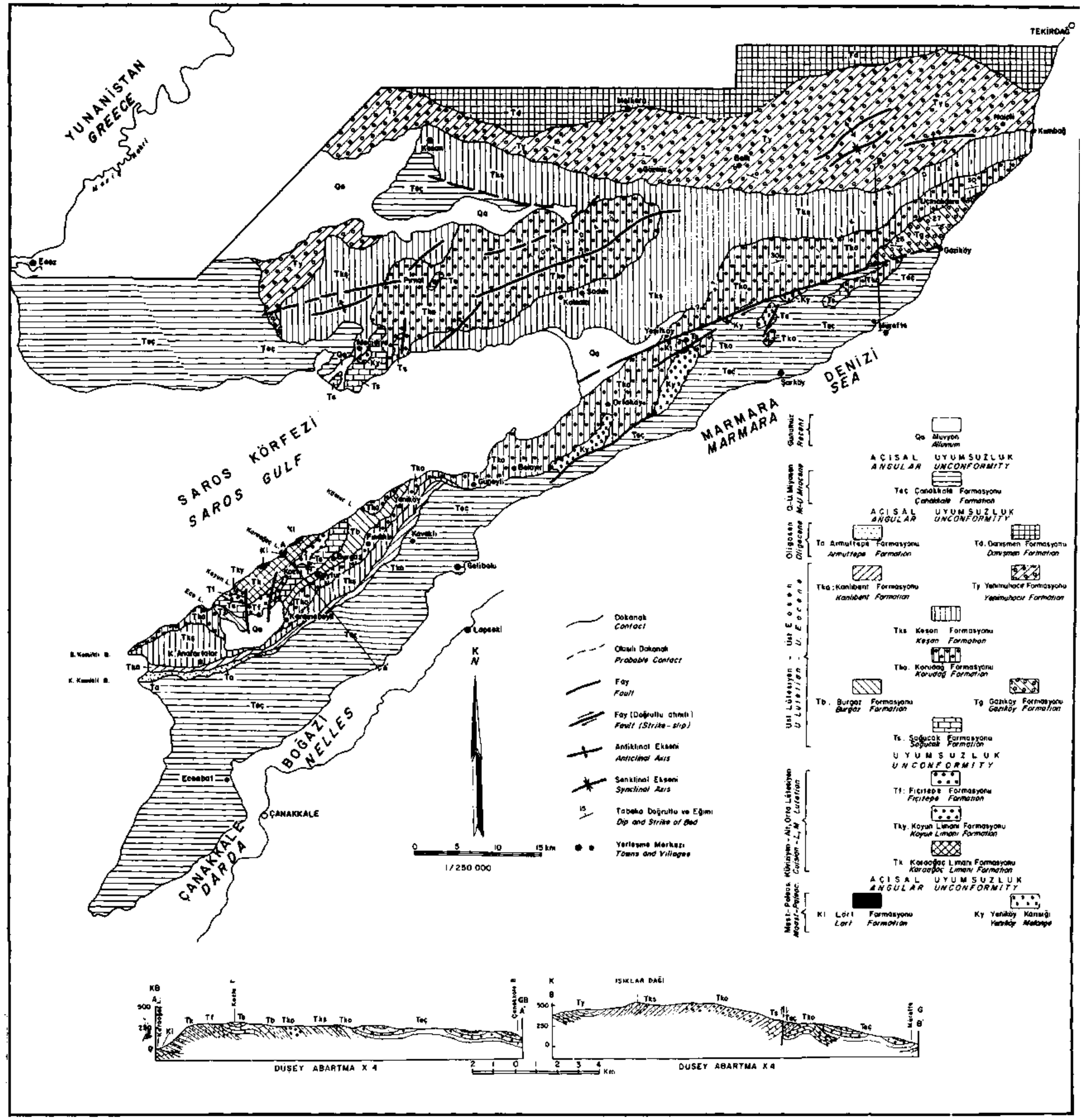


Fig. 2 - Geological map of the investigated area.

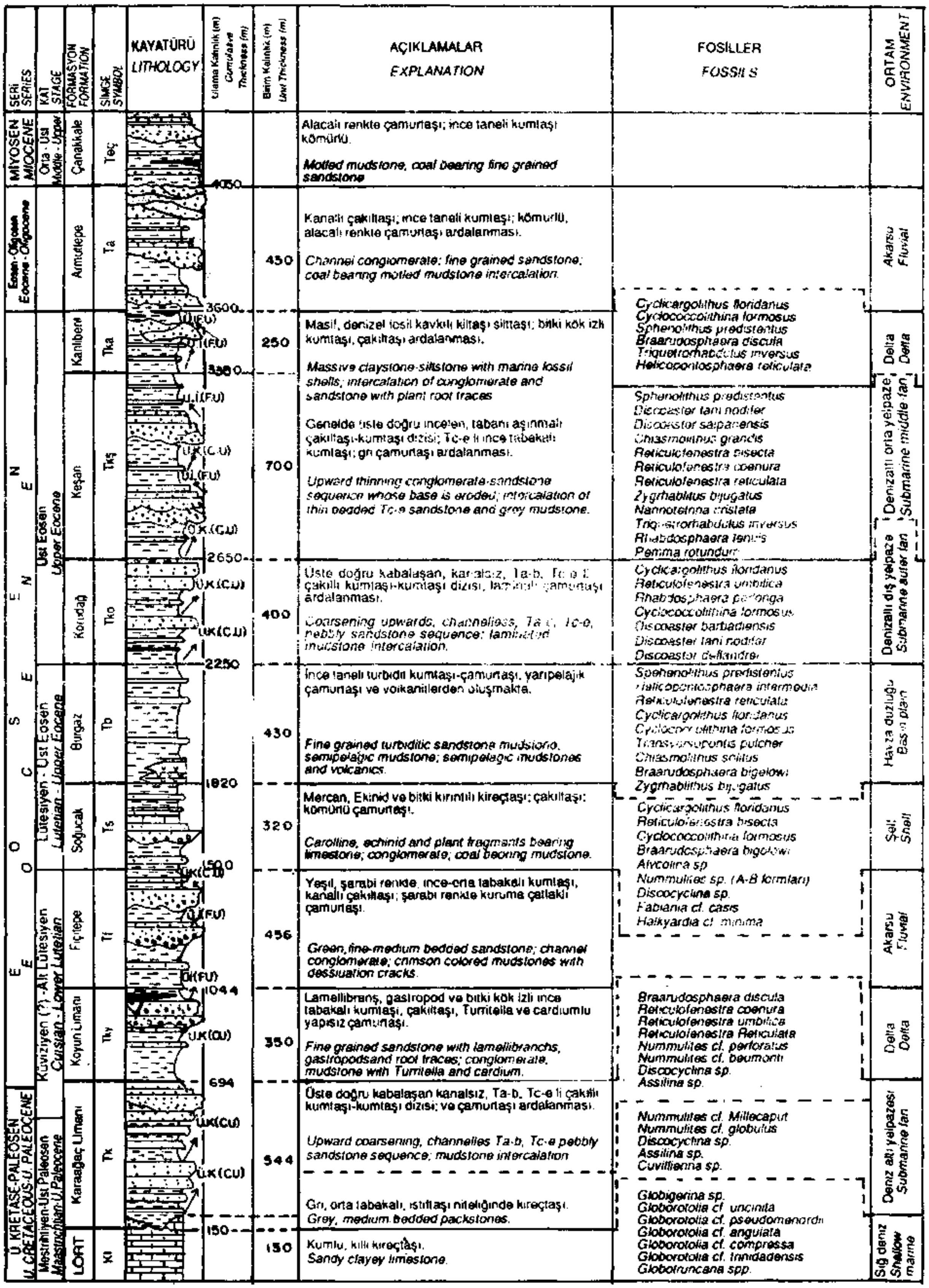


Fig. 3 - Generalized, scaled stratigraphic columns of the Eocene sediments in the Gelibolu peninsula.

weakly affected by tectonic movements, reverse faults and overthrusts are seen in the southern parts (Sümengen and others, 1987).

STRATIGRAPHY

The Eocene sediments that occur in the study area were subdivided into 11 formations, with regard to facies and depositional environments. Each formation will be described under subtitles such as definition and name, type section and type locality, distribution and setting,lithologic features and depositional environment.

Karaağaç limanı formation (Tk)

Definition and name. _ It consists of alternating siltstone, claystone, and sandstone, intercalated with lenses of conglomerate. In addition, a limestone horizon lying at the base was defined for the first time by the present writers (Fig. 3). Druit (1961) and Kellog (1973), named this unit "Karaağaç formation". Later on, it was named "Karaağaç limanı formation" by Turkse Shell (1969), 'Tayfur formation" by Ünal (1967), and Saltık and Saka (1972, and 1973) and "Karaburun formation" by Önem (1974), and Saltık (1975). "Karaağaç limanı formation" is preferred by the authors, since, it is best exposed near Karaağaç limanı and this name is commonly used by previous researchers.

Type section and type locality. _ This formation is typically exposed along a coastal area extending from Manda limam to Koyun limanı. Measured type section is located in this area. In addition, some sections along the road of Saz limanı-Tayfur village are type localities for this formation.

Distribution and setting. _ Exposures of this formation are seen only in a limited area to the south coast of the Saves bay (Fig. 2).

The Iower contact of this formation has been differently interpreted by earlier workers.Druit (1961) and Turkse Shell (1969) report that the contact is conformable, whereas Kellog (1973), Önem (1974) and Saltık (1975) regard it as unconformable contact. The fact that basal conglomerate is seen at the lower contact and the formation rests upon various levels of the underlying formation suggests that the contact between two formations is unconformable.

Lithoiogic features. _ Limestone in the lowermost part of the Karaağaç limanı formation is restricted to a small area. This limestone is moderately to thickly bedded, contains abundant fossil and has a packslone character. Dominant lithologies are unbedded claystone, sandstone sequence becoming thickly bedded and coarsening upward and channel fill deposits. The claystone contains small lenses of unbedded sandstone with ripple marks, and plant fragments. The sandstone is fine to medium grained, moderately to thickly bedded and contains a variety of sedimentary structures (graded bedding, ripple marks, sole markings etc.). In addition, channel fill deposits composed of conglomeratic sandstone, and conglomerate occur widespread in the uppermost levels of the formation (Fig. 3).

The thickness of the formation is variable in different places. In general, the thickness was measured to be between 500 and 1100m.

Age. _ Turkse Shell (1969), Kellog (1973) and Önem (1974) assigned a Lower Eocene age to this formation. In contrast, Paleocene-Lower Eocene age was assigned to it by Saltık (1975). The age of the formation is Lower Eocene (Cuisian)-Lutetian (Lower) on the basis of benthonic foraminifera contained in the underlying limestones and nannoplanktons identified from claystones (Fig. 3).

Depositional environment. _ It is concluded that the underlying limestone was deposited in a shallow sea environment, whereas the overlying claystone, and sandstone were deposited in submarine fan environment on the basis of lithologic characteristics, sedimentary structures, geometries and fossil contents of the sediments within the formation, and their relations will; the overlying formation.

Koyun limanı formation (Tky)

Definition and name. _ While the lower parts are made up of unbedded mudstone, the upper parts are made up of sandstone and conglomerate. This unit was mapped as a differentiated formation and named for the first time during the present studies. It is named after Koyun limanı where it is best exposed.

Type section. _ A type section was measured over a coastal area extending from Koyun limanı southwestward.

Distribution and setting. _ This formation does not occur widespread as does the overlying formation. It is seen confined only to a small area between Koyun limanı and the locality of Sağırtaş, south coast of the Saros bay (Fig. 3).

The formation gradually passes into the underlying Karaağaç limanı formation (Fig. 3).

Uthologic features. _ The formation begins with an unbedded mudstone with a total thickness of 250 m. at the base. The mudstones are enriched in carbonate and display globular and striped exfoliations. They are rich in plant fragments and sea shells. They gradually pass upward to alternating sandstone and mudstone. The sandstone is thin to medium bedded, fine-grained, and comprise ripple marks. Its lower and upper contacts are sharp. It contains small scale slump structures and small sized nummulites. Sea shells, variable scale animal burrows and organic marks were determined in both sandstone and mudstone. This part grades upward to massive and cross bedded, medium to coarse grained sandstone and mudstone. The sandstone is observed as lenticular horizons as much as 5 m. thick, thinning upward. It contains plant roots, coal-bearing bands, a variety of sedimentary structures and sole markings. The uppermost portion of the formation consists of levels of red and green clayey silty mudstone and fine grained sandstone, mostly having a wavy appearance (Fig. 3).

The thickness of the formation was measured to be 350 m., 250 m. of mudstone level and 100 m. of sandstone, and mudstone.

Age. _ No fossils were found for age determination, although the samples (mudstone) collected from the formation was studied in detail for identification of nannoplanktons. However, the fact that this formation shows lateral and vertical transitions into the underlying Karaağaç limanı formation suggests that it may be of Lutetian age (Lower ?) (Fig. 3).

Depositional environment. _ On the basis of sedimentary features and other available data, it may be suggested that the Koyun limanı formation was deposited as deltaic sediments in a shallow sea environment influenced by river actions.

Fıçıtepe formation (TO

Definition and name'. - The formation consists of alternating mudstone and sandstone, intercalated with conglomerate as lenses. It is termed "Fıçıtepe unit" by Sfondrini (1961) and Druit (1961), Panayırtepe formation" by Turkse Shell (1969), "Fıçıtepe formation" by Kellog (1973). "Sağırtaş member of Tayfur formation" by Önem (1974) and Saluk (1975) and 'Tayfur formation" by Ünal (1967) and Saltık and Saka (1972, and 1973). During the presents studies, it was termed after Fıçıtepe where it is best seen.

Type section and type locality. - Type locality is located to the north of Kozlutepe. Type section was measured at this locality Other type localites include northern part of Tayfur village, locality of Sağırtaş, Fıçıtepe and its surrounding.

Distribution and setting. _ The outcrops of this unit are seen as parallel to the Saros bay, Gelibolu peninsula (Fig. 2). It is readily identifiable by its distinct red and wine color.

The formation gradually passes into the underlying Koyun limanı and Karaağaç limanı formations (Fig. 3).

Lithologic features. _ The Fıçıtepe formation consists of conglomerate sandstone fades, usually fining upward, interbedded with mudstone (siltstone, claystone) and very fine-grained sandstone (Fig. 3). The conglomerate sandstone fades ranging from 5 to 10 m. in width and having an average length of 50 m. occurs as horizontal lenticular sequences fining upward. Pebbles are mostly derived from limestone and various rocks of metamorphic and volcanic origin, and clast supported or cemented by sand to clay size material. The sandstone is medium to coarse grained, fines upward and exhibits cross bedding, grading and sorting. Bute casts are common markings of the lower surfaces. The mudstone is wine colored, and laminated and commonly contains organic tracks, remnants, and fragments of plant roots, desiccation cracks and carbonate concretions. Mudstones are inierbedded with thinly bedded, fine to very fine grained green sandstones with ripple marks.

The thickness of the formation was measured to be 450 m. in the vicinity of Kozlutepe, 540 m. immediately north of Tayfur village. However, this thickness shows variations and ranges from 200 to 600 m. in average.

Age. _ Due to lack of fossil, the Fıçıtepe formation has been dated on the basis of stratigraphic relationships. This formation conformably overlies the Koyun limanı formation of Lutetian (Lower ?) age. These two formations show lateral transitions into each other in some places. It is suggested that this formation is likely to be of Lutetian age, on the basis of the fact that it is unconformably overlain by the Soğucak formation (Fig. 3).

Depositional environment. _ On the basis of grain size distribution pattern within the fades of conglomerate sandstone, and wine colored mudstone, constituting the formation, internal structures, color, lateral and vertical relations of the facies, it is concluded that these lithologies are sediments of meandering rivers, and flood plains.

Soğucak formation (Ts)

Definition and name. _ This unit consisting mostly of limestone, and locally of sandstone, and claystone with subordinate conglomerate was differently named by earlier workers. It was named "Tayfur formation" by Druit (1961), "Mecidiye and Pırnal member" by Kellog (1973), "Kozlutepe member" by Önem (1974), "Mecidiye formation" near Şarköy and "Kozlutepe member" in Gelibolu peninsula by Saltık (1974). During the present studies it was termed after Soğucak, a common name used within the entire Thrace by TPAO workers where it is best seen.

Type section and type locality. _ Type locality is located near Kozlutepe in Gelibolu peninsula. A type section was measured at this locality. The other type localities are located near Tayfur village, in a stream bed near Pırnal village, along a road cut between Mecidiye and İbrice quay, and at Doluca tepe near Şarköy.

Distribution and setting. _ This formation crops out in different places of the study area. Exposures of this formation are seen near Kozlutepe and Tayfur village in Gelibolu peninsula, near Mecidiye village and Pımal village, south of Keşan, around Doluca tepe and Kamil tepe, near Şarköy (Fig. 2).

The lower contact of the formation was differently interpreted by many workers. Druit (1961), Kellog (1973) and Saltık (1975) report that this unit conformably rests upon the underlying unit. Conversely, the lower contact was interpreted to be unconformable by Turkse Shell (1969). The present observations indicate that the formation rests on the basement in the vicinity of Mecidiye and on ophiolitic basement around Yenice village, immediately north of Şarköy by angular unconformities. On the other hand, there is an uncertain unconformity between this formation and the underlying Fıçıtepe formation in Gelibolu peninsula (Fig. 3,4, and 5).

LUhologic features. _ The sequence from Gelibolu peninsula begins with sandstone, and conglomerate at the base, grades upward into limestone and continues with sandstone and marl including limestone olistoliths, the latter representing the uppermost part of the sequence (Fig. 3). The sandstone at the base is medium to thick bedded, unsorted and contains plant fragments and clayey horizons with coaliferous bands. Pebbles of conglomerate are up to 5 cm. long, subangular and matrix and clast supported. The conglomerate is unsorted and grading is indistinct The limestone from Gelibolu peninsula and Pırnal village is gray, dark gray colored, moderately bedded and locally imbedded, contains abundant fossils and very scarce sandstone strata and shows wackestone packstone character. The limestone from Mecidiye and Şarköy is brownish yellow, locally white colored, generally unbedded and folded and contains abundant shells of macrofossils. The limestones are overlain by sandstone and limestone olistolith bearing marl as the uppermost level in Gelibolu peninsula. The formation is characterized only by limestone in other places of the study area (apart from Gelibolu peninsula) (Fig. 4, and 5).

The formation has a thickness of 313 m. near Kozlutepe and 242 m. in the vicinity of Tayfur village in Gelibolu peninsula. The thickness was measured to be 100 m. near Mecidiye, 150-200 m. near Pırnal and 100-200 m. at Doluca tepe.

Age. _ On the basis of benthonic foraminifera and nannoplanktons determined, the formation is of Upper Lutetian Upper Eocene age (Fig. 3,4, and 5).

Depositional environment. _ It may be concluded that the unit was deposited in an open restricted shelf microfacies environment on the basis of microscopic studies of samples collected from limestones of the formation as well as fauna contained in carbonates and sedimentary structures in sandstones.

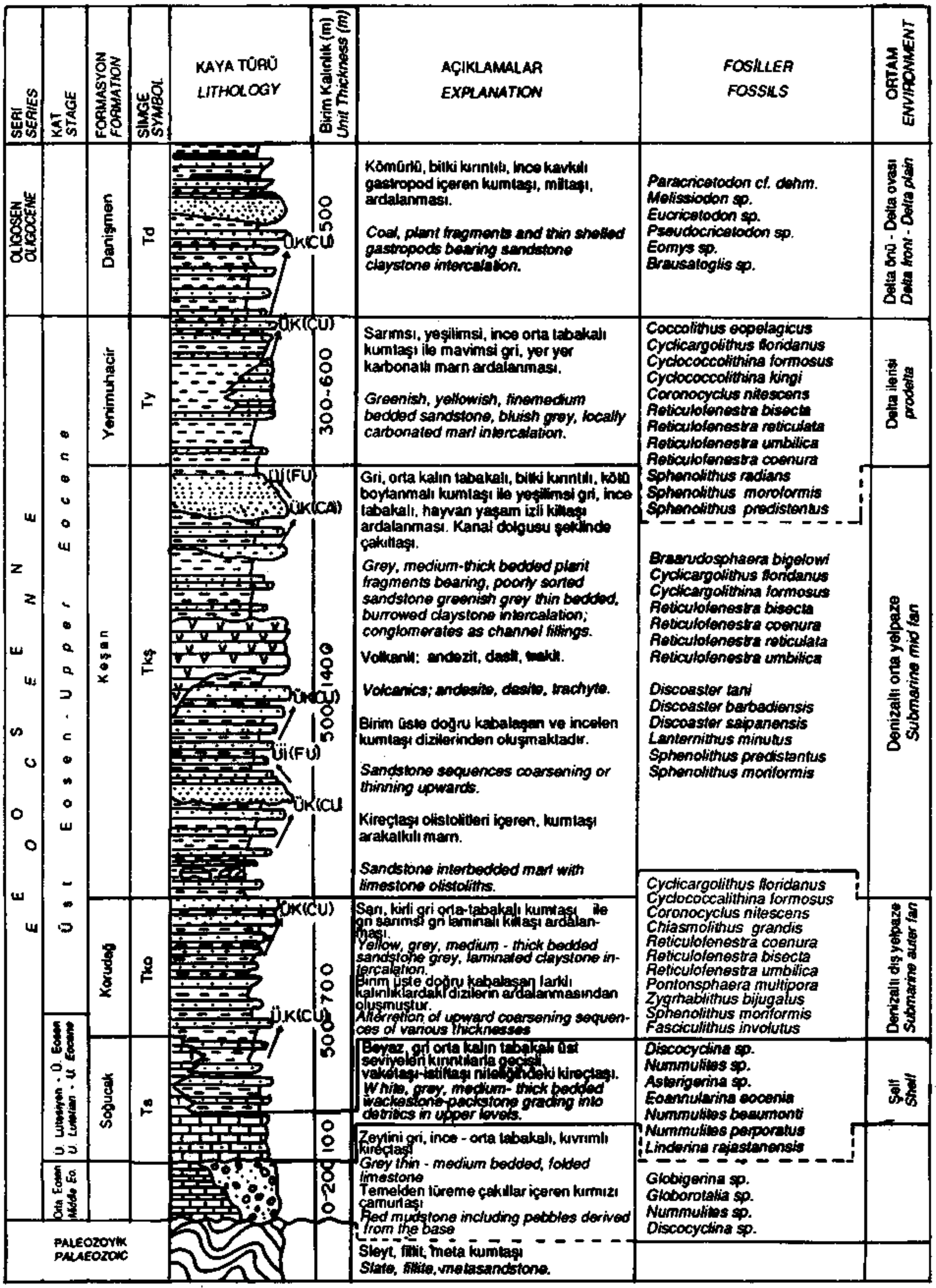


Fig. 4 - Generalized scaled stratigraphic columns of the Eocene sediments in the Korudağ-Keşan region.

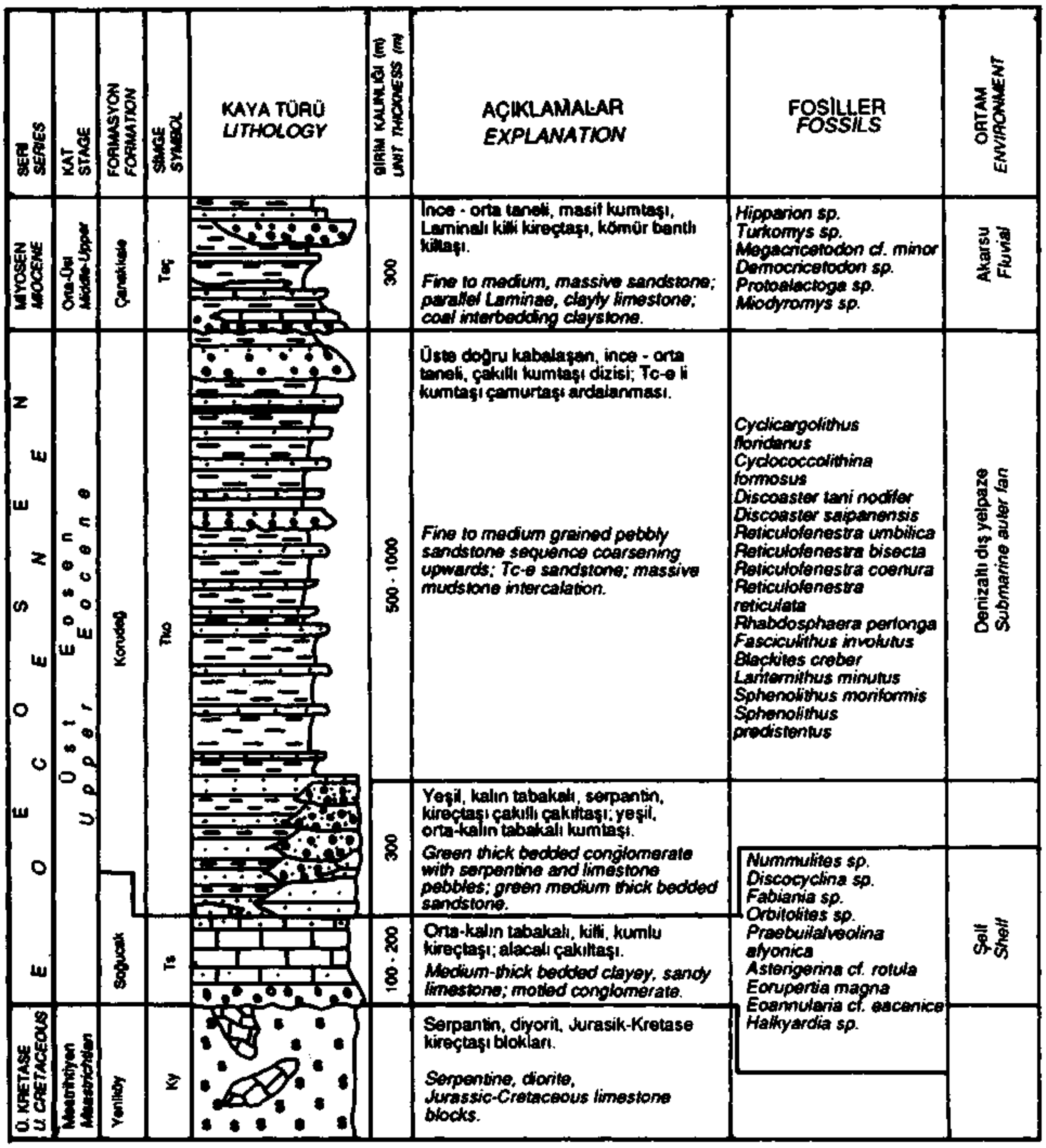


Fig. 5 - Generalized scaled stratigraphic columns of the Eocene sediments in the Şarköy-Mürefte region (South of the Gaziköy-Saroz fault).

Burgaz formation (Tb)

Definition and name. _ This formation consists of carbonate mudstone locally bearing volcanic levels, and unstratified mudstone. Earlier workers have used different names for this unit. It was named "Burgaz formation" by Druit (1961), "Member of Tayfur formation" by Turkse Shell (1969), "Yeniköy formation" by Saltık and Saka (1972), "Burgaz formation" by Kellog (1973), "Küllüdere formation" by Saltık (1975) and "Karaağaç member of Burgaz formation" by Önem (1974). Of these names, "Burgaz formation" was adopted to be used during the present studies.

Type section and type locality. _ Type locality is a small gully situated to the southeastern pan of Ece limanı. Measured type section was made at this locality. Besides, a stream valley to the southeast of Tayfur village, a stream valley through Burgaz village and both sides of the road between Fındıklı village and Kömür limanı are other type localities for this formation.

Distribution and setting. _ The formation occurs widespread particularly around Burgaz and Fındıklı villages (Fig. 2). In addition, it is observed to the southeast of Ece limanı and in the vicinity of Karainebeyli and Tayfur villages.

It grades into the underlying Soğucak formation. The contact between these units is coincident with the site where massive mudstone begins (Fig. 3).

Lithologic features. _ The Burgaz formation from the base up consists of volcanic tuffs, carbonated mudstone, and imbedded mudstone (Fig. 3). The volcanic facies within the formation is divided into two units; thin bedded tuff and unbedded tuff. At the base, a tuff containing a varying size of mud particles, pebbles, and volcanic rock fragments, which are embedded in a fine grained volcanic groundmass occurs. This tuff grades upward either into bedded or imbedded fine grained tuffs. The latter grades upward into carbonated mudstone. The mudstones are thinly bedded, enriched in carbonate exhibit no sedimentary structure and rarely contain thin bedded granular sandstone levels. The carbonate mudstones grade upward into imbedded mudstones. These mudstones are gray, imbedded and contain vertical, and horizontal animal burrows. In addition, they include interbeds of thin to medium bedded, fine grained turbiditic sandstone in the upper sections.

Measured thickness of the formation is 560 m. However, this thickness shows variations. It ranges from 300 to 600 m., depending on basin morphology.

Age. _ On the basis of nannoplanktons identified. Middle Upper Eocene age is assigned to the formation (Fig. 3).

Depositional environment. _ Having regard to the straligraphic position of the Burgaz formation in relation to the other formations, lateral and vertical relations of the facies constituting the formation with each other, and internal structures of the facies, the lithologies that make up the formation are considered to be deposits of deep sea basinal plain.

Gaziköy formation (Tg)

Definition and name. _ This unit consisting of fine grained turbiditic sandstone mudstone and hemipelagic mudstone is described for the first time during the present studies and named the Gaziköy formation.

Type section and type locality. _ This formation is typically exposed along the road of Gaziköy-Uçmakdere and type section was made at this locality.

Distribution and setting. _ The formation crops out over an area including Mürselli, Gaziköy and Uçmakdere villages (Fig. 2). The lower contact relation of the formation is disrupted due to movement of a strike slip fault. Thus, the relation is unclear. Presumably, it unconformably overlies the pre Tertiary units.

Lithologic features. _ The formation displays a regular sequence that consists generally of turbiditic sandstone mudstone and hemipelagic mudstone (Fig. 6). The upper sections contain submarine slump deposits composed of tuff horizons, and volcanic rocks. Sandstone strata laterally show continuity. Its lower contact with turbiditic mudstone and hemipelagic mudstone is sharp and eroded on a small scale, whereas the upper contact is transitive and seldom sharp. Te, Tc-e and Tb-e units are present from sandstone strata, and Tc-e unit is typically observed. Hemipelagic mucstone differs from turbiditic mudstone by having a light color. Individual bed of hemipelagic mudstone begins with a sandy level ranging from 10 to 20 cm. in thickness at the base. It grades upward into silty and clayey horizon rich in carbonate.

Age. _ On the basis of nannoplanktons identified, the formation is of Middle Upper Eocene age (Fig. 6).

Depositional environment. _ The fact that turbiditic sandstones typically include Tc-e units, the proportion of sandstone mudstone is relatively low, turbiditic sandstones are interbedded with hemipelagic mudstones, any regular sequence is absent from facies, strata laterally persist, constantly ramaining in thickness and the formation grades upward into submarine outer fan deposits suggests that the sediments of the formation were deposited in a deep sea basin.

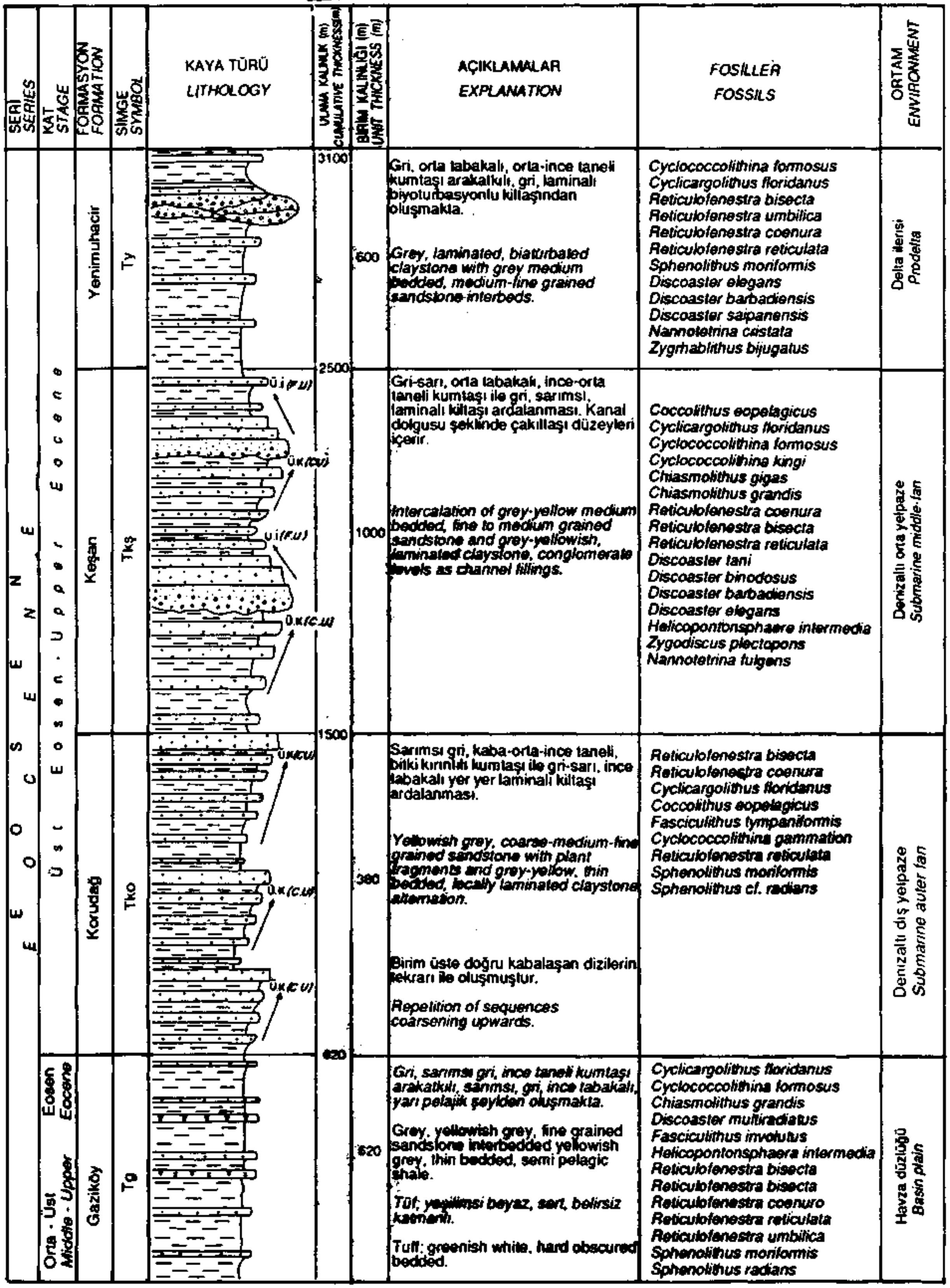


Fig. 6 - Generalized scaled stratigraphic columns of the Eocene sediments in the Işıklar mountain region.

Korudağ formation (Tko)

Definition and name. _ It consists mainly of sandstone, and mudstone and locally intercalations of conglomerate. This unit that occurs over a very extensive area was defined under different names during the earlier studies in the vicinity of Korudağ and Işıılardağ in Gelibolu peninsula. On the other hand, Kellog (1973) called the same unit exposed near Korudağ and Işıklardağ the Korudağ formation. The facies considered to be equivalents to the same unit are named the Korudağ formation by the present writers.

Type section and type locality. _ This formation is typically exposed along the road of Uçmakdere Yeniköy and type section was made at this locality. Besides, the line connecting Ayvasıl stream with Limni stream along the coast and Ece limanı are the other type localities for this formation.

Distribution and setting. _ The formation is exposed within an area including Büyük Kemikburnu, Ece limanı and Küçük Anafartalar from Gelibolu peninsula and around Korudağ and Işıklardağ in the vicinity of Karainebeyli and Yeniköy (Fig. 2).

Lithologic features. „ The Korudağ formation consists of thin bedded, fine grained turbiditic sandstone, and mudstone and moderately to thick bedded, medium to coarse grained sandstone (Fig. 3,4,5, and 6). These two facies are observed as sequences coarsening and thickening upward that developed depending on grain size and thickness of bed in vertical direction.

Each negative sequence begins with fine grained, thin bedded turbiditic sandstone, and mudstone at the base. Tc-e units are well developed within sandstones. This facies grades upward into moderately to thickly bedded, medium to coarse grained sandstone rarely containing pebbles. Ta-b, Ta-c and Ta units are particularly well developed within these sandstone strata. Small scale, and large scale collapse structures, flute casts and groove marks are observed on lower surfaces of sandstone strata.

Age. _ On the basis of identified, nannoplanktons Upper Eocene age is assigned to the formation (Fig. 3,4,5, and 6).

Depositional environment. _ On the basis of its lower and upper contact relations with the other units and sedimentary features of sandstone sequences coarsening and thickening upward, the formation was interpreted to be submarine outer fan deposits.

Keşan formation (Tkş)

Definition and name. _ The formation consists mainly of conglomerate, sandstone as channel fill deposits and massive clayey silty mudstone, and locally of interbeds of tuff. The unit was defined under different names during the earlier studies in the vicinity of Korudağ and Işıklardağ in Gelibolu peninsula. G6k9en (1967) and Kellog (1973) named these units as the Keşan formation during the studies near Korudağ and its surroundings.

Type section and type locality. _ The formation is typically exposed along the road connecting Yeniköy with Mermerköy and type section was made here. Other type localities include neighborhood of B. Kemikburnu from Gelibolu peninsula, shoreline between Dut limanı and Kumbağ near Işıklardağı, and Karanlık dere to the east of Keşan.

Distribution and setting. _ The Keşan formation occurs very widespread as does the Korudağ formation (Fig. 2). It is observed within an area bounded by K. Kemikburnu, B. Kemikburnu and K. Anafartalar and between Karainebeyli and YenikSy in Gelibolu peninsula; near Keşan, Gözsüz, Evreşe, Suluca, Kalealtı, Kanlı, and Karatepe in the vicinity of Korudağ; near Yeniköy, Mermer and Kumbağ in the vicinity of Işıklardağ.

This formation conformably overlies the Korudağ formation and there is a gradual transition between these units (Fig. 3,4, and 6).

Lithologic features. _ The formation is characterized by thinly bedded, fine grained sequence of sandstone, siltstone, and mudstone and sequences of medium to coarse grained, moderately to thickly bedded channel fill sandstone, which fine upward (positive) and show lateral discontinuities (Fig. 3.4, and 6). Each sequence begins (ascending) with largely eroded surface and overlying massively to weldedly bedded pebble sandstone. This pebble bearing level grades upward into medium to coarse grained, moderately to thickly bedded sandstone. Ta-c, Ta and Ta-b units are well developed in these sandstones. These sequences are overlain by massive mudstones. These sandstone sequences of varying thicknesses are encompassed by a second fades consisting of fine grained sandstone, and siltstone and claystone. The most pronounced features of sandstones within this fades are that they have sharp upper surfaces with current ripples and laterally thin out at a short distance and finally pass into mudstones. Siltstones and claystones are commonly massive and locally display parallel laminations on millimeter to centimeter scale. The formation includes tuffaceous horizons in the vicinity of Keşan.

Age. _ On the basis of nannoplanktons identified, the formation is of Upper Eocene age (Fig. 3,4, and 6).

Depositional environment. _ The fining upward sequences that begin with thickly and weldedly bedded massive pebble sandstones and grade upward into classical turbiditic sandstone, and mudstone are interpreted to be distributive channel fill sediments formed within submarine fan system, whereas coexisting siltstone claystone fades is regarded as intracharmel sediments.

Kanlıbent formation (Tka)

Definition and name. _ While its lowermost sections consist of claystone and siltstone, its uppermost sections consist of alternating sandstone, and conglomerate. This formation that appears confined only to Gelibolu peninsula was named and defined during the present studies.

Type section and type locality. _ The formation is typically exposed along the Kanlıbent stream cut to the east of K. Anafartalar village. Type section was made at this locality.

Distribution and setting. _ The formation is also exposed near Sivli village and its surroundings and between Yeniköy and Kavaklı mahallesi (Fig. 2).

The formation gradually passes into the underlying Keşan formation (Fig. 3).

Lithologicfeatures. _ The formation occurs as a sequence coarsening upward. This sequence (ascending) begins massive mudstone and grades upward into silty sandstone and thickly bedded pebble sandstone (Fig. 3). The uppermost levels of the sequence are overlain by mudstones interbedded with coal bearing horizons. Sandstones are massively bedded and contain abundant plant and leaf remnants, whereas pebble sandstones have eroded lower surfaces and laterally occur as lenticular bodies. Coaliferous horizons 10 to 20 cm. thick are locally found within the formation.

Age. _ On the basis of nannoplanktons identified from samples of mudstone collected from the lower sections of the formation. Upper Eocene age is assigned to the formation (Fig. 3).

Depositional environment. _ Having regard to a change in grain size throughout the sequence (from the base up) from silt to coarse sand (coarsening upward), lateral and vertical stratigraphic relations, sedimentary structures, and geometries of fades, it may be suggested that the sediments making up the formation were deposited in an environment similar to a deltaic environment.

Yenimuhacir formation (Ty)

Definition and name. _ This unit that consists dominantly of claystone, and siltstone and locally of sandstone levels was named the Yenimuhacir formation by Gökçen (1967), Turkse Shell (1972) and Lebkuchner (1974).

Type locality. _ Numbers of measured stratigraphic section was made for this unit during the present studies. However, the Soğukkaynak stream through Yenice village to the north of Işıklardağ, the Kocakirazlık stream near Naipli village and an unnamed stream through Yenimuhacir village can be suggested as type localities.

Distribution and setting. _ The formation crops out to the south of the line connecting Tekirdağ, Malkara and Danınment together and to the north of the line connecting Kumbağ, Mermer and Keşan together (Fig. 2).

The formation conformably overlies the Keşan formation. The boundary between these formations is coincident with the site where massive mudstone begins and was mapped on the basis of this relation (Fig. 4, and 6).

Lithologic features. _ The formation consists commonly of alternating fine grained, thinly bedded sandstone, and massive mudstone and sand to pebble channel fill sediments (Fig. 4, and 6). The sandstones are fine grained and thinly bedded. Their lower surfaces are sharp and upper surfaces include current ripples. Strata are laterally continuous and lenticular in appearance. Small scale cross bedding and rippled lamination are common within the sandstones. Conversely, sandstones are also found as thinly bedded sequences that thicken upward in places. Channel fill pebble sandstones that have eroded lower surfaces and laterally extend as lenticular bodies are observed either as individual beds or as occurring in the uppermost levels of sandstone sequences that thicken upward. These levels include leaf remnants and lamellibranch shells.

Age. _ On the basis of narmoplanktons identified, the formation is of Upper Eocene age (Fig. 4, and 6).

Depositional environment. _ Because of the fact that it is bounded by submarine fan (middle fan) deposits at the bottom and by river and deltaic plain deposits at the top and of internal structures of facies, the formation is interpreted to be deltaic deposits (developed forward from delta and on slope).

Armuttepe formation (Ta)

Definition and name. _ The formation consists of green siltstone, sandstone and pebble to sand channel fill deposits. It was named and described for the first lime during the present studies.

Type section and type locality. _ The formation is typically exposed along the line extending from Kanlıbent stream to Armuttepe and type section was made at this locality.

Distribution and setting. _ Outcrops of the formation are not common. It appears confined only to small areas near K. Kemikburnu, Armuttepe and Sivli in Gelibolu peninsula (Fig. 2).

The formation gradually passes into the underlying Kanlıbent formation (Fig. 3).

Lithologic features. _ The formation consists mainly of conglomerate, sandstone, siltstone and mudstone (Fig. 3). The most prominent feature of the formation is that it comprises the sequences of the above lithologies of varying thicknesses which become thin bedded and fine upward. Each sequence is bounded by eroded lower surface overlain by conglomeratic level that laterally shows discontinuity. This pebble bearing level in turn grades upward into the coarse to very coarse grained sandstone with large scale cross bedding, medium grained, horizontally bedded sandstone, fine to very fine grained, thin silty sandstone displaying parallel and cross lamination, and finally imbedded mudstone, and siltstone. These sequences are overlain and underlain by red, green and brown siltstone, and mudslone horizons. The latter includes calcium carbonate concretions of varying size, oxidized surfaces and common animal burrows.

Age. _ Because no fossil evidence is available, the formation has been dated on the basis of straligraphic relations. The formation conformably overlies the Eocene Kanlıbent formation everywhere in the study area. On the other hand, it is overlain by Middle Miocene Çanakkale formation with angular unconformity. These relations suggest that the formation is of Upper Eocene-Oligocene (?) age (Fig. 3).

Depositional environment. _ On the basis of lithologic, paleontological evidence and many other features (concretions composed of calcium carbonate, desiccation cracks, etc.), it is suggested that the formation was deposited in an alluvial environment.

CONCLUSIONS

The following conclusions were drawn from the present stratigraphic studies;

1 - As a result of the studies, the detailed stratigraphy of Eocene units was defined, applicable to the southwestern Thrace.

2 - The stratigraphic nomenclatures suggested by earlier workers comply with the rules.

3 - The Koyun limanı, Gaziköy, Kanlıbent and Armuttepe formations were named, defined and mapped for the first rime by the present authors.

4 - An exposure of Lower Eocene (Cuisian) limestone was recognized at the base of the Karaağaç limanı formation.

5 - The ages of the formations were discussed in detail and documented on the basis of identified fossil evidence.

6 - Although the Keşan, Yenimuhacir and Kanlıbent formations were previously considered to be of Oligocene age by Kellog (1973) and Önem (1974), the present studies suggest that they are all of Upper Eocene age.

7 - The presence of two transgressive episodes that occurred during the Eocene was recognized.

8 - The lithologic features, sedimentary structures, fossils and geometries of the formations were studied in detail and their depositional environments were defined on the basis of certain data.

ACKNOWLEDGEMENTS

This study was carried out by the Department of Basic Researches of MTA in the period between 1979 and 1982. The writers thank the authorities of General Directorate of MTA for providing facilities that made this study possible, the colleagues who conducted the studies on biostratigraphy and tectonics of the same region within the framework of "Thrace Tertiary Project", Şükrü Acar and Emin Erkan for assistance in dating, and Ali Yılmaz and Ahmet Aksay for criticism and useful comments on the manuscript.

Manuscript received November 30,1990

REFERENCES

Allen, J.R.L., 1964, Studies in fluviatile sedimentation; six cyclothems from the Lower old Ret sandstone: Sedimentology, 3, 163-198.

______. 1970, Studies fluviatile sedimentation: Jour. Sed. Petrology, 40,298-323.

Bouma, A.H., 1962, Sedimentology of some flysch deposits; a graphic approach to fades interpretation: Elsevier, 168, Amsterdam.

Druit, C.E., 1961, Report on the petroleum prospect of Thraco, Turkey: Turkish Gulf Oil Co. (unpublished).

Gökçen, L.S., 1967, Keşan bölgesinde Eosen-Oligosen sedimantasyonu, Güneybatı Türkiye Trakyası: MTA Bull., 69,1-10. Ankara-Turkey.

Guido, Ghibaudo, 1980, Deep-sea fan deposits in the Macigno formation (Middle-Upper Oligocene) of the Gordona Valley, northern Apennines, Italy: Jour. Sed. Petrology, 50,723-742.

______, 1981, Deep-sea fan deposits in the Macigno formation (Middle-Upper Oligocene) of the Gordana Valley, northern Apennines, Italy: Jour. Sed. Petrology. 51,1015-1033.

Kellog. H.E., 1973, Geology and petroleum prospects Gulf of Saroz and vicinity southwestern Thrace: Ashland Oil of Turkey, Inc. Türkiye Petrol İşleri Genel Md. arşivi (unpublished).

Lebkuchner, R.F.. 1974, Orta Trakya Oligosen'inin jeolojisi hakkında: MTA Bull., 83.1-29. Ankara-Turkey.

Mutti, E., 1977, Distinctive thin-bedded turbidite facies and related depositional environments in the Eocene Hecho Group (South central Pyrenees, Spain): Sedimentology, 24,107-131.

______and Ricci Lucci, F., 1972, Le turbiditi deli Appennino settentrianale; introduzione all "analisi di facies: Mem. Soc. Geol. Italy, 11; 161-199.

______and______, 1974, La signi fication de certaines unites seguentielles dans les series a turbudites: Bull. Soc. Geol. Fr., 16,577-582.

______and______, 1978, Turbidites of the northern Apennines Introduction to facies analysis Interat: Geology Rev., 20,127-166.

Önem, Y., 1974, Gelibolu ve Çanakkale dolaylarının jeolojisi: TPAO Rep. 877 (unpublished), Ankara-Turkey.

Ricci Lucci, F., 1975, Depositional cycles in two turbidite formations of northern Apennines (Italy): Jour. Sed. Petrology, 45, 3-43.

Saltık, O., 1974, Şarköy-Mürefte sahaları jeolojisi ve petrol olanakları: TPAO Rep. 879 (unpublished), Ankara-Turkey.

______, 1975, 1. Bölge Malkara-Tekirdağ-Işıklardağı sahalarının jeolojisi ve petrol olanakları: TPAO Rep. 918.

______and Saka, K., 1972, Saroz Körfezi, Gelibolu yarımadası, İmroz, Bozcaada ve Çanakkale sahil şeridi jeoloji incelemesi: TPAO Rep. 716 (unpublished).

______and________, 1973, Bozcaada I (continental Oil Company of Turkey): TPAO Rep. 848 (unpublished), Ankara-Turkey.

Sfondrini, G., 1961, Surface geological report on AR/TGD/1/338 ve 537 (Eceabat-Çanakkale areas): Turkish Gulf Oil co. Report, Turkish Petrol Adm. Archives, (unpublished), Ankara.

Stewart, D.J., 1981, A meander-belt sandstone of the Lower Cretaceous of Southern England: Scdimentology, 28, 1 -20.

Sumengcn, M.; Terlemez., İ.; Şentürk, K., Karaköse, C.', Erkan, E.; Ünay, E.; Gürbüz,, M. and Atalay, Z., 1987, Gelibolu Yarımadası ve Güneybatı Trakya Tersiyer Havzasının Stratigrafisi, Sedimantolojisi ve Tektoniği: MTA Rep., 8128 (unpublished), Ankara-Turkey.

Şentürk, K. and Okay, I.A., 1984, Saroz körfezi doğusunda yüksek basınç metamorfizması: MTA Bull., 97/98, 152-155, Ankara Turkey.

Ünal, O.T., 1967, Trakya jeolojisi ve petrol imkanları: TPAO Rep. 391, Ankara-Turkey.

Wilson, J.L., 1975, Carbonate facies in geologic history: Springer Verlag, Berlin, Heidelberg, 471 s. New York.

Walker, Rogen G., 1978, Deep-water Sandstone facies and ancient Submanne fans: Models for exploration for stratigraphic traps: The American Association of petroleum Geologists: V. 62, P. 932-966.

GEOLOGY AND PETROLOGY OF THE NEOGENE VOLCANICS IN THE VICINITY OF HINIS-VARTO-KARLIOVA REGION-TURKEY

Niyazi TARHAN*

ABSTRACT— Neogene volcanic rocks start with the Bingöl Mountain Group of Middle Miocene age in the investigated and a joining areas. Varto Group of Upper Miocene age rests unconformably on these volcanics. Both of these groups are mutually overlain by the horizontal strata of Middle/Upper Pliocene age and the Hamurpet lava of Lower Pliocene age. In the region, N-S compressional forces produced by a post Lower Miocene collision (or compression) causing crustal thickening, thrusting and slicing. All these events caused sinking of the continental crust into the mantle and formed detachment faults and zones of weakness leading to partial melting and volcanism. The volcanic sequence display distributional and sectional variations of chemistry interpreted to have been caused by variations in lilhologic character. The rocks are generally andesitic in composition with calc-alkaline to weak alkaline affinity. The volcanic rocks have been deformed by the dextral North Anatolian and sinistral East Anatolian faults.

Mineral Res. Expl. Bull., 113,31-63, 1991

GEOLOGY AND MINERALOGY OF THE BİGADİÇ BORATE DEPOSITS AND VICINITY

Cahit HELVACI* and Orhan ALACA**

ABSTRACT. - In the Bigadiç volcano-sedimentary basin, Palaeozoic-Mesozoic basement rocks are overlain unconformably by the Miocene rock units. The straligraphic sequence of Miocene units, from the bottom to the top in ascending order is, basement volcanic unit, basement limestone unit, lower tuff unit, lower borate bearing unit, upper tuff unit, upper borate bearing unit, and basalt unit. Miocene units are overlain unconformably by the recent sediments, and alluvium rests unconformably on the recent sediments. In the region, Palaeozoic and Mesozoic basement rocks were subjected to block faulting and dislocation during the pre-Miocene. As a result of these movements, large and small sized several playa lake type sedimentation basins were formed, and Miocene sediments were deposited in these basins. In the study area, the general strike of the fold axis is NE-SW. Beds generally dip towards MW or SE with 5°-35°. Borate deposits occur as two different horizons in the upper and lower borate bearing units, which are separated from each other by the upper tuff unit. In the region, the lower and upper borate zones show thickness varying between 35-130 meters and 20-110 meters, respectively. Boron ores are alternated with claystone, mudstone, tuff and thin-bedded limestone, and generally exhibit lenticular structures. Colemanite and ulexite are the dominant ore minerals in both of the ore zones. In addition to these, other boron minerals such as pandermite, probertite, howlite, tunellite, meyerhoffente, hydroboracite and inyoite have also been determined in the basin. Colemanite in the lower and upper borate zones have possibly precipitated directly from the solutions contemporaneous with sedimentation, within the unconsolidated sediments under the sediment/water interface. Nodules continued to develop, parallel to the compaction of sediments. Formation of ulexite resembles that of colemanite and it reflects the period when Na-concentration of the solution has increased.

INTRODUCTION

Bigadiç town, located on the Balıkesir-İzmir highway, about 37 km. to Balıkesir, is the biggest residential center within the investigated area (Fig. 1).

After the discovery of borate deposits around Bigadiç in 1950, various studies were carried out by different investigators (Meixner, 1952, 1953, 1956; Helke, 1955; Bekişoğlu, 1961; Kutlu, 1963; Kalafatçıoğlu, 1964; Özpeker, 1969; Borsi et al., 1972; Yılmaz, 1977). More recent studies in the area are given below:

1- Çakır and Dündar (1982), prepared the 1:25.000 scale geological map of the area, and determined that borate was deposited as two separate zones, contrary to the former acceplion of a single ore zone; 2- Gündoğdu (1982), determined the stratigraphic sequence of the basin, and carried out detailed mineralogic and geochemical investigations on the individual rock units; 3- Helvacı (1983), realized the correlation of Turkish borate deposits to the world deposits, and determined the common characteristics of the Turkish borate deposits. In addition, characteristics of boron minerals constituting the borate deposits and their mineralogic features are presented in detail; 4- Helvacı and Alaca (1984), give a survey of the geology of Bigadiç borate deposit and explain the mode of occurrence of borate minerals determined at the area; 5- Helvacı and Dora (1985), explain the howlite and tunellite formation phases at Bigadiç borate deposits; 6- Helvacı et al. (1987), review the geology of Turkish borate deposits in a survey of the stratigraphy and economic potential of West Anatolian Neogene sediments. Also general features of the depositional environments are presented by the correlation of stratigraphic sequences of various borate deposits; 7- Alaca et al. (1987), have carried out the geological exploration of western section of the Bigadiç borate basin.

This present study aims to cover distinguishing the stratigraphic units at the Bigadiç volcano-sedimentary basin and its close vicinity; a detailed investigation of the borate bearing units; determination of the boron minerals within the borate deposits, and ore grades.

STRATIGRAPHY

Basement rocks, comprising Palaeozoic schist and marble, and Mesozoic ophiolitic rocks, limestone, radiolarite and sandstone are overlain unconformably by the Neogerte volcanic and volcano-sedimentary rocks in the study area (Fig. 2).

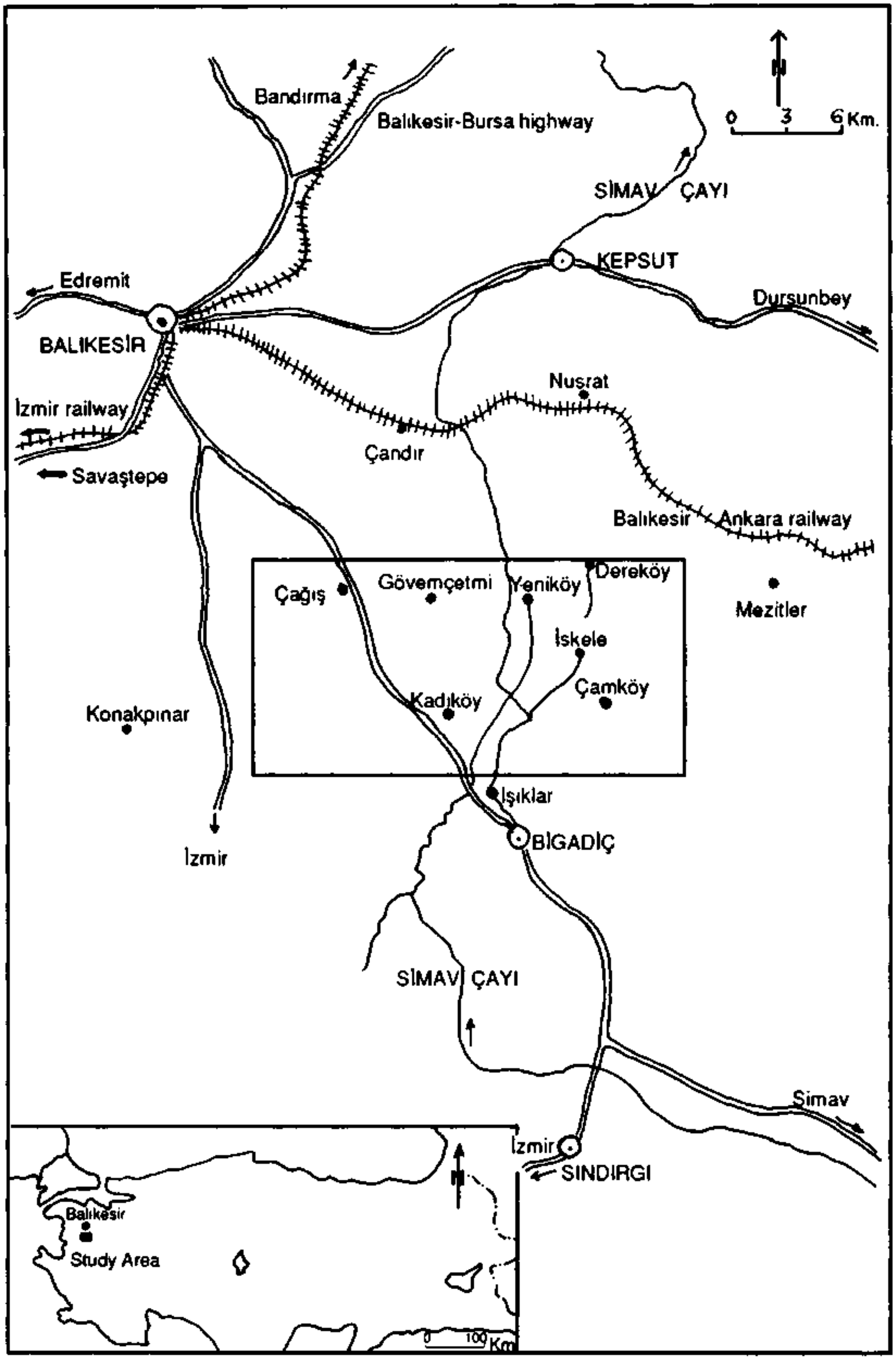


Fig. 1 - Location map of Bigadiç basin.

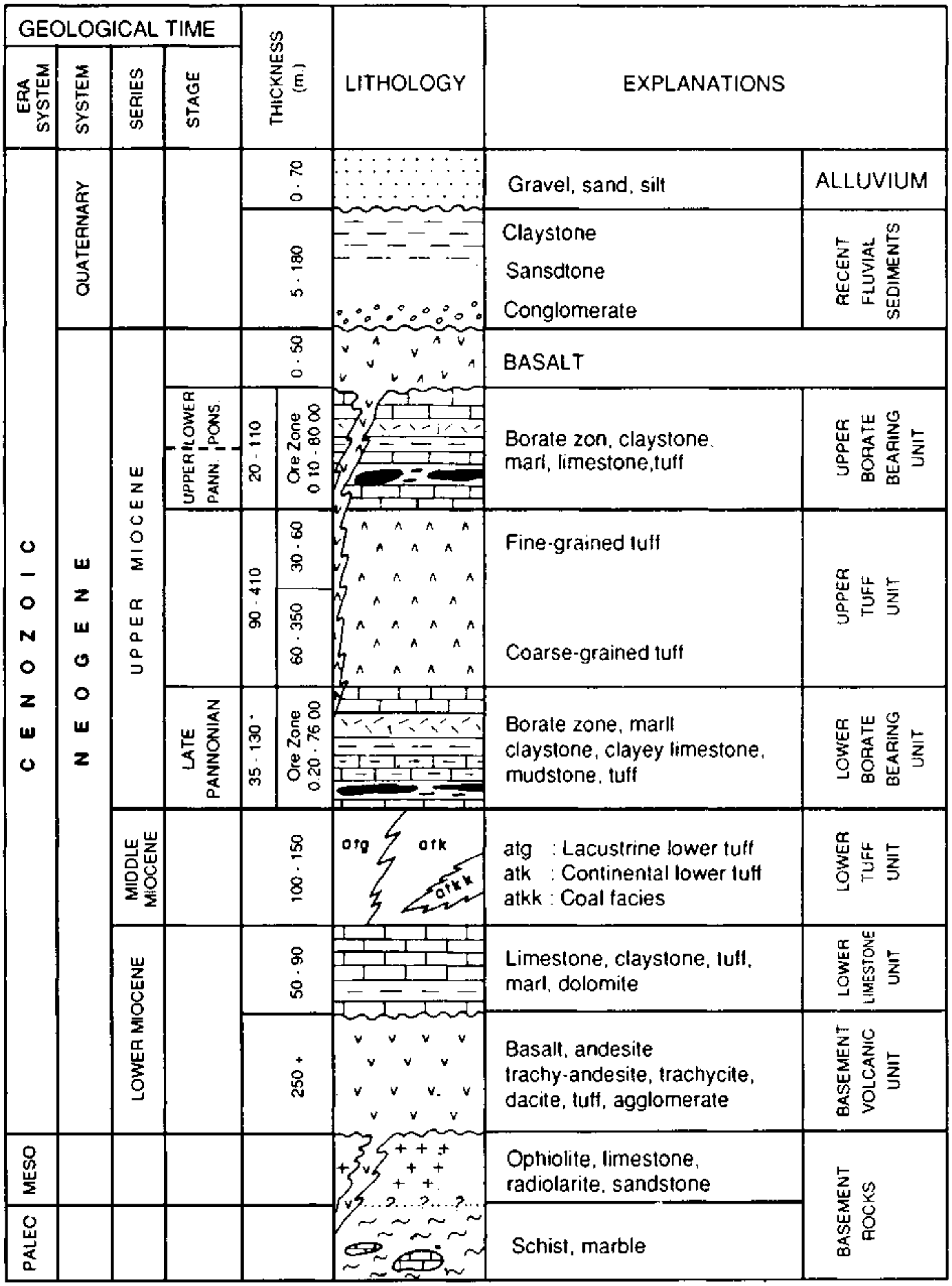


Fig. 2 - Generalized stratigraphic coloumn of Bigadıç region.

Neogene volcanic and volcano-sedimentary rocks have been classified from bottom to top as: basement volcanic unit, basement limestone unit, lower tuff unit, lower borate bearing unit, upper tuff unit, upper borate bearing unit and basalt.

Recent sediments of Quaternary and actual alluvial deposits overlie the Neogene lithologic units unconformably in the study area. Geological map of the study area is given in Figure 3.

PALAEOZOIC AND MESOZOIC

Basement rocks

Palacozoic rocks (schist, marble) and Mesozoic rocks (ophiolitic rocks, limestone, radiolarite, sandstone) have been distinguished as the basement rocks in the study area.

The green and grayish-blue schists arc in albite-sericite and chlorite-epidote-muscovite composition. Marbles are usually fine-crystalline and occur in alternation with schists.

Peridotites are mostly serpentinized. Tale alteration is frequently observed within these light to dark green colored rocks.

Limestones, which arc dark gray and occasionally black in color, contain abundant fractures. Coarse-grained calcite minerals exhibit cleavage in two directions and pressure-twins, and some bear iron oxide, calcite and occasional quartz fillings in the fractures.

Radiolarite is composed of spherical radiolaria fragments bound together with cryplocrystalline quartz and limonite. Color is dark brown.

Sandstone comprises quartz, feldspar, muscovite, calcite and opaque minerals, whose grain size varies between 0.05 and 0.2 mm. This rock is badly sorted and graded. Color is dark gray and greenish.

Basement rocks are overlain by the basement volcanic unit in the study area. To the north of Güvemçetmi village, lower borate bearing unit overlies the basement rocks. Unconformity exists between the basement rocks and the overlying units.

CENOZOIC

Neocene units

Basemeni volcanic unit. _ The lithologic unit comprising greenish-gray, gray, pink, greenish-black colored andesite, basalt, trachyandesite, trachyte,dacite, agglomerate and tuff has been distinguished as the basement volcanic unit.

Fresh surfaces of the basalt is greenish-black colored, while the altered parts show reddish-brown color. Pyroxene minerals can be distinguished when examined carefully with naked eye. Plagiodase and opaque minerals have been determined in the rock. Plagioclase is idiomorphic to hypicliomorphic, sometimes having a zoned structure, and is composed of labrador with 55 % An. Polysynthetic twins are common. Augite is hypidiomorphic and coarsely crystalline.

Dominant color of andesile is pinkish, and feldspars and biotiles are distinguishable with the naked eye. The rock components are biotite, hornblende, feldspar and quartz phenocrystals in a calcified and clayey vitreous cement. Feldspars contain albite type twins and the composition is close to oligoclase with 25 % An. Most common mafic mineral is biotite with typical cleavage in one direction. Hornblende crystals are rare. Chloritized parts of spherulitie texture are occasionally observed in the matrix.

Dacitie rocks in the area generally exist together with tuff and agglomerate. These rocks are whitish, gray, pale-green but mostly light colored. Tuff predominated parts show obvious erosional influence. Flow-structure is characteristic for dacite which composes of quartz, feldspar, mica and amphibole minerals. Hyalopilitic texture is also observed in thin sections. Feldspar, biotite, quartz and to a lesser extent hornblende microliths occur as floating in a vitreous matrix, showing both flow structure and crystalline structure. Feldspars are mostly in oligoclase-andesine composition. Quartz crystals are coarse

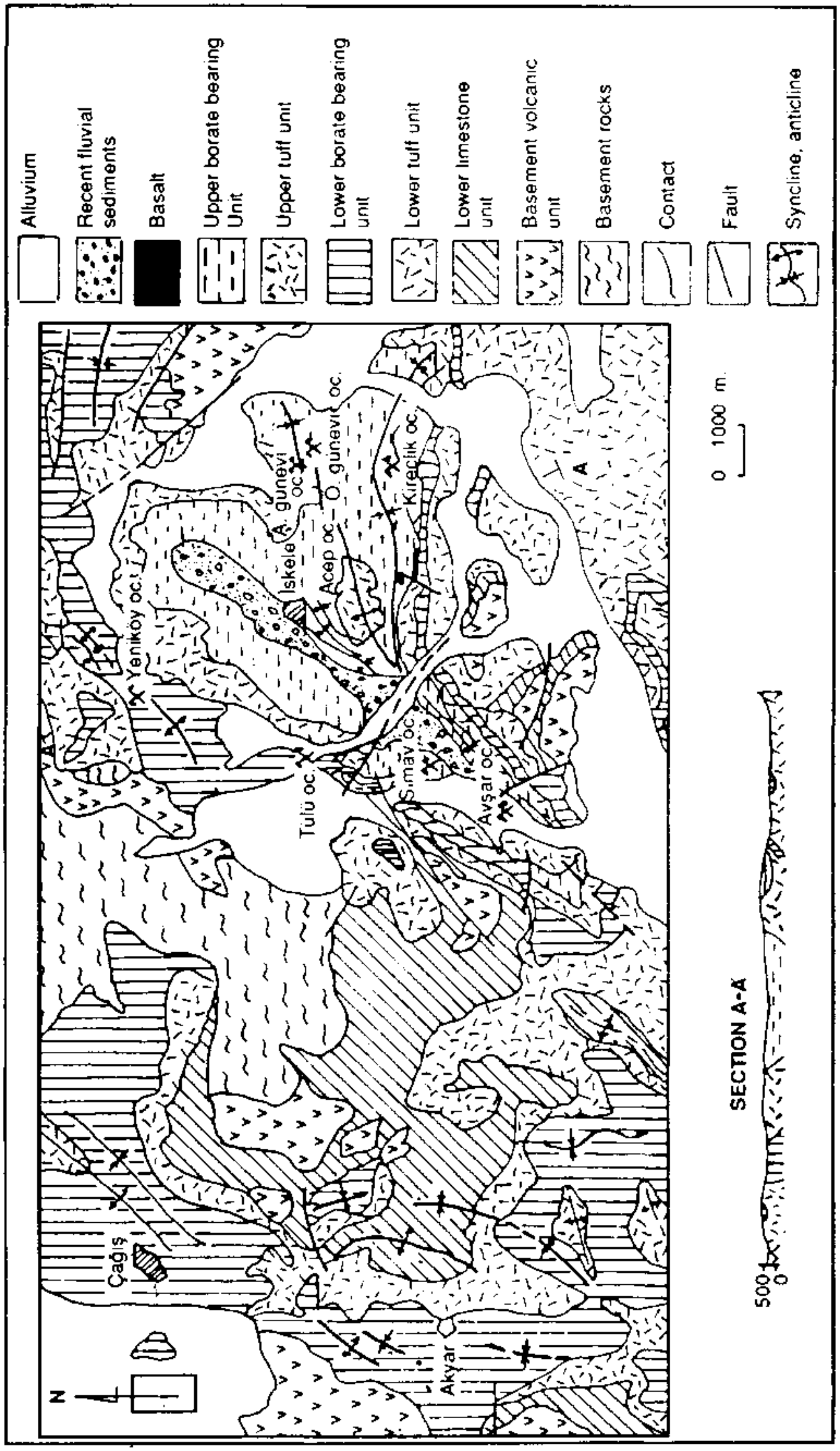


Fig. 3 - Geological map of Bigadiç borate basin and vicinity.

grained. Cleavage surfaces and edges of biotite show opacity due to alteration. The rock bears very little amount of opaque minerals.

Trachytie rocks at the area also occur together with tuff and agglomerate. These rocks are dirty yellow to grayish colored and arc composed of cuhedral and subhedral sanidine crystals of 3-4 cm., in a vitreous and crystalline matrix.

Trachyandesites occasionally occur together with trachytes and comprise plagioclase, biotite and hornblende phenocrystals floating in a vitreous matrix, and random quartz, crystals. Plagioclase is in oligoclase-andesine composition. Partial chlorilization is observed in the matrix, and opaque parts on hornblende and biotite. Scarce and fine-grained opaque minerals arc distributed in the matrix.

Tuff and agglomerate of volcanic rocks in the region exist in various amounts together with these rocks. Tuffs are generally composed of a fine-grained vitreous matrix and abundant feldspar, quartz and biotite crystals within the matrix. Plagioclase is represented by albite, oligoclase and andesine. Some clay minerals arc observed due to the alteration of luff. Agglomerates are made up of andesite and dacite fragments, and cemented by tuff. Pebbles arc rounded and sometimes angular, and tuffaceous horizons are found as interbeds.

Hot water springs are present in andesite-trachyte at Hisarköy, in the cast of the study area. Water samples from these springs yielded 10 ppm B. Hotness of water is about 90°C.

Basement volcanic unit overlies the basement rocks unconformably. On the other hand, this unit itself is generally overlain unconformably by the basement limestone unit. In some places (e.g. around Yeniköy) lower borate bearing unit directly lies over the limestone unit.

Age of the basalt cropping out at Kocakır Tepe within this unit was determined to be 17 million years, by the K-Ar method (Yılmaz, 1977).

Basement limestone unit. -This unit, which is composed of white, yellowish white, green, creamy and beige colored, thin bedded and laminated marl, limestone, claystone, dolomitic limestone and tuff, forms gentle slopes in the study area.

The unit starts with whitish creamy colored, thin bedded dolomitic limestone, with abundant cracks and fractures. Over this lies a platy limestone-marl.alternation with tuff bands. An alternation of claystone-limestone-tuff-marl constitutes the uppermost section of the unit.

Limestones at the lower section of the unit generally exhibit micritic and locally sparitic character. Thickness of beds range among 5-40 cm. Fractures and solution cavities are common, and sometimes filled by calcite. Tuffs arc yellowish green in color and are composed of volcanic ash.

Basement limestone unit rests on the basal volcanic unit unconformably. Lower tuff unit overlies conformably, at the upper contact.

Samples for palinologic investigation were collected from the clayey horizons within the unit, but they were sterile and contained no pollens suitable for age determination (Akgün, 1985).

Presence of tuff bands in the unit indicate that volcanic activity was continuing during the sedimentation of the unit. Presence of dolomitic limestone in the lower levels show that chemical sedimentation starled in the playa lakes which started developing al the begining of Lower Miocene with the transportation of epiclaslic and pyroclaslic material into the basin middle and upper levels of the unil sedimented conscqulively.

Lower tuff unit. _ This yellowish white to dark gray colored unit has generaled in relation to the active volcanism around the lacustrine basins. Successively, terrestrial and lacustrine phases have developed.

Fresh surfaces of the lacustrine facies samples of the unit arc dark gray colored, and abundant biotite, feldspar and quartz grains can be distinguished by naked eye. Samples from the lower tuff unit in lacustrine facies yield abundant feldspar, quartz, biotite and rare hornblende, in addition lo a liltle amount of volcanic fragments, usually occurring in a vitreous matrix. Tuffs in lacustrine facies contain zeolite minerals (clinoptilolite and hculandite).

Lower tuff unit in terrestrial facies is well exposed around the Köteyli village, to the north of Balıkesir province, outside the investigated area (Figs. 4 and 5). Samples from this location has been described as andesitic crystalline tuff, by petrographic studies. Cement of the rock comprise volcanic components together with plagioclase microliths in a lesser extent, which are ash sized. Opaque minerals such as hornblende and biotite have also been determined in the rock.

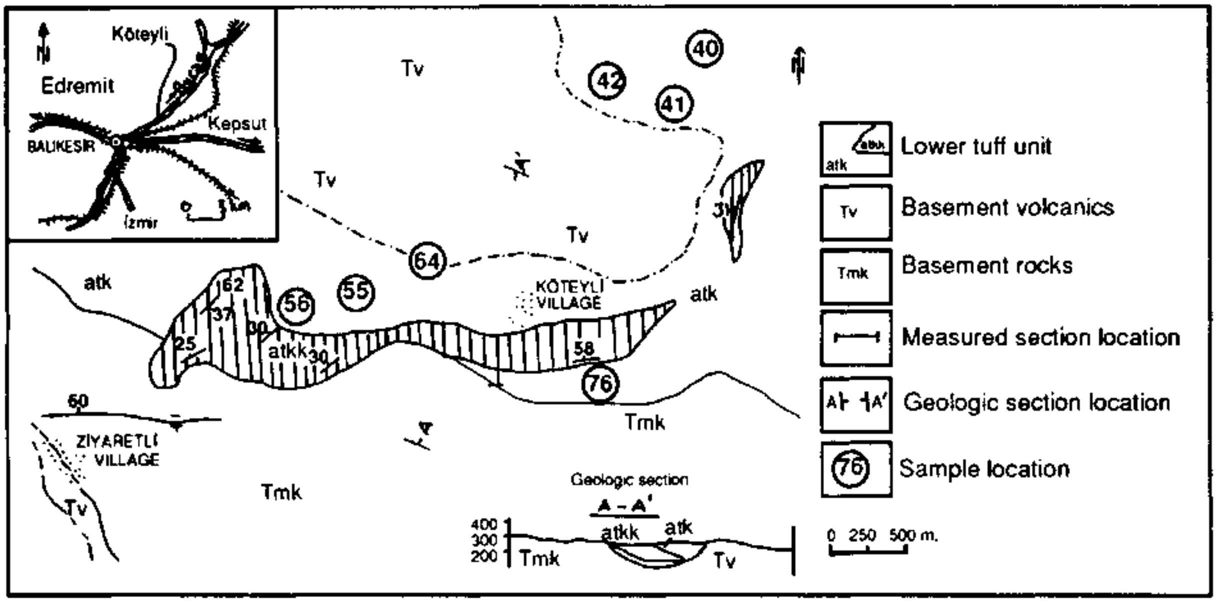


Fig. 4 - Geological map of Köteyli village surroundings.

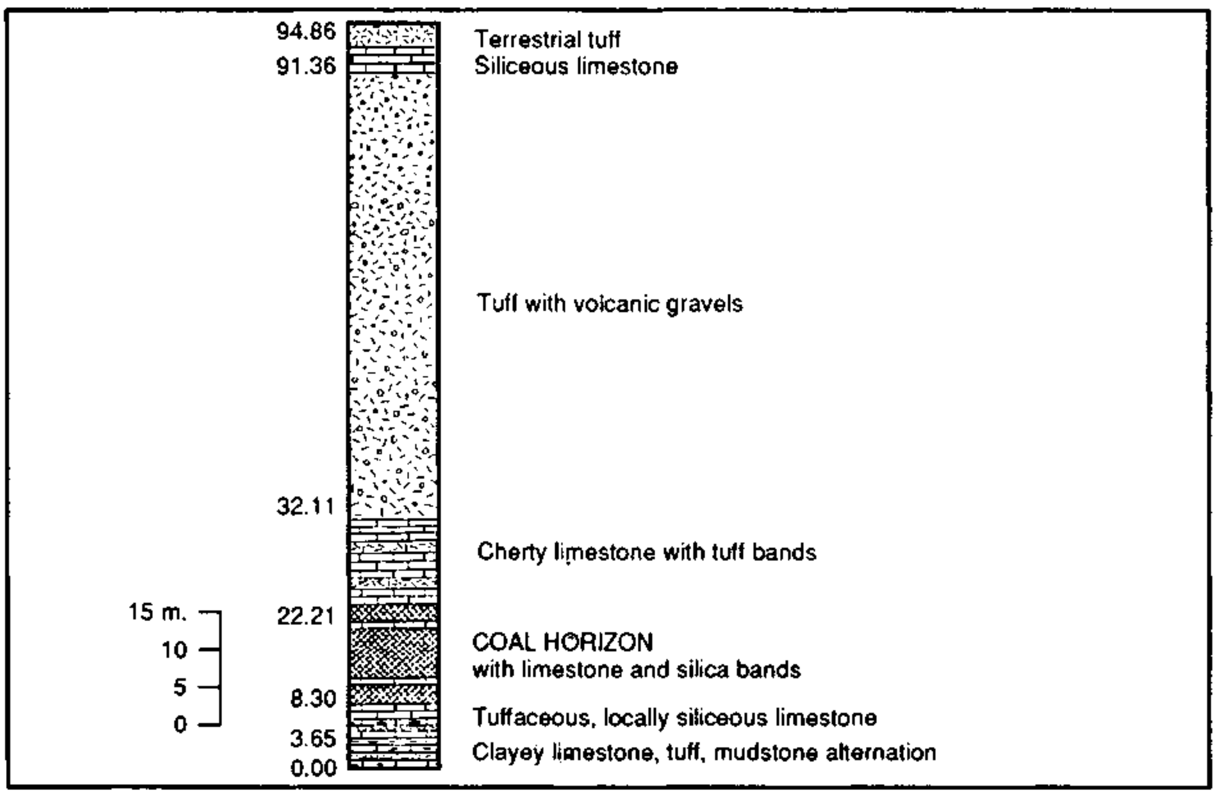


Fig. 5 - Measured type section of coaly facies of the lower tuff unit.

Lacustrine facies of the lower tuff unit overlies the basement limestone unit conformably. In places where the basement limestone unit is lacking, it overlies the basement volcanic unit sharply and unconformably. Lower borate bearing unit rests on this unit with a concordant and gradational contact.

Samples have been collected from the coal bearing horizon of the coal facies, which crops put locally within the terrestrial lower tuff. These samples have been investigated by Akgün (1985) and the following pollens were determined:

Laevigatisporites haardti

Inaperturopollenites polyformosus

Triatriopollenites pseudorurensis

Pityosporites microalatus

Triatriopollenites rurensis

Triatriopollenites bituitus

Triatriopollenites coryphaues

Triporopollenites simpliformis

Triporopollenites lapraferus

Subtriporopollenites simplex

Polyvestibulopollenites verus

Polyporopollenites stellatus

Polyporopollenites undulosus

Tricolporopollenites cingulum

Trlcolporopolleniles megaexactus

Tricolpopollenites densus

Tricolpopollenites microhenrici

Predominance of the pollen species with wide vertical distribution within this association, and the absence of characteristic pollen species of pre- and post-Miocene suggest that coal formations around the Köteyli village are Middle Miocene aged.

Lower luff unit has formed by the precipitation of pyroclastic material in dust size, which were produced by volcanic eruption, on to the lake or land area.

Lower borate bearing unit. _ Yellowish white colored unit shows medium to well compaction, thin to intermediate bedding and lamination. The unit carries borate beds at the bottom parts, and is composed of limestone, clayey limestone, marl, claystone, mudstone and tuff alternations.

Lower borate bearing unit is well exposed at the Tülü open pit mine (Fig. 6) and Yeniköy underground mine (Fig. 7). The unit starts with a thin bedded, occasionally laminated marl-limestone-tuff alternation.Over this alternation lies an ore zone of 0.20-76.00 m. thickness. Alternations of gray colored tuff, platy clayslonc-limestone and interlayers of thin bedded limestone and claystone occur together with the borates within the ore zone. The ore zone is covered by an alternation of laminat-

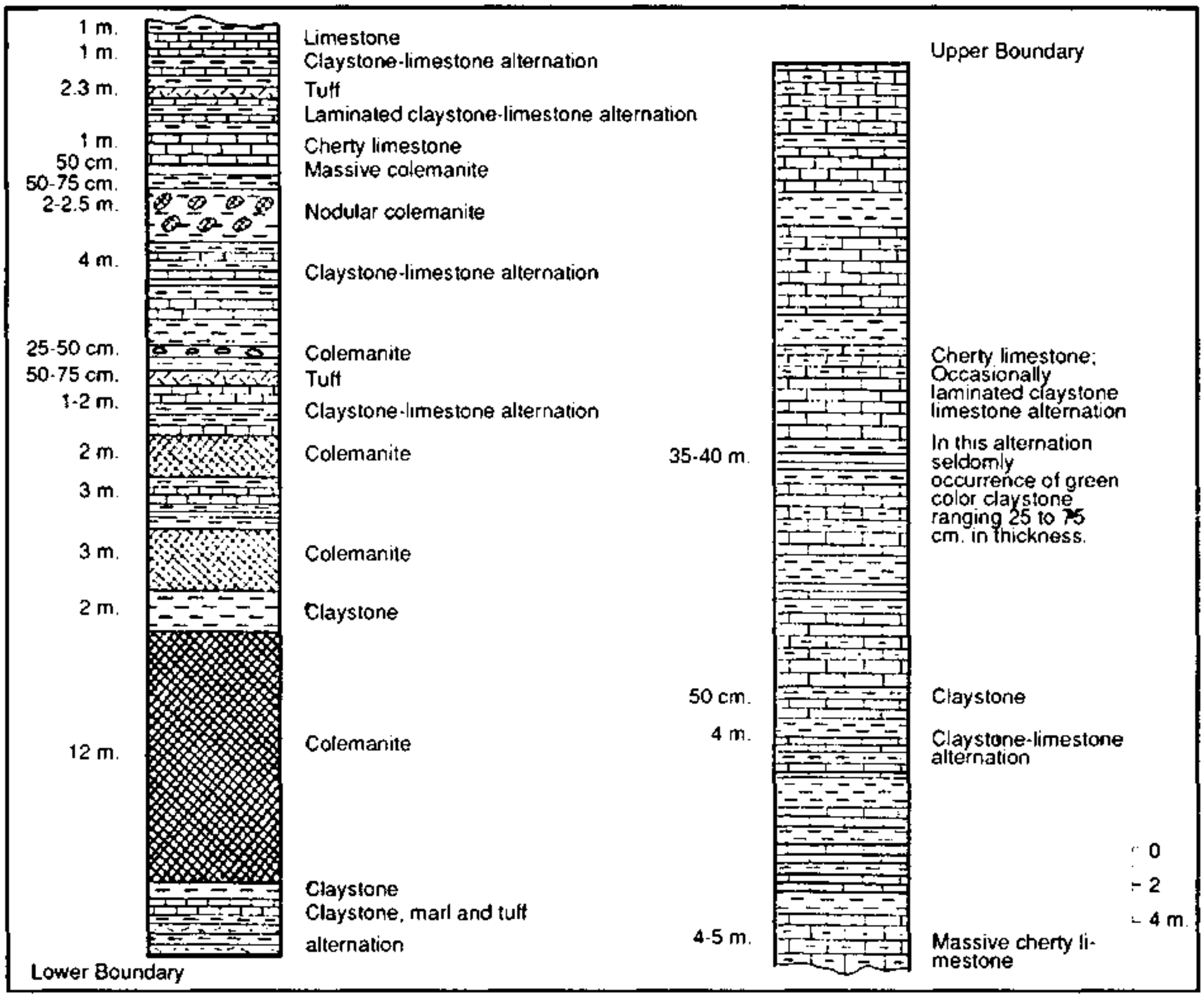


Fig. 6- Measured section of Tülü open pit.

cd, brown clayslonc and grayish white limestone. The unit progresses upward with an alternation of medium bedded cherty limestone, claystone and limestone. Around Yeniköy village, chert bands of 40-60 cm. thickness and porous limestone are observed at the upper parts of the unit.

Limestones within the unit are composed of sparite, biosparite, fossiliferous sparite, microsparite and micrite. Clayey limestones comprise calcite and clay minerals. They contain a little quartz. Locally they exhibit a dolomilic marl character comprising dolomite, clay, calcite and feldspar. Mudstones are generally made up of carbonaceous mud with weak compaction. They contain little amount of volcanic fragments. Tuffs occur as intercalations or interbeds within the unit.

Thickness of the ore zone at the lower parts of the unit is variable between 0.20 to 76.00 m. Boron minerals occurring at the ore zone are colemanite, ulexite, howlite, probertite and hydroboracite. Colemanite and ulexite arc the minerals in economic significance. Together with borates, various amounts of non borate minerals also occur within the ore 7.one. Borate minerals are generally accompanied by calcite, dolomite, anhydrite and gypsum. Most common clay minerals arc monunorillonite and illite (Helvacı 1983).

Lower borate bearing unit generally rests on the lower tuff unit conformably and shows gradation into the latter. Thickness of the gradation zone is variable. The unit sometimes overlies the basement volcanics unconformably, as in the case of Yeniköy village. At the top, a conformable and gradational contact exists between the lower borate bearing unit and the upper tuff unit.

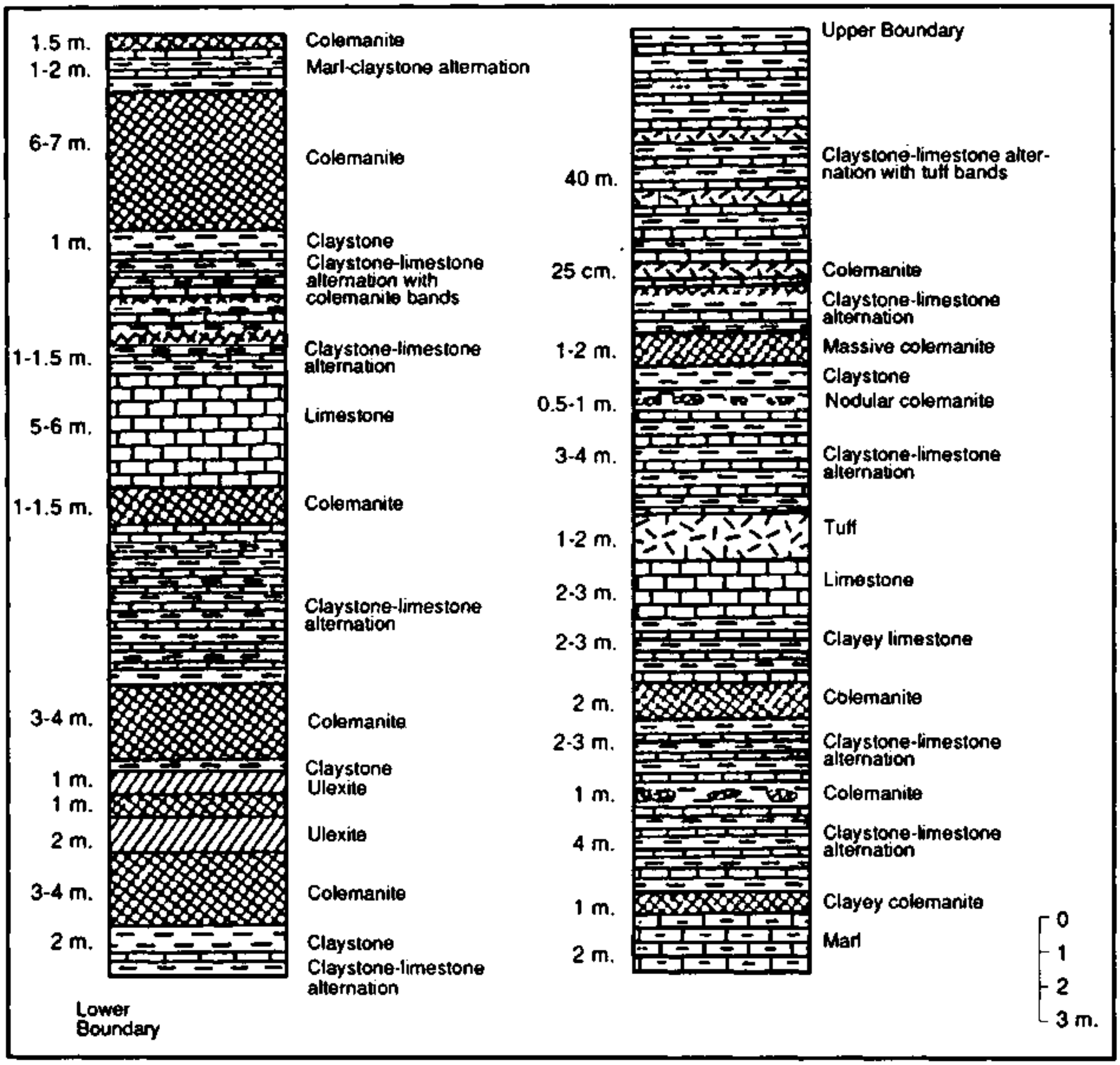


Fig. 7 - Measured section of Yeniköy deposit.

Pityosporites lapdacus

Triatriopollenites biluitus

Triatriopollenites coryphaeus

Triporopolleniles simpliformis

Triporopollenites labraferus

Subtriporopolleniles simplex.

Polyvestibulopolleniles verus

Tricolporopollenlles undulosus

Tricolporopolleniles microhenrici

Tricolporopolleniles pacalus

Tricolporopolleniles cingulum

Tricolporopolleniles megaexactus

Tricolporopollenites sp. (compositae)

Telracolporopolleniles sp.

Periporopolleniles multiporatus

Pollen species with wide vertical distribution comprise a small percentage of this association, while no pre-Miocene species could be determined. On the other hand, various Pliocene species occur among the principal types. Thus, the unit has been ascribed to Late Miocene (Late Pannonian-Dacian).

The unit rests on the basement volcanics or basement rocks at the marginal parts. At the central part of the basin, the unit overlies the lower tuff unit regularly. Considered the extension of the unit, it may be claimed that the depositional environment was very extensive during the deposition of the unit. Deposilional environments were lacustrine playa basins interconnected to each other or not. The mentioned playa basins had been rather deep during limestone deposition, but shallow during ore deposition.

Upper tuff unit. _ This unit is extensive at the central part of the study area. Upper tuff unit arises with coarse-grained tuff at the basement. This part is characteristic with its yellowish green color. Dark green pumice fragments and porous structure arc typical features. These arc used as light-weight construction material in the area due to their lightness and resistance. Upper parts of the unit, on the other hand, is composed of very fine-grained, light tuff with conchoidal fracturing. Fresh surfaces arc gray in color, and no mineral can be distinguished macroscopically.

Coarse-grained tuff contains two or three dimensional fracture systems, which have been stained red to brownish by the effect of circulating water, rich in iron oxide. Petrographic investigation of this tuff yielded rather high amounts of pumice, heulandite, clinoplilolite and analcime, besides lesser amounts of sanidine, quarz., plagioclase and biotite. Pumice with fibrous texture has been distributed irregularly within the rock. Some horizons of the unit arc predominated by zcolite minerals such as hculandite and clinoptilolile to an extent to be considered as economic zcolite deposit. This aspect of the unit has attracted attention for various exploration programmes and evaluation projects, which may result in the starting of cxploitatfon as a significant zcolite deposit, in near future. " .

Lower contact of the unit with the lower borate bearing unit is conformable and gradation exists. Upper contact with the upper borate is also conformable but no gradation exists.

The absence of carbonaceous and epiclastic intercalation within the unit, which was deposited by a new activity of volcanism that had been inactive during the sedimentation of lower borate unit, point to that volcanism continued without any interruption.

Thickness of the unit increases towards north within the basin (Fig. 8). This situation may be due to either the intensity of volcanic activity or the closeness of material to the feeding source and the depth of sedimentary environment.

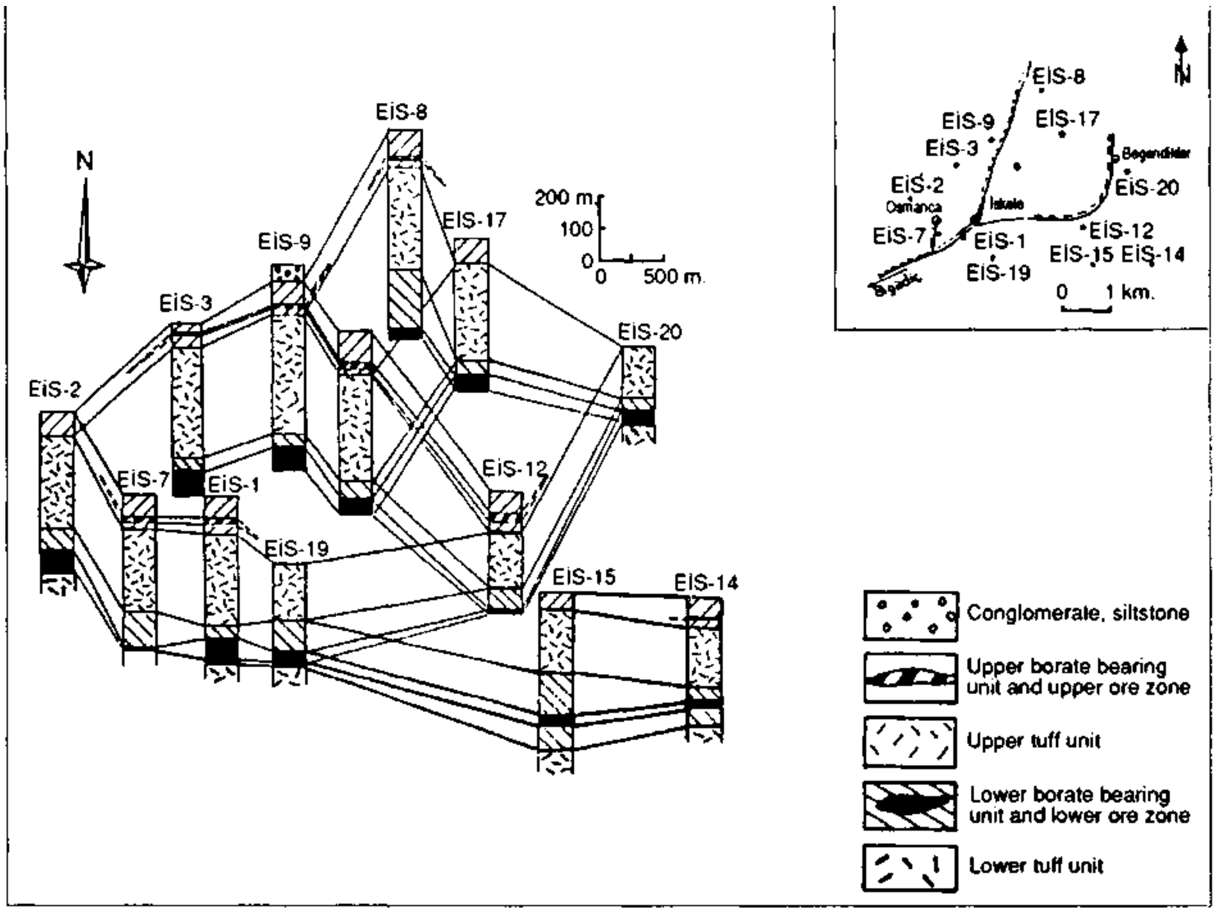


Fig. 8 - Correlation of deep drillings completed in Bigadiç basin.

Upper borate bearing unit. _ The unit comprises an alternation of limestone, claystone, clayey limestone, marl and tuff, and carries borate beds at intermediate levels.

The unit starts with an alternation of thin-bedded, tuff banded claystone, limestone and marl at the bottom. Over this alternation, a soapy platy claystone and ore zones rest. Ore zone is overlain by reddish-brown laminated claystone. An alternation of claystone and limestone, with thin to medium tuff and limestone bands covers the former lithclogies. The unit ends up with a thick bedded limestone, occasionally containing chert bands (Fig. 9).

Color of the limestone in this unit is whitish to creamy. It is partly siliceous and contains dissolution cavities. Thickness of beds vary between 0.2 to 40 cm. Thin bedded marl is yellowish to creamy colored. Color of the tuffs is yellowish green due to alteration. They are medium bedded. They contain macroscopic biotite and feldspar. They locally reach thickness of 3 to 5 m. Clays are reddish-brown, green and gray in color, and have a soapy appearance. Platy claystones form guide levels at the top and bottom of the ore zone.

Ore zone occurs at the middle parts of the upper borate bearing unit. Thickness of the ore zone changes between 0.10 to 80.00 m. Economically exploited boron minerals are colemanite and ulexite. Ulexite is dominant at the Acep, Kireçlik,

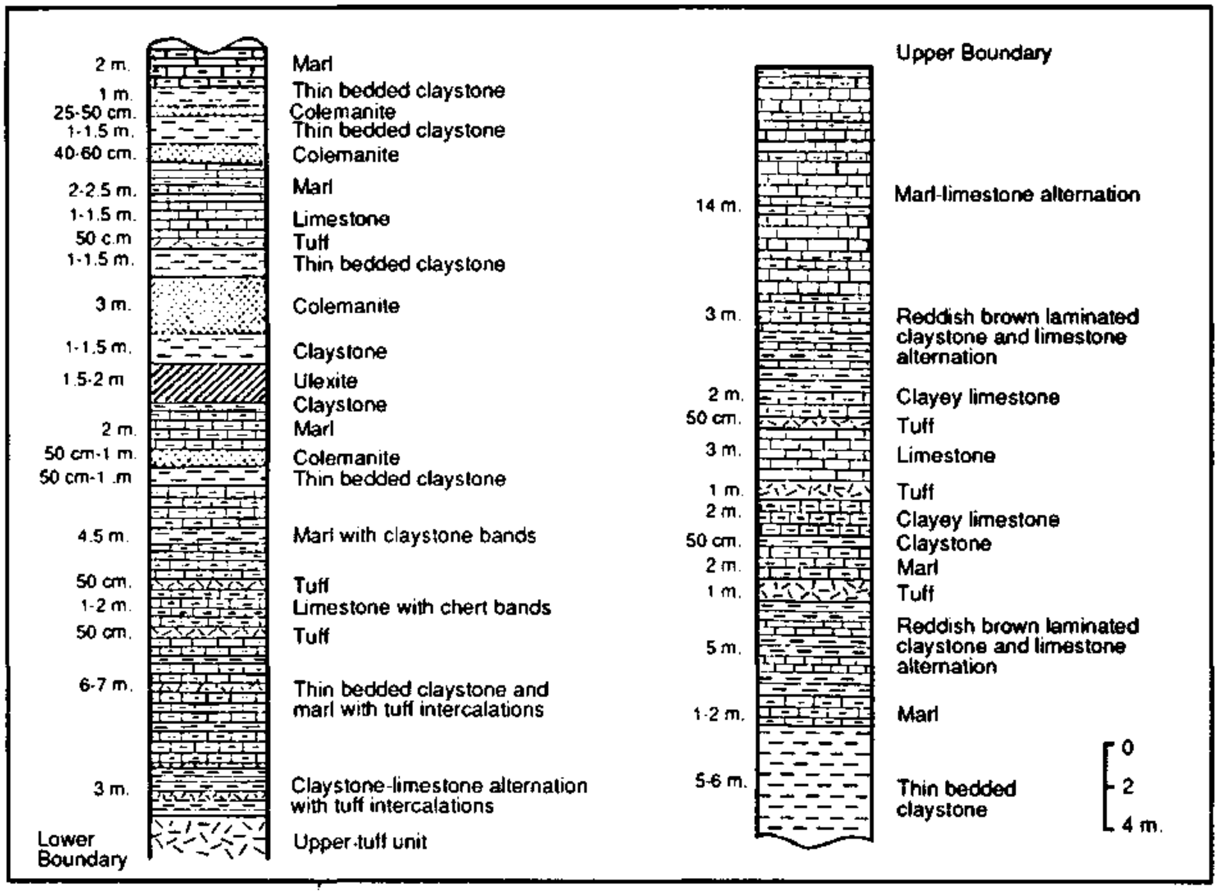


Fig. 9 - Generalized section of upper borate bearing unit in Kireçlik region.

Arka and Öngünevi deposits, while colemanite predominates in Avşar and Simav deposits. Other boron minerals determined at the ore zone of upper borate bearing unit are, mcyerhofferile, pandermite, probertite, howlite, tunellite, hydroboracite and inyoite. Thickness, number and distribution of borate beds at the productive pits are rather variable. In general, the borate beds have a lenticular structure.

Upper borate bearing unit overlies the upper tuff unit sharply and conformably at the bottom. At the top of the unit, recent sediments overlie unconformably.

The following ostracoda species were determined in the samples from various levels of the upper borate bearing unit (Gündoğdu, 1982):

Bakunella dorsoarcute (Zalanyi)

Candona convexa Livental

Candona paralella pannonica (Zalanyi)

Amplocypris cf. *recta* (Resus)

Hungarocypris hieroplyphica (Mehes)

This association indicates Upper Pannonian for the lower and middle parts of the unit, and *Lower* Pontian for the upper part of it.

The unit is a product of clastic and chemical sedimentation that started again following the volcanic activity, which produced the upper tuff unit. Laminated alternation of carbonaceous rocks and clastic rocks reflects the seasonal climatic changes during the precipitation of the unit and as well as facies changes and water level flactuation in the basin. Tuff bands within the unit, on the other hand, indicate that the volcanic activity also continued during sedimentation, though in short intervals. As the unit is observed in a rather limited area, it can be concluded that the dcpositional environment became very small during the deposition of the upper borate bearing unit.

Basalt. - This black and grayish black colored unit has cut all the other units older than itself. Thickness is not so big.

By the petrographic examination of the samples collected from the unit, a matrix of ophitic texture due to the irregular distribution of feldspar microlyths was determined, together with augite and olivine crystals that present between the feldspar crystals.

QUATERNARY

Recent sediments

These rocks crop out around the İskele and Osmanca villages, and between the Avşar and Simav pits, at the central part of the investigated area.

The unit starts with a basal conglomerate with limestone pebbles. The conglomerate is overlain by claystone, sandstone and pebblestone banded siltstone. Siltstone is gray and locally yellowish red in color, and thin bedded. Claystone is yellowish red and laminated. The cement of pebblestone components is tuff, which is partly altered into clay. Thickness of the unit ranges among 3 to 180 m.

The unit overlies upper borate bearing unit unconformably. At the top, it underlies alluvium, again unconformably. The unit carries pre Neogene and Neogene aged materials. By regional correlation, it has been ascribed to Quaternary in age. Alluvium, which covers all the units unconformably, is composed of the pebbles, sand and clays of basement rocks and Neogene units.

TECTOMSM

Neogene sediments of the Bigadiç volcano-sedimentary basin have deposited in a number of individual or interconnected basins, bordered by extensive basement rocks. The formation of these basins may go back as far as the beginning of Neogene. General trend of the sediments is NE-SW. Main tectonic elements of the investigated area arc folds, faults and unconformities.

Units composing the stratigraphic sequence at the area have general dips of 0°-35°, except for some local variations. The beds generally dip to NW and SE.

Folds

Synsedimentary and post-depositional folds can be distinguished at the Bigadiç volcano-sedimentary basin. Synsedimentary folds are common among the claystone and claystone-limestone alternations. The horizons at the lop and bottom of these folds do not show any inflection or dip changes.

Post-depositional folds have a general axial trend in NE-SW. These folds, contrary to the synsedimcntary ones, have affected the ore zone. Ore-bearing horizons are thicker at the apices of synclines but thinner at the flanks of folds.

Small-scale folds are abundant in the upper borate bearing unit. These small-scale folds appear as overturned anticline and synclines, isoclinal folds and flexures. The lower borate bearing unit, however, does not bear so frequent small scale folds. The reason is that, the unit is overlain by the upper tuff and upper borate bearing unit, which protected the unit against deformation.

Faults

In the Palaeozoic and Mesozoic rocks, comprising the basement at the area, various rise and falls occured due to the block faulting of pre-Miocene growth faults and dislocations. This resulted in the formation of sedimentary basins, where the Neogene sediments were deposited. Large scale faults, which gave rise to the generation of the sedimentary basins, have also served to conduct the boron exhalations to the environment during the deposition of the lower and upper borate bearing units.

Contemporaneous faults with the deposition of units (growth faults) caused the thickenning of ore-zones. Examples of these faults are the Kisekaya fault and the one observed in the south of Beğendikler village.

Recent faults in the basin have affected the ore zones. Ore veins have altered within the fault zones.

BİGADİÇ BORATE DEPOSITS

Bigadi9 borate deposits occur in two zones, as the lower and upper borate zones, separated from each other by the upper tuff unit. Distribution of the thickness of upper borate zone, occurring in the middle part of upper borate bearing unit, according to borehole data is as follows:

District	*Ore zone thickness (m.)*
Avşar-Simav	2-80.00
Günevi	0.5-23.60
Kireçlik	0.7-39.00
Yellicetepe	3.3-18.60
Around İskele	0.2-73.70

Aerial distribution of thickness of lower borate zone, occurring in the lower portion of the lower borate bearing unit, according to borehole data is given below:

District	*Ore zone thickness (m.)*
Yeniköy	0.2-76.00
Tülüovası	8.2-54.00
Deep boreholes	8.2-67.90

According to these data, thickness of the upper borate zone varies between 0.10-80.00 m. and that of lower borate zone between 0.20-76.00 m. Asihough the thickness of the upper borate zone appears to be bigger than the lower borate zone, net ore thickness of lower borate zone is bigger than that of the upper (Figs. 10 and 11).

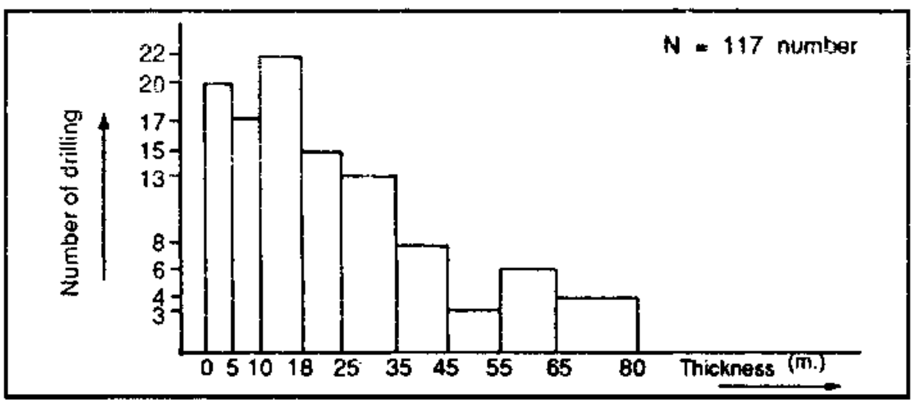


Fig. 10 - Geometric frequency distribution of ore zone thickness according to the drillings completed in upper borate bearing unit.

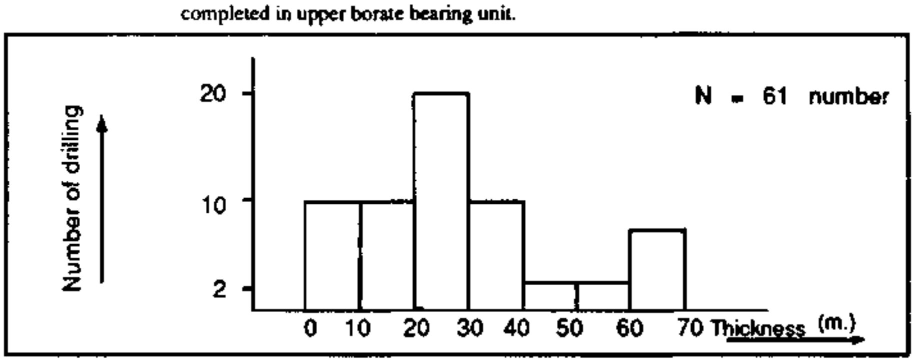


Fig. 11 - Geometric frequency distribution of ore zone thickness according to the drilling completed in lower borate bearing unit.

Correlation of the ore veins cut by drilling at the lower borate zone is easier than that of the upper zone. The reason is that, the extension of ore veins in the lower borate zone is more regular. In addition, alteration is not as effective in the lower borate veins as the upper zone, because the upper tuff and upper borate bearing units have preserved it Tuff bands within the ore zone of lower borate bearing unit are more abundant than the upper borate zone.

Correlation of the deep boreholes performed at the basin is given in Figure 8. As seen from the figure, thickness of the lower borate ore zone is more homogenous than the upper borate ore zone.

Etibank's mineral production in the area comes from open pit and underground mines. Distribution of mines in the area is as follows: Yeniköy underground and Tülü open pit mines at the lower borate zone, and On and Arkagünevi, Kireçlik, Avşar, Simav underground and Acep open pit mines at the upper borate zone.

Other than the currently producing mines, there are closed mines in the basin. These are; Mezarbaşı, Acep, Salmanlı, Beğendikler and Çamköy underground and Kurtpınarı open pit mines in the upper borate zone. Detailed stratigraphy of these pits are presented here under.

Avşar and Simav deposits

Avşar and Simav underground mines are located at the southwestern margin of the basin within the upper borate bearing unit. Colemanite is more dominant than ulexite in these deposits. Nevertheless, both minerals are produced together.

6 ore veins exist at the Avşar mine. 4 of these veins comprise colemanite and the remaining 2, ulexite. The order of veins from bottom to top is as follows: Colemanite (30 % B_2O_3), ulexite(32 % B_2O_3), ulexite (33 % B_2O_3), colemanite (34 % B_2O_3), colemanite (42 % B_2O_3), colemanite (35 % B_2O_3). Claystone-limestone-marl alternations of variable thickness occur between the veins.

At the Simav mine, the sequence in the ascending order is as follows: 2-2.5 m. colemanite, claystone-limestone alternation, 4 m. ulexite (34 % B_2O_3), tuff and limestone bands, 2.5-3 m. colemanite (35 % B_2O_3), claystone-limestone alternation , 2.5 m. colemanite (36 % B_2O_3), claystone and tuff bands and 2.5 m. thick colemanite ore (29 % B_2O_3) (Fig. 12).

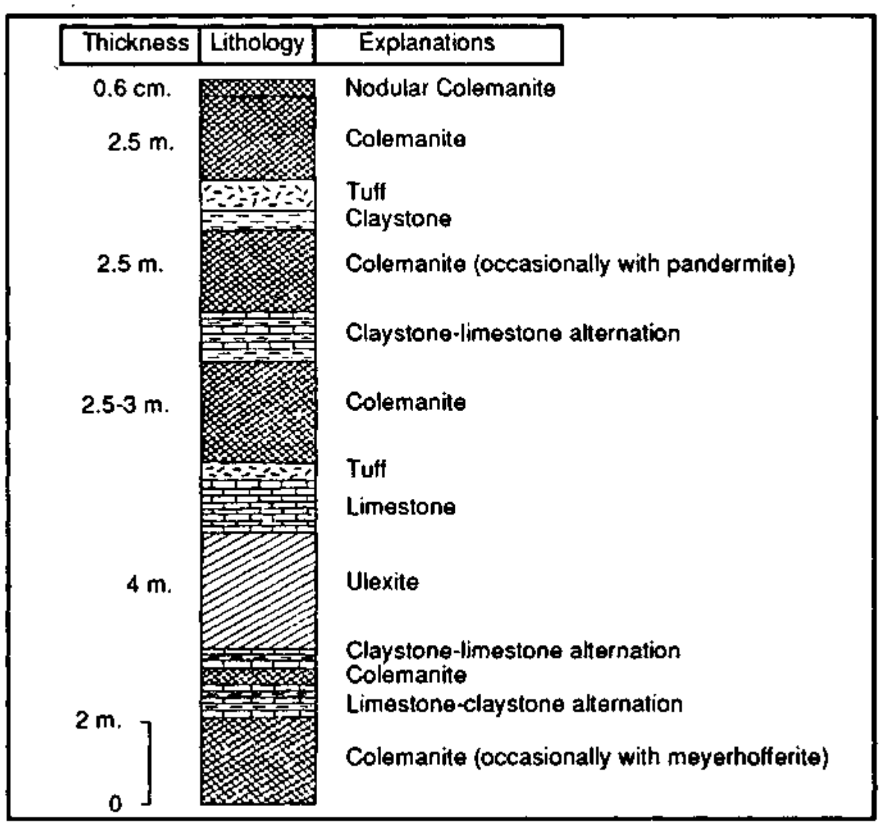


Fig. 12 - Detail measured section of Simav deposit.

In Figure 13, ore zone profile and % B_2O_3 grades of ore veins are given for the AS-4 borehole at the Avşar-Simav area.

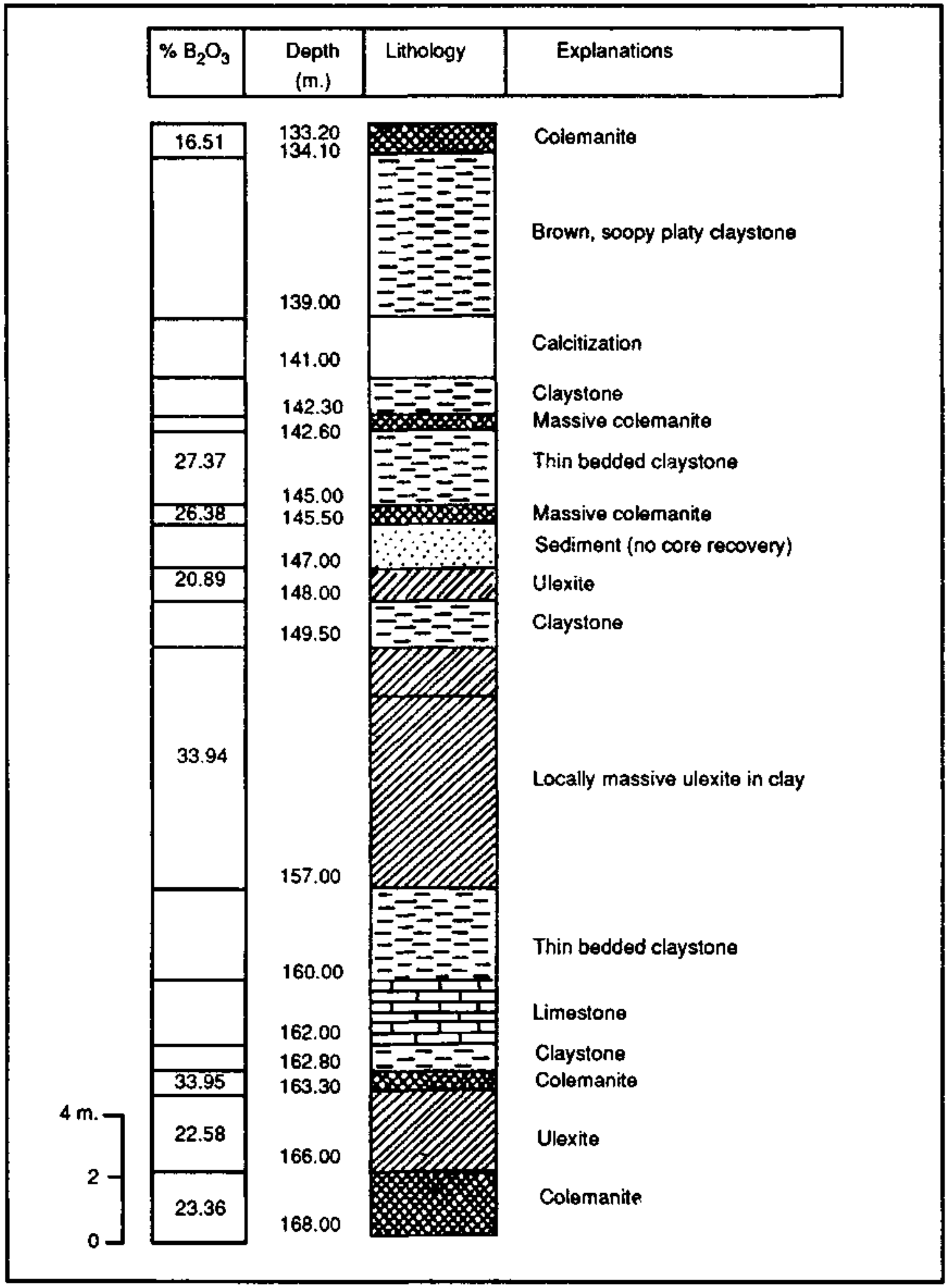


Fig. 13 - Ore zone distribution and % B_2O_3 contents of ore beds of AS-4 drill core completed between Avşar and Simav deposits.

Kireçlikdeposit

This deposit is located at the southeastern part of the basin, in the south of Kireçlik hill, within the upper borale bearing unit. Colemanile and ulexite are exploited from the mine.

Ore zone arises with white colored, pure and massive colemanite at the bottom, whose thickness is about 0.5-1 m. Proceeding upward, an ulexite vein of thickness 3 to 4 m. lies on the colemanite. Upper part of this ulexite vein carries secondary ulexite veins of 5-10 cm. thick. Over the ulexite lies a laminated claystone-limestone-tuff and marl alternation, 4-5 m. thick, in which limestone is dominant. Another ulexite vein of thickness 3-4 m. lies over this alternation and it carries 5-10 cm. thick bands of meyerhofferite. A 2.5 m. thick claystone-limestone alternation covers the ulexite. At the uppermost part of the ore zone, 2.5-3 m. thick colemanite has deposited (Fig. 14). Produced ore grade of ulexite is 30.50 %B_2O_3 and colemanite 34 % B_2O_3 at the Kireçlik mine.

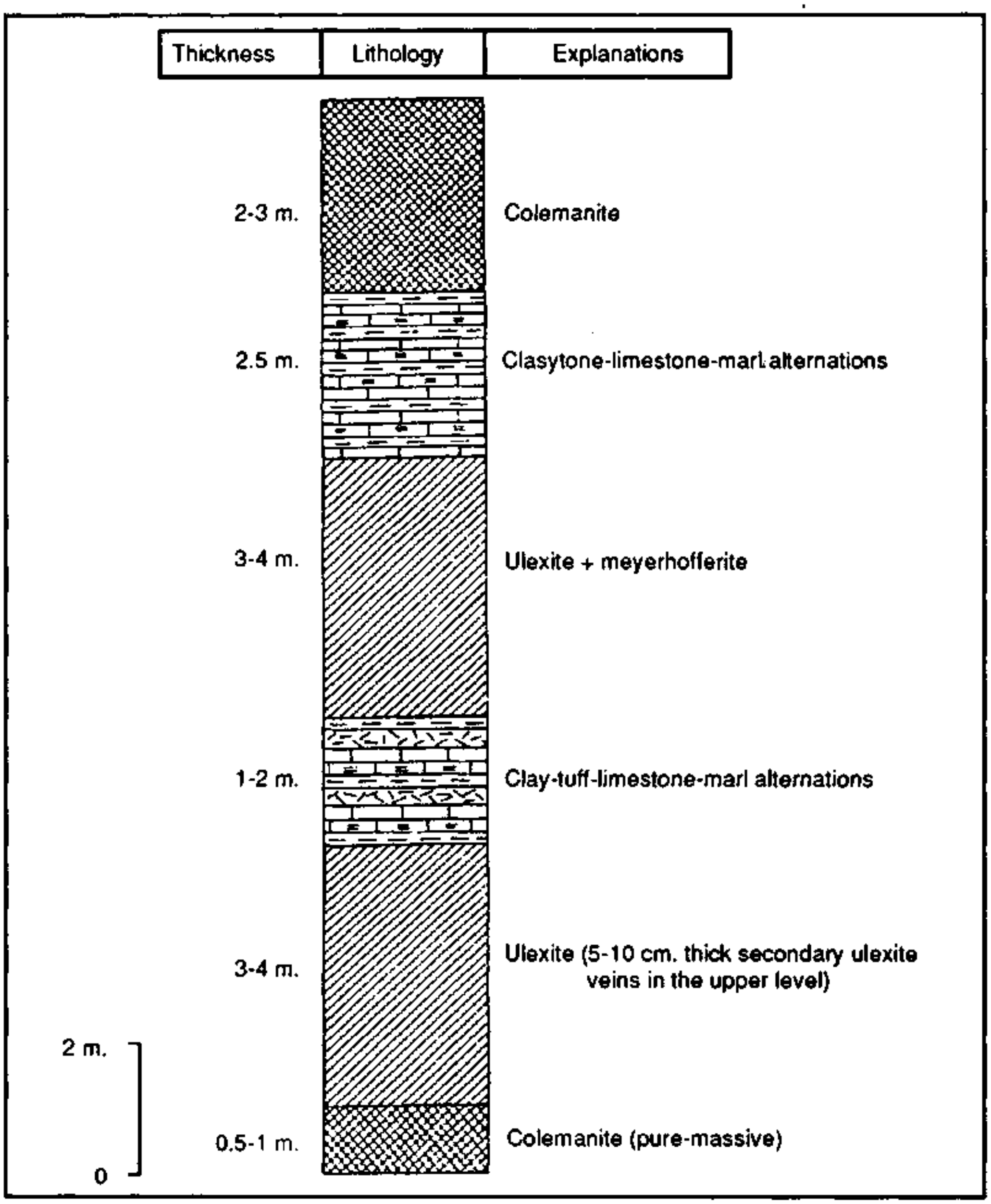


Fig. 14 - Measured section of Kireçlik deposit.

In Figure 15, ore zone profile and % B_2O_3 grades of ore veins are given for the KS-17 borehole, drilled in the north of the mine.

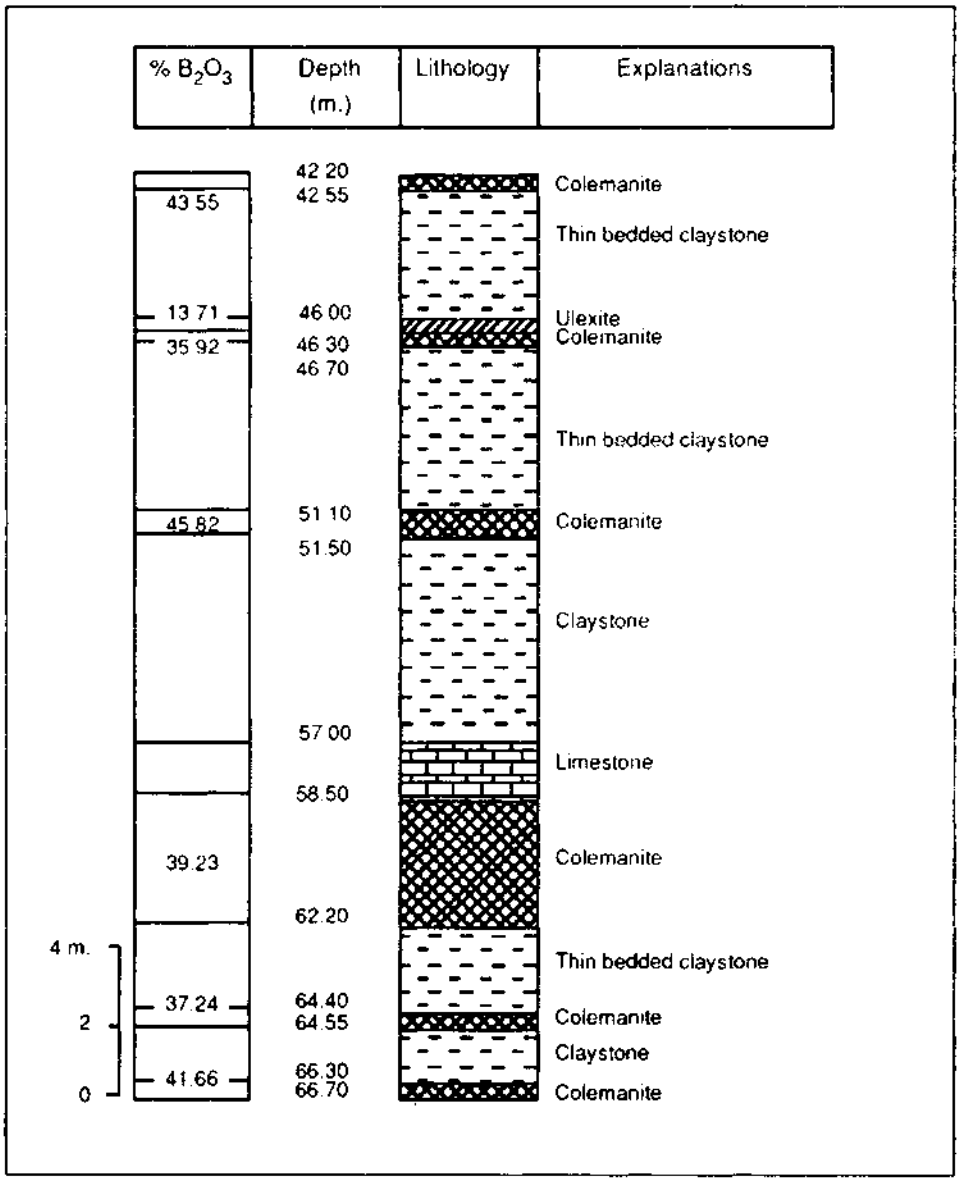


Fig. 15 - Ore zone distribution and % B_2O_3 contents of ore beds of KS-17 drill core completed in Kireçlik area.

Günevi deposits

Günevi deposit are located in the northeastern part of the basin, within the upper borate bearing unit. Ulexile is more dominant than colemanite.

Ore zone of the Öngünevi deposit starts with 10-15 cm. thick colcmanite at the basement. Clays, intercalated within the colcmanite occasionally contain hydroboracite. An ulexite zone of 5 to 6 m. thick, with camel's-tooth appearance lies over the colemanile. These camel's-tooth like ulexite crystals may be as big as 5 cm. Clay has filled the space between the crystals. Tunellite mineral, which looks like muscovite flakes with its glimmering crystals, occur within the ulexite. Diameter of the crystals is about 2 cm, 10-15 cm. thick hydroboracite horizon occurs over the ulexite. Another ulexite of 1-1.5 m. thick with clay bands overlies hydroboracite. Thickness of clay bands is about 10-15 cm. The uppermost level comprise gypsiferous colemanite with thickness 1-1.5 m. (Fig. 16).

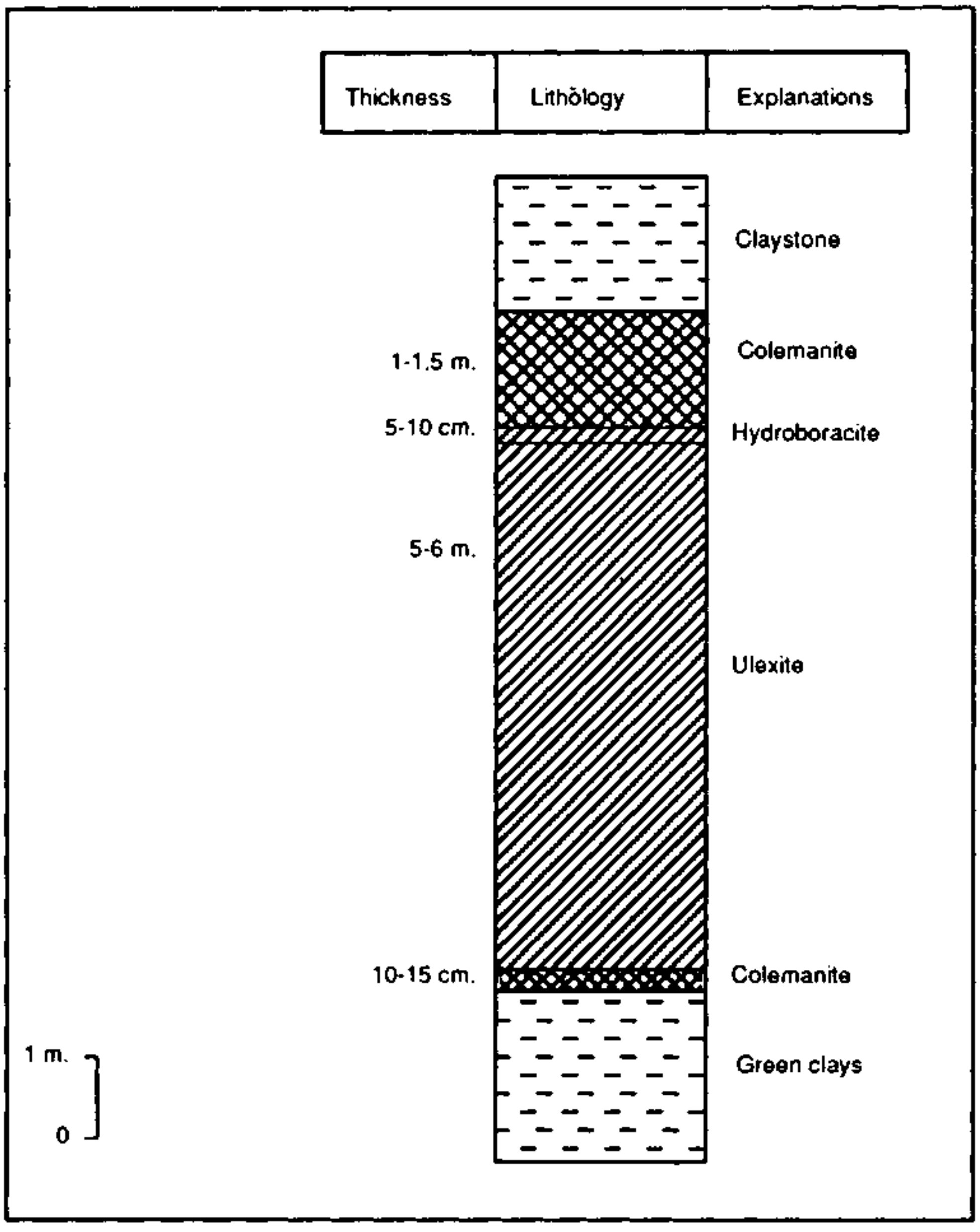


Fig. 16 - Measured section of Öngünevi deposit.

The ore zone of Arkagünevi deposit arises with colemanile at the basement. It proceeds with an ulcxile vein of 4-6 m. thickness, which contains a 20-25 cm. thick clay band. Ulexite is overlain by a clayey horizon and between these two, tunellitc and colemanile layers have been determined. Thickness of these are 5-10 cm. Clayey bed contains marl bands. Another ulexite in camel's-tooth type, whose thickness varies from 3 to 3.5 m., overlies the clayey bed. 1.5-2 m. thick another clay *zone* covers the ulexite, followed by a colemanite zone, in which fibrous colemanite is intercalated with clays. Thickness is 5-10 cm. At the upper levels of colemanite zone, colemanite crystals are observed within nodular, soapy clays. Fractures, developed during the late-diagenesis stage have been filled by secondary white, glimmering and pure colemanite (Fig. 17). Ore grade of the ulexite produced from Arkagünevi deposit is 31 % B_2O_3.

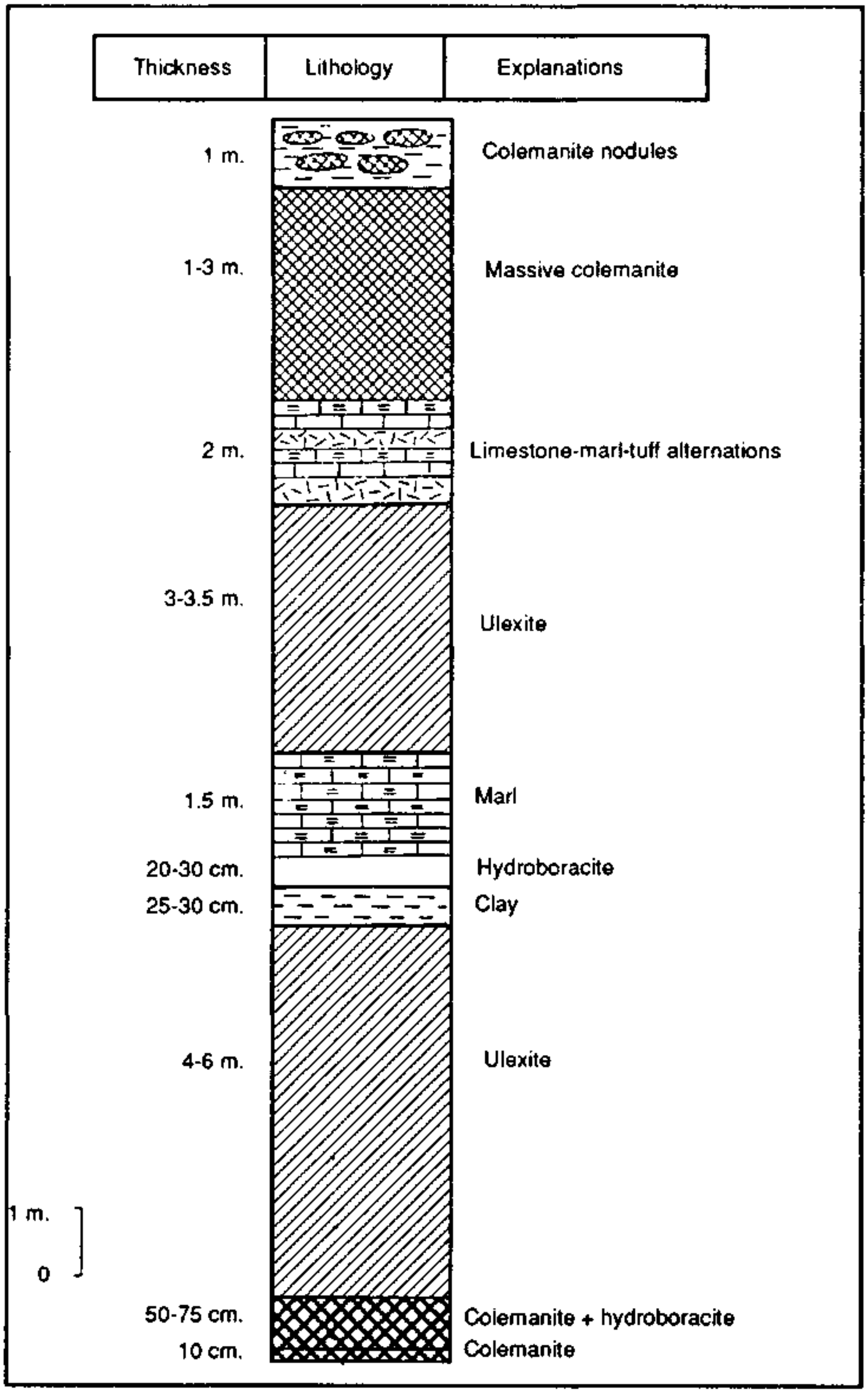


Fig. 17 - Measured section of Arkagünevı deposit.

In Figure 18. ore zone profile and % B_2O_3 contents of ore veins are given for the GS-3 borehole at the Günevi mining area.

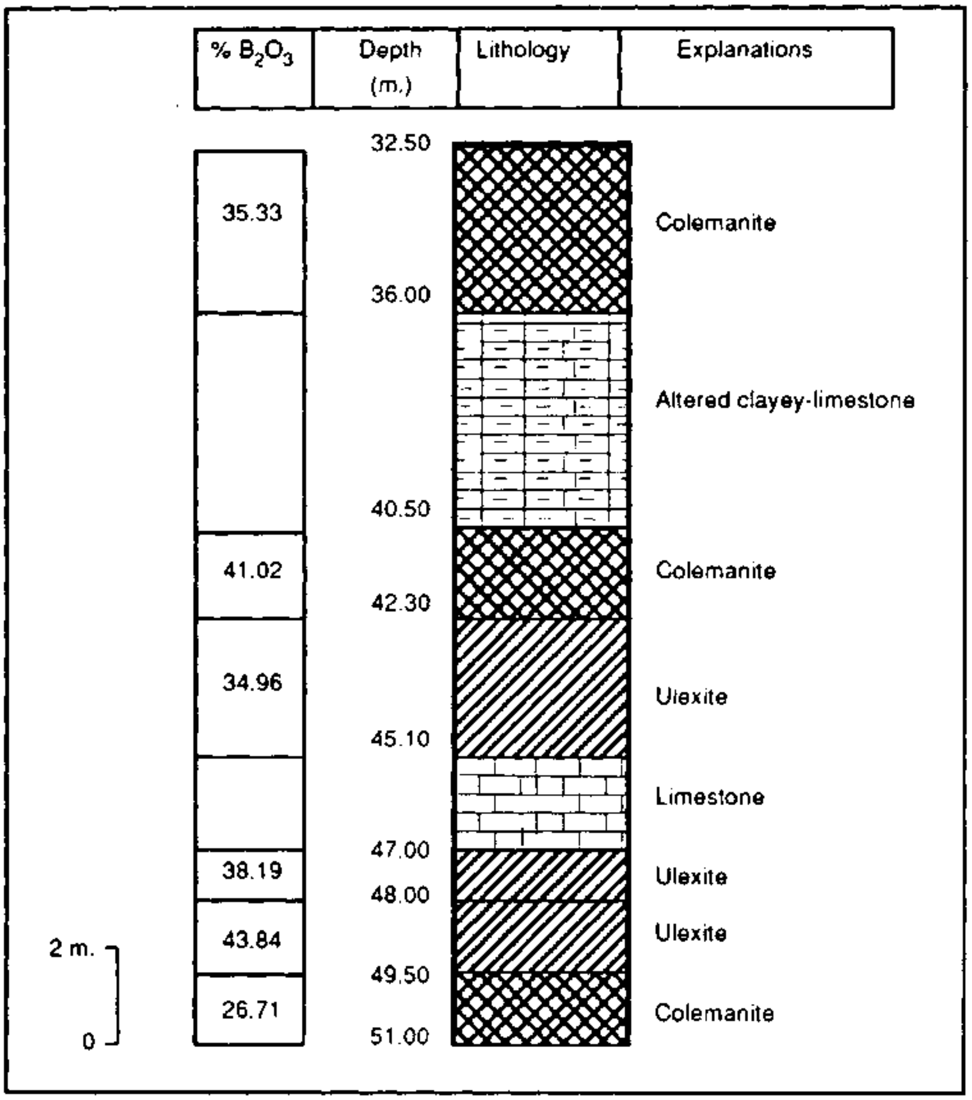


Fig. 18 - Ore zone distribution and % B_2O_3 contents of ore beds of GS-3 drill core completed in Gunevi area.

Acep deposit

This mine is located almost in the central part of the basin within the upper borate bearing unit. Both colemanite and ulexite are produced from the deposit, but ulexite is more dominant. The sequence from the bottom in the ascending order is as follows: 0.5-1 m. thick colemanite (33 % B_2O_3) horizon, 25-50 cm. clay horizon. 1.5-5 m. thick ulexite (30 % B_2O_3) (this horizon contains two separate colemanite layers whose thickness may reach 20 cm. locally), 25 cm. colemanite, 1-2 m. thick marl and clay horizon, 50 cm. thick ulexite (Fig. 19). Proceeding upward, clay and marl alternations increase in number and non economic colemanite bands occur. At the uppermost part, an alternation of claystone and limestone is observed. There arc sporadic occurrences ofinyoite,meyerhofferiteand gypsum within the bed. Ore zones dip north, towards the İskele village.

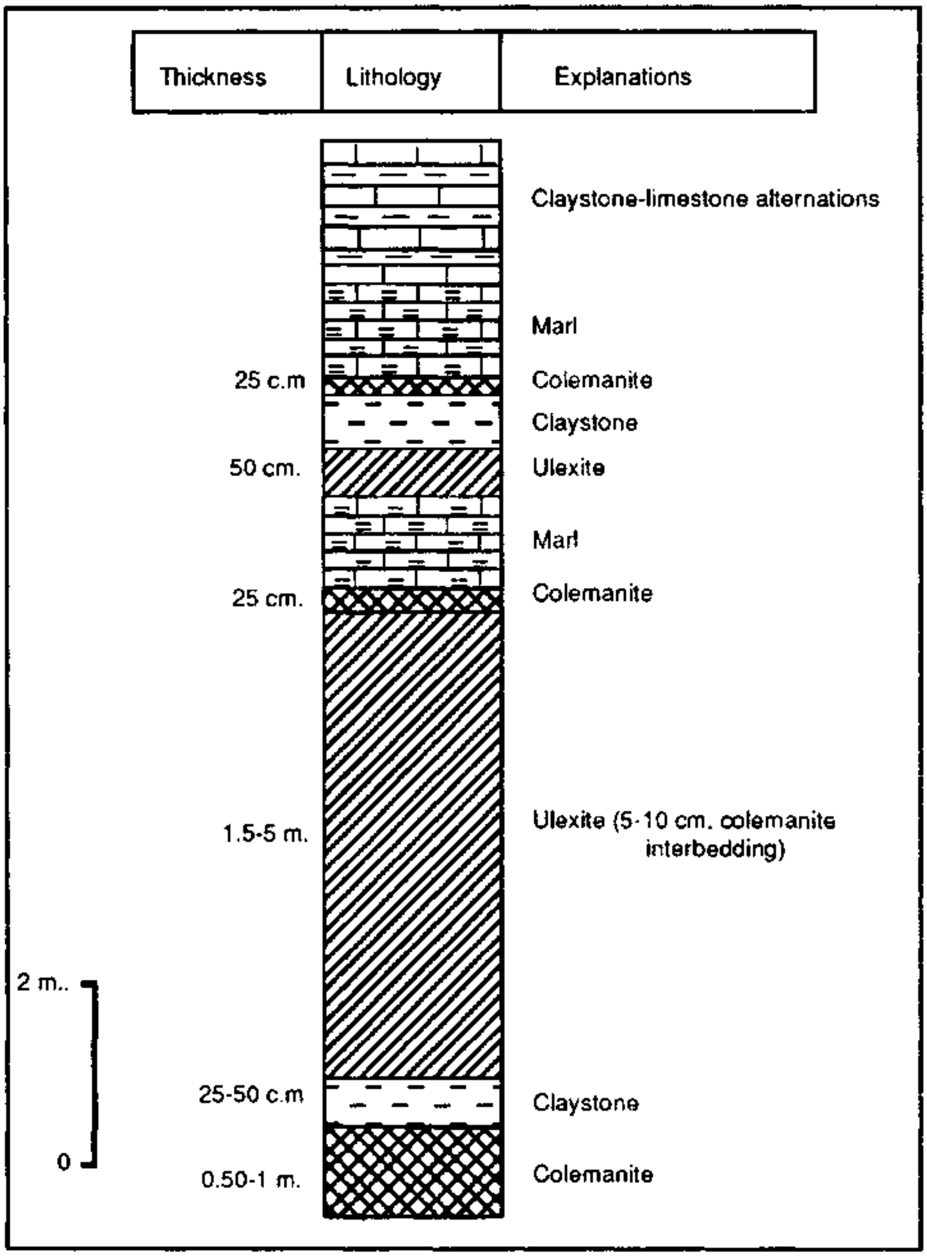


Fig. 19 - Measured section of Acep deposit.

In Figure 20, ore zone profile and % B_2O_3 contents of ore veins are given for the APZ-22 borehole.

Tülü deposit

Tülü deposit is located in the lower borate bearing unit. Colemanite is produced from the deposit.

The sequence observed within the deposit from bottom to lop is as follows: 10-12 m. thick colemanite (33 % B_2O_3), 2 m. clay, 2-3 m. thick colemanite (as small nodules), 2.5-3 m. thin laminated clay-limestone alternation, 2 m. colemanite, 4-5 m. claystone-limestone alternation, 25-30 cm. colemanite, 7-8 m. claystone-limestone alternation, 2.5-3 m. nodular colemanite, 50-75 cm. clay, 15-50 cm. massive colemanite (Fig. 16).

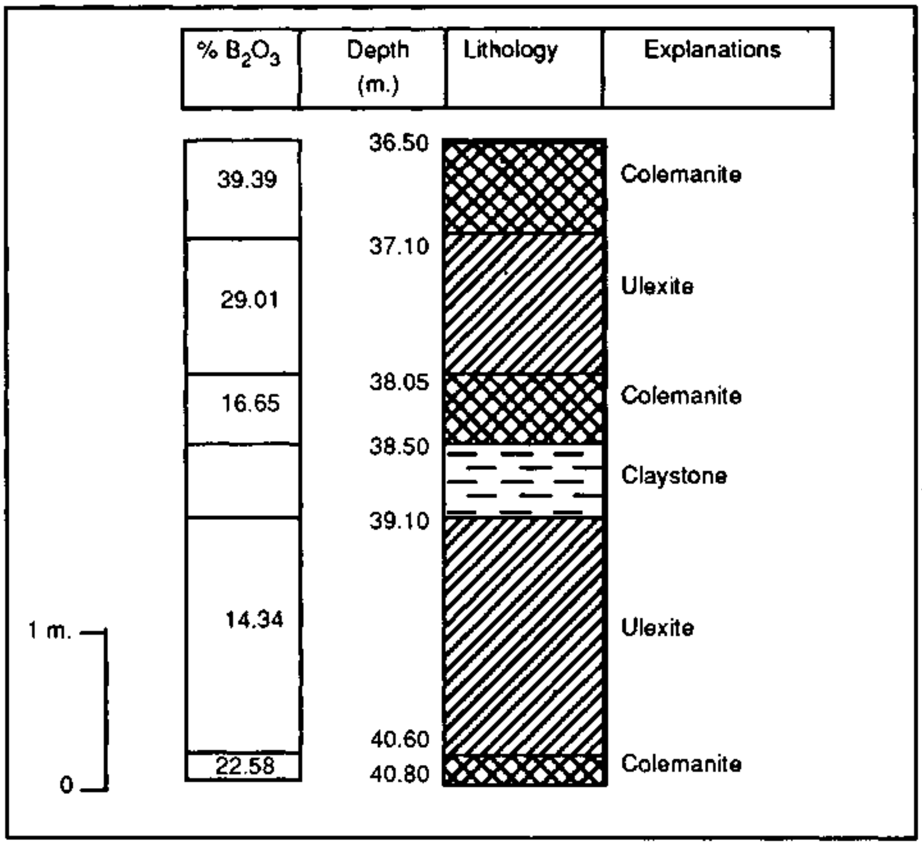


Fig. 20 - Ore zone distribution and % B_2O_3 contents of ore beds of APZ-22 drill core completed in Acep area.

In Figure 21, ore zone profile and % B2O3 contents of ore veins are given for the TS-5 borehole at Tülü plain.

Yeniköy deposit

This mine is located at the northwestern part of the basin, in the lower borate bearing unit. Ulexite deposition is more dominant than colemanite in this deposit.

The sequence from bottom to top is as follows: 3-4 m. colemanite, 2 m. ulexite, 1 m. colemanite, 1 m. ulexite, 20-30 cm. clay, 3-4 m. colemanite with clay bands, 12-14 m. claystone-limestone alternation with 10-15 cm. colemanite, 1-1.5 m. colemanite, 5-6 m. limestone, 20 m. claystone-limestone alternation with colemanite bands, 1 m. green clay, 6-7 m. colemanite, 1-2 m. marl, 1.5 m. colemanite, 9-10 m. claystone-limestone alternation (contains a colemanite band of 1 m. thickness), 2 m. colemanite, 0.5-1 m. clay, 25 cm. colemanite (Fig. 7).

The mines, whose stratigraphic sequences have been explained above, are the currently producing mines. There are also closed mines in the area, which are Mezarbaşı, Acep, Salmanlı, Beğendikler, Çamköy underground mines and Kurtpınarı open pit, located in the upper borate zone.

Although detailed stratigraphy of the closed mines cannot be given here, boron minerals characteristic for each deposit, determined from the tailing dumps, may be slated as follows: colemanite (and pandermite) for Mezarbaşı deposit; colemanite and ulexite for Acep deposit; colemanite for Salmanlı deposit; colemanite and ulexite for Beğendikler deposit; colemanite and ulexite for Çamköy deposit (tailings also contain meyerhofferite). Colemanite and ulexite had been produced from the Kurtpınarı open pit, where howlite nodules are found within the clays alternating with colemanite.

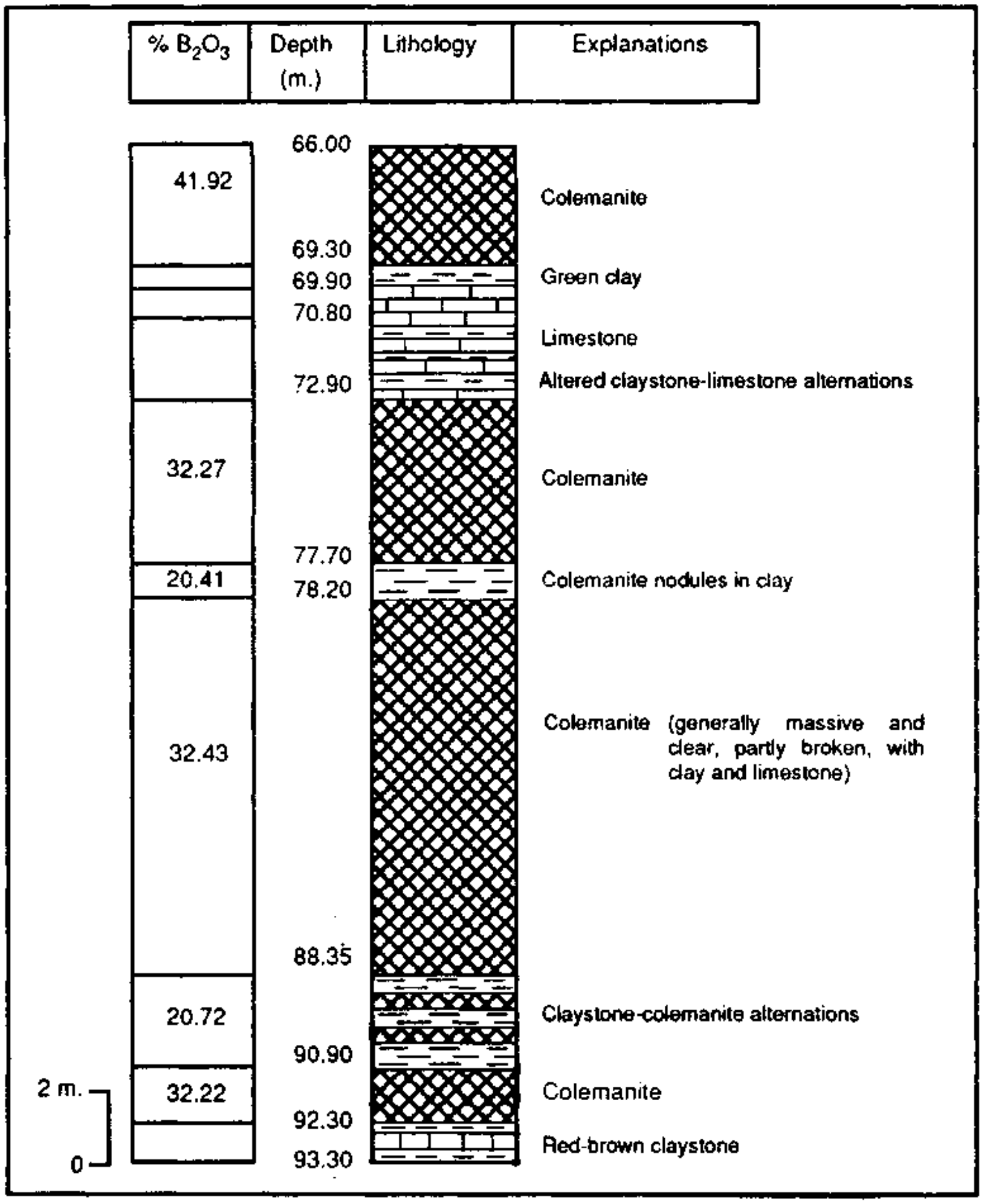


Fig. 21 - Ore zone distribution and % B_2O_3 contents of ore beds of TS-5 drill core completed in Tülü plain.

MINERALOGY

As the borate precipitation follows that of calcium carbonate, and due to the *Ca.*$^{++}$ abundance, the first borates to precipitate should be Ca-borates. As the sedimentation and evaporation progress, Ca-Na-borates start to precipitate. If the suitable circumstances exist and if the Na-concentration has reached the satisfactory level, Na-borate precipitation follows. Further precipitation sequences include the re-precipitation of Ca-Na-borates and Ca-borates, respectively. This zonation represents a complete mineralogic evolution in a borate deposit (Helvacı, 1983).

As the Na-borates have not precipitated at the Bigadiç borate deposit, it exhibits an incomplete sequence of mineral distribution. Moreover, Bigadiç borate deposit may roughly be considered as a Ca-borate deposit.

In both of the individual borate zones at the Bigadiç: basin, colemanite and ulexite are dominant over other boron minerals. Other boron minerals, determined within the basin are; howlite, probertite and hydroboracite in the lower borate zone; inyoite, meyerhofferite, pandermite, probertite, hydroboracite, howlile and tuncllite in the upper borate zone (Helvacı and Alaca, 1984).

Table 1 gives the list of boron minerals determined at the deposits in Bigadiç basin, and Table 2 shows the chemical analysis results of minerals produced.

Clays, accompanied with boron minerals, generally belong to the smectite group. Zeolite minerals, such as heulandite and clinopulolite have been determined in the tuff horizons. Calcite, aragonite, dolomite, gypsum, quartz and opal-CT are distributed all over the deposits (Helvacı and Dora, 1985).

Boron minerals of economic signiflcance

Economic borate exploitation covers the colemanite and ulexite minerals in all deposits of the area.

Colemanite occurs as nodular, platy, banded, fibrous and, to a lesser extent, as euhedral crystals. Diameter of nodular colcmanites may reach even uplo 40 cm. Nodules are sometimes formed by radial growth from one unique center, and other times multi central growth is observed. Multi central nodules generally occur as an interference of crystal bundles. Small nodules, which compose the larger ones are enclosed by thin clay films. When these nodules are broken, the clay films can be distinguished. Radial crystals show various evolutionary stages during the formation of nodules. Fibrous colemaniles establish bands in different horizons. This type of colemanites are pure and white colored. At some instances, these may be confused with ulexite developed in a similar manner. However, ulexite's silky luster and softness are important criteria in distinguishing the two minerals (Helvacı and Dora, 1985).

Due to the late diagenetic influences, fracturing from the center to the marginal parts and solution at the center occurs. Secondary pure, transparent and euhedral colemanite crystals have generated by circulating water within the solution cavities and fractures. Such crystals have also formed in the spaces between different beds.

Although being variable, thickness of massive colemanite beds may reach even uplo 5 m. This type of colemanites do not carry so much foreign material; they are rather pure and white in color. However, clayey colemanites exhibit a composite structure together with clay. Ore grade of these colemanites change in relation to the amount of clay contained.

Ulexites exhibit camel's-tooth, nodular and banded structures in the deposits. Camel's-tooth structured ulexites dominantly occur intercalated with clay. Color of this type of ulexitcs is dirty white. These ulexites, which make very strong and resistant horizons in underground mines, easily disintegrate under atmospheric conditions. Length of the tooth like crystals of camel's tooth ulexite may reach upto 5 cm. Thickness of the ulexite horizons vary from 1.5 to 5 m. at the deposits. Ulexites show a wide distribution especially in the central part of the basin. Proceeding to the margins, ulexite horizons end up in lenses and colemanite becomes dominant. Banded ulexites are composed of thin, radial crystal fibers, developed perpendicular to band walls. Due to their more compact texture, they are harder than camel's-tooth ulexites. Banded ulexitcs with silky luster are pure and light colored. In the case of nodular ulexites, mostly mulli central radial crystal bundles occur intersecting each other. Finally, these crystal bundles form a big nodule. These nodules occasionally lose their radial character and gain a massive structure.

Secondary ulexite has developed in the fractures and cavities, formed during and after late diagenesis. These ulexites with a distinct silky luster contain no impurity. Thickness of these ulexites, which usually cut the bedding plane, may reach as much as 10cm.

Gradation from colemanite into ulexite is mostly very sharp but sometimes gradational transition also occurs. At the gradational transition zones, colemanite and ulexite have grown together.

Non-economic boron minerals

Inyoite, one of the non-economic boron minerals occurring at the Bigadiç area, is observed as uniform and transparent crystals. This mineral occurs together with colemanite in the Acep and Kireçlik deposits.

Yellowish white colored meyerhofferite occurs in a net-texture, generally composed of regularly oriented crystals and occasionally nodules with radial structure. It is observed in the Avşar, Simav and Kireçlik deposit together with colemanite.

Table 1- Boron minerals determined at the productive deposits in the Bigadiç basin

DEPOSITS / MINERAL NAME	UPPER BORATE BEARING ZONE							LOWER BORATE BEARING ZONE	
	AVŞAR	SİMAV	ACEP	ÖNGÜNEVİ	ARKAGÜNEVİ	KİREÇLİK	KURTPINARI	YENİKÖY	TÜLÜ
Colemanite	+	+	+	+	+	+	+	+	+
Ulexite	+	+	+	+	+	+	+	+	+
Meyerhofferite	+	+	+			+			
Inyoite			+			+			
Pandermite		+						+	
Tunellite				+	+				
Howlite							+		
Hydroboracite				+	+	+			
Probertite				+	+				

Table 2- Chemical analysis of colemanite and ulexite ores produced from the deposits in the Bigadiç basin

MINE NAME MINERAL NAME	B_2O_3	Fe_2O_3	Al_2O_3	SiO_2	SrO_2	BaO	CaO	MgO	Na_2O	K_2O	P_2O_5	KK*	Cu	Ni	Zn	Pb	Mn	As	S
COLEMANITE																			
Avşar	35.85	0.07	0.04	8.94	0.98	0.31	26.21	4.18	0.14	0.03	0.01	23.96	0.02	0.01	0.015	0.005	0.01	0.007	0.02
Simav (1. damar)	30.67	0.06	0.07	10.46	0.84	0.33	27.70	4.54	0.064	0.03	0.01	25.56	0.003	0.005	0.004	0.003	0.009	0.008	0.01
Yeniköy	24.01	0.06	0.03	7.12	0.28	0.43	38.35	2.99	0.064	0.04	0.02	29.10	0.005	0.005	0.02	0.01	0.16	0.006	0.01
ULEXITE																			
Avşar	31.92	0.05	0.12	10.32	1.24	0.23	16.72	5.46	3.96	0.04	0.01	29.01	0.003	0.01	0.003	0.003	0.007	0.006	0.01
Simav	33.71	0.03	0.04	7.71	0.51	0.20	16.14	4.21	4.88	0.03	0.01	30.21	0.005	0.003	0.003	0.003	0.007	0.006	0.01
Yeniköy	30.97	0.05	0.13	8.74	0.32	0.22	20.15	4.56	3.97	0.04	0.01	30.36	0.005	0.003	0.003	0.003	0.006	0.006	0.01
Yeniköy	24.09	0.12	0.33	12.15	0.28	0.31	22.73	6.59	2.87	0.07	0.02	31.06	0.005	0.002	0.005	0.004	0.01	0.006	0.01
Öngünevi (Tb Ulexite)	44.19	0.05	0.01	1.58	0.56	0.18	13.41	0.55	6.10	0.01	0.01	29.99	0.02	0.005	0.007	0.004	0.005	0.006	0.001
Öngünevi (Tv Ulexite)	40.15	0.02	0.02	5.20	0.38	0.19	13.89	2.00	5.35	0.02	0.01	29.38	0.006	0.006	0.003	0.003	0.004	0.007	0.03
Arkagünevi (Tv Ulexite)	37.71	0.04	0.05	11.40	0.45	0.18	12.15	4.89	4.86	0.04	0.01	27.45	0.004	0.01	0.003	0.003	0.006	0.01	0.01
Arkagünevi	39.73	0.03	0.03	6.40	0.42	0.17	12.24	2.96	5.80	0.03	0.01	29.31	0.003	0.01	0.003	0.003	0.005	0.009	0.025
Arkagünevi	39.73	0.03	0.03	6.84	0.36	0.17	12.30	2.97	5.65	0.03	0.01	29.06	0.005	0.01	0.003	0.003	0.004	0.008	0.03
Kireçlik (Tv Ulexite)	34.98	0.02	0.01	10.36	0.72	0.21	11.98	5.40	4.86	0.04	0.01	28.54	0.004	0.01	0.003	0.003	0.006	0.006	0.04
Kireçlik (Tb Ulexite)	37.56	0.04	0.03	9.74	1.35	0.21	13.07	4.24	4.08	0.04	0.01	30.32	0.003	0.01	0.003	0.003	0.005	0.005	0.04

* KK = Loss on Ignition (H_2O+CO_2)

Pandermite is a fine crystalline, milky white colored mineral. At some localities, it exhibits a hard, horn like structure, but upon disintegration turns into a kaolin like mass. The mineral occurs together with colemanite in the Sirnav, Mezarbaşı and Yeniköy deposit.

Dirty yellow and dirty white colored probertite generally occurs as radial crystals. Infra crystalline spaces are mostly filled with clay. The mineral occasionally forms 20-30 cm. thick bands in ulexite veins. Probertite is determined in the deep drill cores from Öngünevi, Arkagünevi and lower borate ore zones.

Hydroboracite is white colored and occurs in masses composed of randomly oriented needles from a common center. These needles intersect with each other. Hydroboracite is derived from colemanite and forms thin horizons within the interbedded clay. The mineral is determined in the Öngünevi, Arkagünevi and Kireçlik deposit.

Tunellite is colorless and transparent. The crystals resemble muscovite flakes and show parallel cleavage. The mineral is derived from ulexite by lateral segregation, and commonly occurs within ulexite as transparent packs *of* thin platelets. It occurs in the Öngünevi and Arkagünevi deposits.

The lower borate ore zone, in particular, carries howlite bearing horizons. The mineral is white colored, compact and finely nodular. Small nodules of howlite tracing a certain horizon occur together with colemanite in the clays alternating with colemanite in the Kurtpınarı open pit, in the upper borate bearing unit.

Ore formation mechanism

Bigadiç borate deposits have formed in independent or interconnected playa lakes, located in areas where volcanic activity had been effective and supplied hydrothermal solutions and thermal water, under arid or semiarid climatic conditions. The deposits are interbedded with tuff, tuffite, claystone, marl and limestone. Bigadiç borate deposits occur in two separate zones, between which the upper tuff unit has deposited (Helvacı and Alaca, 1984).

In both of the zones, colemanite and ulexite are more dominant than other boron minerals. Thus, colemanite and ulexite are the principal ore minerals, while howlite, inyoite, hydroboracite, tunellite, pandermite and probertite remain as accessory minerals of no economic significance. For this reason, it is more convenient to discuss the composition of a borate deposit in a triple system, with the end members being CaO- Na_2O-B_2O_3.

As the precipitation of borates follows the chemical precipitation of carbonaceous sediments, due to the abundance of Ca^{++} in the playa lake water, first Ca-borates should normally precipitate. Together with Ca-borate precipitation, an enrichment of Na^+ takes place in the lake water. Thus, Ca-Na-borates start to precipitate as the process continues, and evaporation rate increases. Na-borates have not precipitated in the Bigadi9 basin. The reason is probably the lack of sufficient Na^+ within the solutions feeding the basin. This resulted in the precipitation of another Ca-Na-borate sequence. By the alternation of these processes, Bigadiç borate deposits have formed.

Colemanite formation by the transformation of ulexite, which was suggested first by Foshag (1921) for the Californian deposits, does not seem to prevail in the Bigadiç basin, because of the following reasons. First of all, no trace of colemanite with ulexite precursor could be determined anywhere. Na^+ enrichment of clays, in alternation with colemanites at Bigadi9, does not exist (Helvacı, 1989). On the other hand, if the following chemical reaction occurred by an exchange of bases between ulexite and clays, the clays should be enriched in Na^+, theoretically:

$3NaCa\ [B_5O_6(OH)].H_2O + 2Ca^{++} \longrightarrow 5Ca\ [B_3O_4(OH)3].H_2O + 3Na^+ + H^+$ (Helvacı, 1977; Helvacı and Firman, 1977)

Colemanite-borax mineral couple formation thesis due to the disintegration of ulexite is not applicable to the Bigadi9 borate basin, because Na-borate minerals could not be determined here (Helvacı, 1977, 1983; Helvacı and Alaca, 1984).

Colemanites at Bigadiç have not formed by the dehydration of inyoite under burial and diagenetic influence, because inyoite mineral cannot be found in every part of the basin, and pseudomorphic transformations of inyoite have not been determined (Helvacı and Alaca, 1984).

Colemanites occurring in the basin are possibly the primary precipitates from solutions and are contemporaneous to sedimentation, and they have formed within the unconsolidated sediments under the sediment/water interface (Helvacı, 1977, 1984, 1986; Helvacı and Alaca, 1984).

Precipitation of ulexites also occurred in a similar manner, in the period following the Ca-borate precipitation, when the Na+ concentration of the solution increased (Helvacı and Alaca, 1984).

Secondary idiomorphic colemanite and ulexite have formed by the circulation of solutions rich in boron, along the fractures and cavities, that were produced during late diagenesis, and by the disintegration of primary minerals.

Meyerhofferite occurs together with colemanite. No transformation of this mineral into another one or vice versa has been observed.

Hydroboracite, on the other hand, has formed by the transformation of colemanite. In this transformation, just the replacement of Ca^{++} by Mg++, and addition of water are sufficient:

$$2Ca\,[B3O4(OH)_3]\,.H2O + Mg^{++} + 2H_2O \text{———} MgCa\ [B_3O_4(OH)_3]_2.3H_2O + 2Ca^{++}$$

Colemanite hydroboracite

(Helvacı, 1977; Helvacı and Firman, 1977).

This reaction may proceed in the initial stages of diagenesis by base exchange between Mg++ rich luff and clays (Helvacı, 1977; Helvacı and Firman, 1977; Helvacı and Alaca, 1984). '

Howlite crystals have developed within the clays alternating with thin colemanite bands, and reflect a period when Si concentration increased. Due to compaction and diagenesis, small howlite nodules were embedded into still loose colemanite ore (Helvacı and Dora, 1985).

Some ulexite horizons, especially those in the lower borate ore zone, carry probertite bands. These minerals, which generated under the same chemical conditions with ulexite, represent a stronger evaporation period at the playas (Helvacı and Dora, 1985).

In the Sr rich ulexite horizons, solution and recrystallization gave rise to the formation of lunellite.

Clay minerals are capable of retaining 310 ppm or more boron (Goldschmidt, 1954). Thus, significant amount of boron may have deposited together with clays, and nodular ore formed later within clays, by the influence of circulating boron rich solutions.

Mode of occurrence of Bigadiç borate deposit is schematized in Figure 22.

Alteration

Widespread alteration can be traced in the ore veins at deposits and trenches, where exploitation is carried out. The mass of altered ore is termed as "Şekerleme" (candy) locally (Helvacı, 1989). For colemanite, this alteration may be expressed with the following equation:

$$2CaO.3B_2O_3.5H_2\,O + 2CO_2 + nH_2O \text{———} 2CaCO_3 + 6H_3BO_3 + (n\text{-}4)H_2O$$

colemanite calcite boric acid

In general, regular borate horizons are interrupted by alteration, and this also makes the tracing of veins within the ore zone difficult.

Alteration is important especially for the upper borate ore zone. It is not so widespread in the lower borate ore zone, because it generally occurs where erosion and tectonism are active, and underground water mobile (Helvacı, 1989). As thick units overlie the lower borate bearing zone and have protected it against erosion, this ore zone remained without altered.

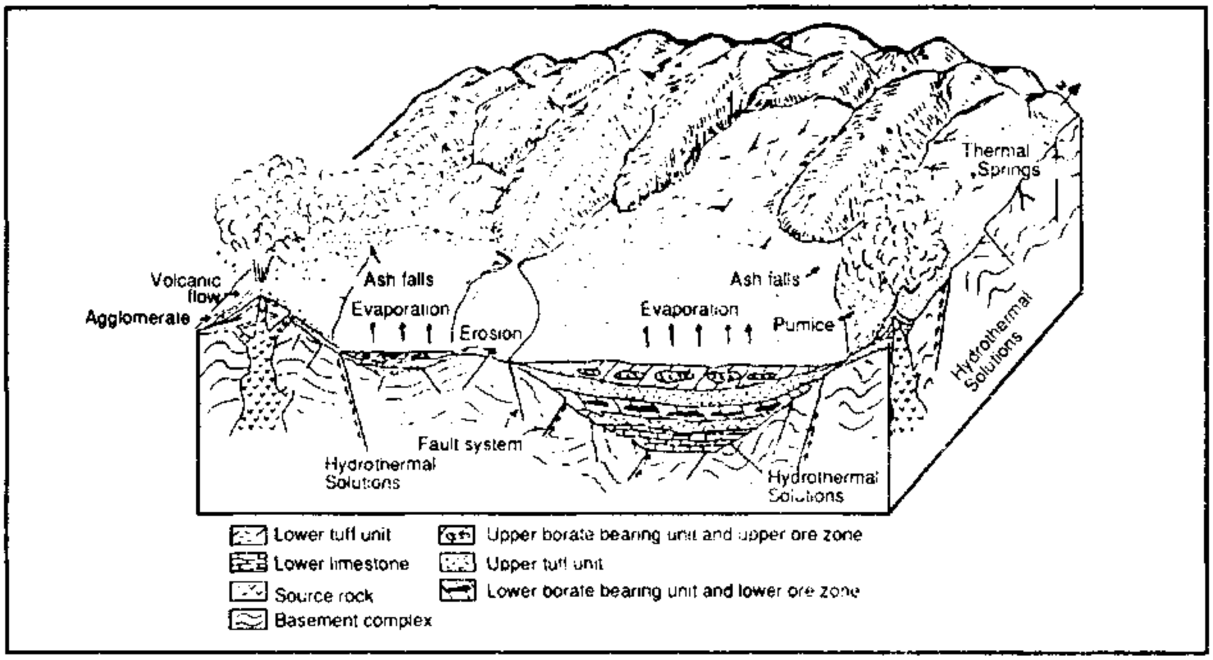


Fig. 22 - Formational model of Bigadıç borate deposits.

Wall rocks and gangue minerals

Maximum thickness of the ore zone in the lower borate bearing unit is 76.00 m. and that in the upper berate bearing unit is 80.00 m. Ore horizons within these zones are accompanied by clay, marl, tuff, limestone, calcite, gypsum and anhydrite. Different grades of ore has formed due to the distribution of these sediments in the are horizons and zones, together with the physical properties of ulexite and colemanite.

Gypsum, anhydrite, calcite, aragonite and clay occur in the basin as gangue minerals. Gypsum is found particularly in deep borcholes of lower borate, as bands between ore horizons in Avşar, Simav, Ön and Arkagünevi deposits and as intercalations within the ore. Anhydrite accompanies colemanite in the lower borate bearing unit. Clay occurs as bands between the ore veins and as laminated alternations with limestone. It may also appear in a composite structure together with colemanite and ulexite.

RESULTS

Sequence of lithologic units in the study area, in ascending order from bottom to top is as follows: basement rocks, basement volcanics unit, basement limestone unit, lower tuff unit, lower borate bearing unit, upper tuff unit, upper borate bearing unit, basalt, recent sediments and alluvium.

Borate deposition in the study area occurs as two separate horizons in the lower and upper borate bearing units. The upper tuff unit of thickness 300-350 m. is set between these units.

Boron minerals of the lower borate ore zone arc colemanite, ulexite, howlite, probertite and hydroboracite. Colemanite, ulexite, inyoite, meyerhofferite, pandermile, probertite, hydroboracilc, howlite and tuncllite have been determined in the upper borate zone. In both zones, colemanite and ulexito are more dominant than the others.

Thickness of the lower borate ore zone varies between 0.2-76.00 m. and that of the upper borate ore zone between 0.15-80.00 m.

Ore zone in the lower borate unit is closer to the basement of the unit, while the ore zone in the upper borate ore zone is located at the middle part.

Tuff bands between the ore veins arc more common in the lower borate ore zone, compared to the upper borate ore zone.

Reddish brown, soapy clays overlying the lower borate ore zone act as reference levels for the lower borate ore zone.

Colemanites at the Bigadiç borate basin are possibly primary precipitates from the solution, and they are contemporaneous with sedimentation. They have precipitated in the unconsolidated sediments under the sediment/water interface.

Ulexite precipitation is similar to that ofcolemaniteand represent the periods when Na+ concentration of the solution increased during Ca-borate deposition.

Secondary idiomorphic, pure and clean colemanite and ulcxite were formed by the circulation of boron rich solutions, in the fractures and cavities developed during late diagencsis and by the solution of primary minerals.

Borates are accompanied by non borate minerals at the ore zones. Borates are generally found together with clays, marl, tuff, limestone, gypsum, anhydrite and dolomite.

Borate beds, which show regular extension in general, are interrupted locally due to alteration, and this process also makes the tracing of veins in the ore zone difficult.

B_2O_3 content of colcmanites range among 24.01 % - 35.85 %, while that of ulexites among 24.09 % - 44.19 %, at the productive mines.

ACKNOWLEDGEMENT

Authors wish to thank Etibank's directors and technical staff, at the General Directorate and mine site, for their close attention during the investigalion of the deposits. Also thanks are extended to F. Akgün, who determined the pollen species; S. Karamımak, who drew the figures, and M. Akdere, who typed the manuscript with great care.

Manuscript received October 20, 1989

REFERENCES

Alaca. O.; İşintek, İ.; Selvi, A. and Kurul, A., 1987, Bigadiç borat havzası batı kesiminin jeolojik incelemesi: Etibank Rep. (unpublished), 37 p., 12 app., Ankara.

Bekişoğlu, K.A., 1961, Türkiye'de bor yatakları ve bunların aracılığı ehemmiyet: MTA Rep. 3400 (unpuslished), Ankara.

Borsi, S.; Ferrara, G.; Innocenti, F. and Mazzouli, R., 1972. Petrology and geochronology of recent volcanism of eastern Aegean Sea: Bull. Volcanol., 36. 473-496.

Çakır, A. and Dündar, A.. 1982. Balıkesir-Bigadiç boratlı Neojen incelemesi hakkında ön rapor: MTA Rep. 7075 (unpublished), Ankara.

Foshag, W.F.. 1921. The origin of the colemanite deposits of California: Econ. Geol. 16. 199-214.

Goldschmidt, V.M., 1954, Geochemistry: Oxford University Press, Oxford.

Gündoğdu, M.N., 1982, Neojen yaşlı Bigadiç sedimanter baseninin jeolojik, mineralojik ve jeokimyasal incelenmesi: Hacettepe Üniversitesi Ph. D. Thesis. 386 p., 3 app., (unpublished), Ankara.

Helvacı, C., 1977, Geology, mineralogy and geochemistry of the borate deposits and associated rocks at the Emet Valley, Turkey: Ph.D. dissertation. University of Nouingham, England.

———, 1983, Türkiye borat yataklarının mineralojisi: Jeo. Müh. Bull.. 17, 37-54.

Helvacı, C., 1984, Occurrence of rare borate minerals: Veatchite-A, tunellite, teruggite and cahnite **in** the Emet borate deposits, Turkey: Mineral. Deposit, 19.217-226.

———, 1986, Emel borat yataklarının kökeni ve jeokimyası: Cumhuriyet Üniversitesi Eng. Fac. Bull., Serie A-Farthsciences V. 3, no. 1, p. 49-73.

———, 1989, Mineralogy and genesis of Bigadiç borate deposits. Western Turkey: 28th International Geological Congress, Washington D.C. USA, 2. 49-50.

———, 1989, Türkiye bor madenciliğinin işletme, stoklama ve pazarlama sorunlarına mineralojik bir yaklaşım: Jeo. Müh. Bull., p. 34-35, 5-17.

———and Alaca, O., 1984, Bigadiç borat yataklarının jeolojisi ve mineralojisi: TJK 38. Bilimsel **ve** Teknik Kurultayı Bildiri Özleri, 110-111.

———and Dora, Ö., 1985, Bigadiç borat yataklarında mineral oluşumları hakkında yeni görüşler: TJK 39. Bilimsel ve Teknik Kurultayı Bildiri Özleri, 75-76.

———and Firman, R.J., 1977, Emel borat yataklarının jeolojik konumu ve mineralojisi: Jeo. Müh. Bull., 2, 17-28.

———; İnci, U.; Yağmurlu, F. and Yılmaz., H., 1987, Batı Anadolu Neojen stratigrafisi ve ekonomik potansiyeli: Akdeniz Univercity Isparta Müh. Fak. Bull.. Jeoloji 3, 31-45.

Helke, A., 1955, Beobachtungen an Türkischen minerallagerstatten II. N. Jb. Min. Abh., p. 178-180.

Kalafatçıoğlu,A., 1964, Balıkesir-Kütahya arasındaki bölgenin jeolojisi: Türkiye Jeol. Kur. Bull., 9, 46-63.

Kutlu, R., 1963, M. Ali Meydan'a ait bortuzu ruhsat sahası (Balıkesir): MTA Rep.. 1011, (unpublished), Ankara.

Mcixner, H., 1952, Einige boratemmerale (colemanit und tertschit ein mineral) aus der Türkei: Fortschr. Mineralogie, 31, p. 39 42.

———, 1953, Neue turkische boratlagerstaiten: Berg. u. Hüttenman, Monatsch. 98, p. 86-92.

———, 1956, Die neue turkische boratprovinz un İskeleköy bei Bigadiç im Vilayet Balıkesir: Sonderabdruck aus kali und Steinsals, part *2,* p. 43-47, Essen, Verlag Glockkauf.

Özpeker, I., 1969, Batı Anadolu borat yataklarının mukayeseli etüdü: Ph. D. thesis, İ.T. Univ., 116 p. İstanbul.

Yılmaz, İ., 1977, Bigadiç bölgesi bazaltik volkanizmasının mutlak yaşı: Doğa Tem. Bil. 1, 210-212, Ankara.

GEOLOGICAL SETTING, DISTRIBUTION AND FORMATION OF KIRKA (SEYİTGAZİ-ESKİŞEHİR) BORATE DEPOSITS

Hüseyin YALÇIN* and Orhan BAYSAL**

ABSTRACT.- Middle-Upper Miocene aged borate deposits in the Kırka basin having volcano sedimentary lacustrine rocks are found within the dolomitic claystone/marls as lense shaped. The most lower and upper parts of the deposit are surrounded by carbonaceous rocks. Borate deposits situated in the two parts of the region were separated by paleotopographic threshold consisting of basement rocks and/or vertical blocking movements. Borate minerals show vertical and lateral mineralogical zonation such as Na, NaCa and Ca-borate in the southeastern area of the basin (Sarıkaya), whereas Ca-borate is represented only in the northwestern area (Göcenoluk). Borate minerals were formed by different processes such as synsedimentary, authigenesis and diagenetic transformation, according to their shapes/forms and kinds.

Mineral Res. Expl. Bull.. 113.65-71. 1991

DISTRIBUTION AND ORIGIN OF DETRITAL GOLD IN KAZIKKAYA (KAĞIZMAN-KARS) PLACERS

Necati TÜYSÜZ*

ABSTRACT. - Geologic, mineralogic and chemical studies indicate a considerable amount of detrital gold in Kağızman-Kazıkkaya placers. Gold values become of economic interest, especially along a 2 meter thick lowermost part of the placers. Amount of gold increases parallel to the heavy mineral content of the placers, reaching a maximum in 0.63 mm. - 0.315 mm. size fraction where heavy mineral content (3 %) shows a four-fold increment comparing to its average value in whole placers. Heavy mineral types identified in the placers are in well agreement with those of rocks exposed in the immediate vicinity. Chemical and physical nature of detrital gold is very similar to that of gold in quartz veins. Hence, the source of gold in the placers is mostly linked to quartz veins and less to the listwaenite and shear zones.

INTRODUCTION

The area of interest is situated between Komik mahallesi and Kazıkkaya village of Kağızman, Kars in the eastern Turkey (Fig. 1). The area is reached by following the paved road westwards from Kağızman for 38 km; then by a gravel road into the Ortakale river valley for about 15 km. after passing Çayarası village (Fig. 1), The roads accessible year round except under heavy winter conditions.

Gold exploration became very attractive in last few years following a boom in gold prices and introduction of low cost technology into the industry.

The Kağızman placers were exploited by Russians during the first World War. Molly (1955). based on the volume of pebble, cobble and bolder piles resulted from hydraulic washing, calculated a 150 kg. gold recovery by Russians in the area. Bergman (1988) and Haude (1989) delineated a 2 meter thick zone on the bedrock enriched with gold during the joint Turkish-German project studies. Haude furthermore reports a 0.9 gr/m^3 . Au grade with 700 000 m^3 . reserves for the 2 meter thick zone.

Pan prospection was first employed around the terrace edges along the contact of the placers with the bedrock during these studies. Gold distribution was rougly estimated in the field using a chart produced by Bergman (1988). Drilling, adit-ing, shafting and trenching were invoked in order to obtain data about gold and grain size distribution of the terraces. A truck mounted TH-60 rotary drill rig, refitted with dual wall drill pipe and using air injected down between the outer pipe and inner pipe of the dual drill system was employed for drilling. Gold content of the panned samples pooled in the field was found by amalgamation followed by ICP readings. Heavy minerals were first separated by Franz isodynamic separator and then were identified by polorizan microscope. In addition, samples collected from adits were concentrated by so called "Aufstrom" pipes after wet sieving into several size fractions. Heavy mineral contents of each fraction were recorded separately. Grains suspected to be any type of PGM (platinum group minerals) were analyzed by scanning electron microprobe.

GEOLOGY

Kağızman complex of Upper Cretaceous age crops extensively out in the catchment area of the placers (Çağlayan and Kral, 1980). Kağızman complex is composed of peridotite, serpentinite, gabbro, basalt and limestone blocks of various sizes in a pyroclastic and epiclastic matrix. Serpenlinites host listwaenite lenses and bands. Kağızman tonalite varying in composition from quartz diorite to tonalite intrudes the complex. Tuzluca formation of Oligocene-Miocene age comprising siltslone, sandstone and conglomerate intercalated with gypsum lenses rests disconformably on the complex. Quaternary is characterized by terrace and alluvial deposits. Ortakale valley seems to gain its present-day configuration through several terrace steps. Terraces occur between Komik mahallesi and Kazıkkaya villages where they reach 43.5 m. at most, presumably a paleo river channel, with an average of 25 m. Average length and width of the terraces in this area are about 2 km. and 0.5 km., respectively. They consits of different types of blocks ranging from several centimeters to about 2 m. in diameter with

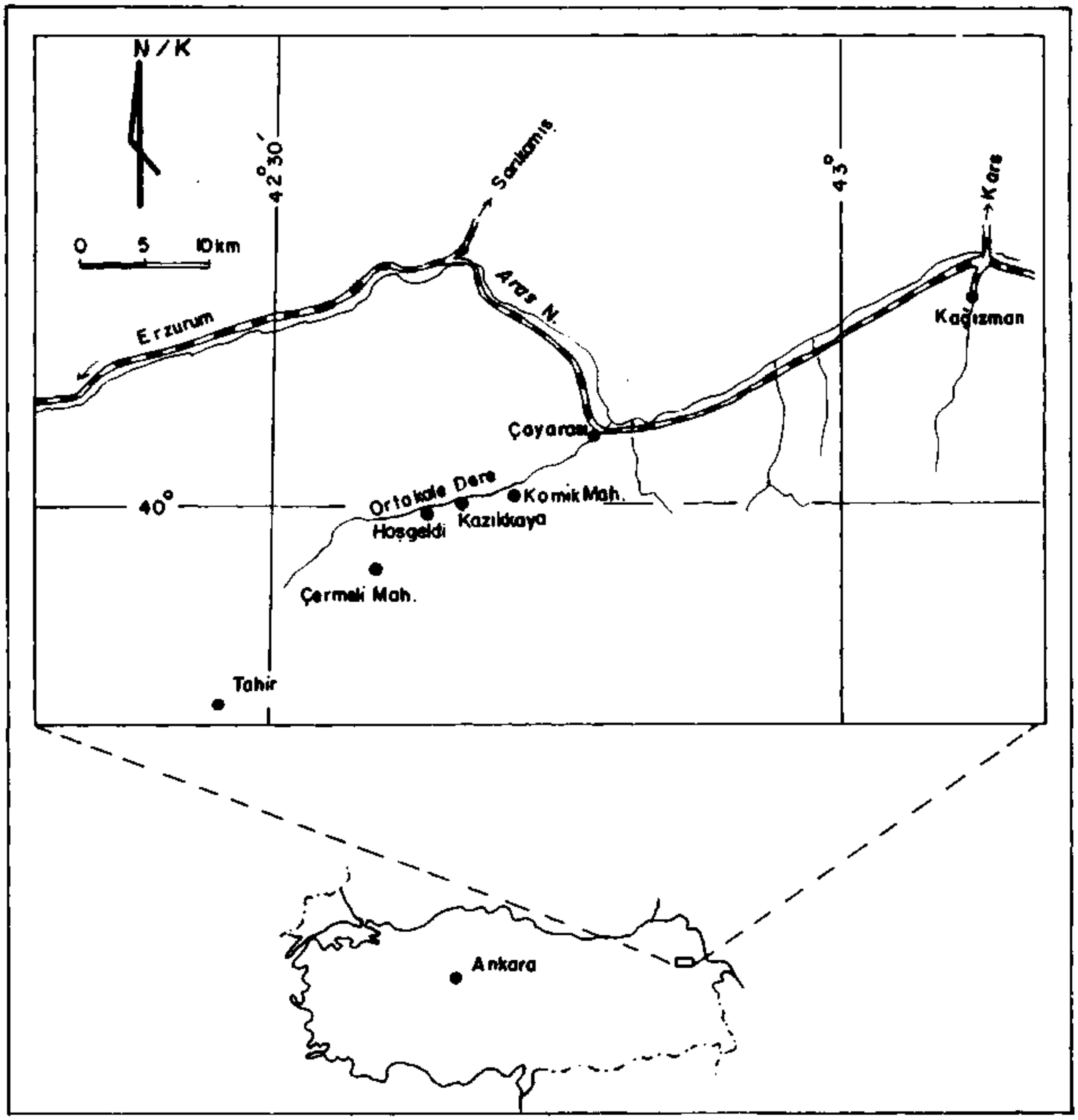


Fig. 1 - Location map.

sand fillings. Blocks are made up mainly of gabbro, serpetinite and basalt, and minor amounts of limestone. The terraces are very poorly sorted and unconsolidated, indicating no sign of bedding.

MINERALOGIC STUDIES

Grain size distribution

A variety of samples were collected from adits and shafts so as to examine grain size distributions (Fig. 2) of the placer. A sample taken from adit 2 represents an ungraded sediment (Haude, 1989; Fig. 3). Approximately 85 % of the sample consists of pebbles or rock fragments coarser than 2 mm. in size whereas only 5 % of it is finer than 2 mm. which con-

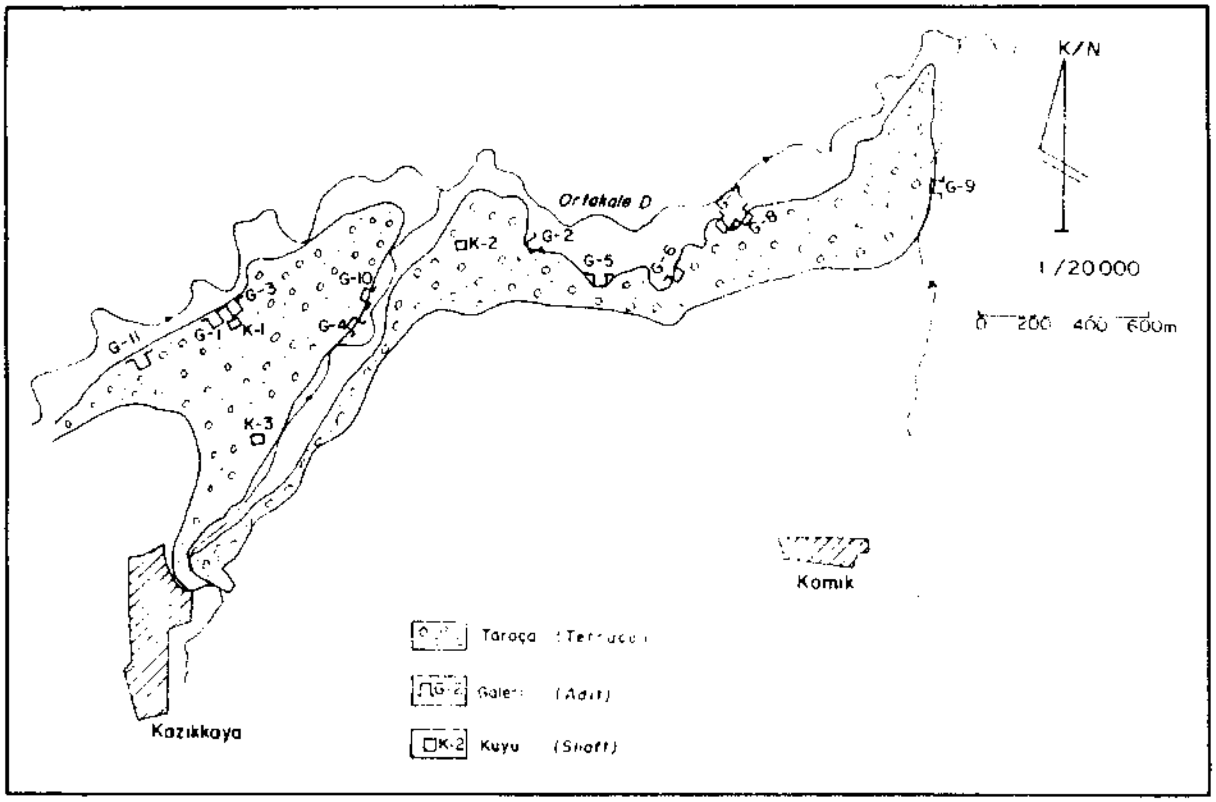


Fig. 2 - Map showing Kazıkkaya (Kağızman-Kars) placers.

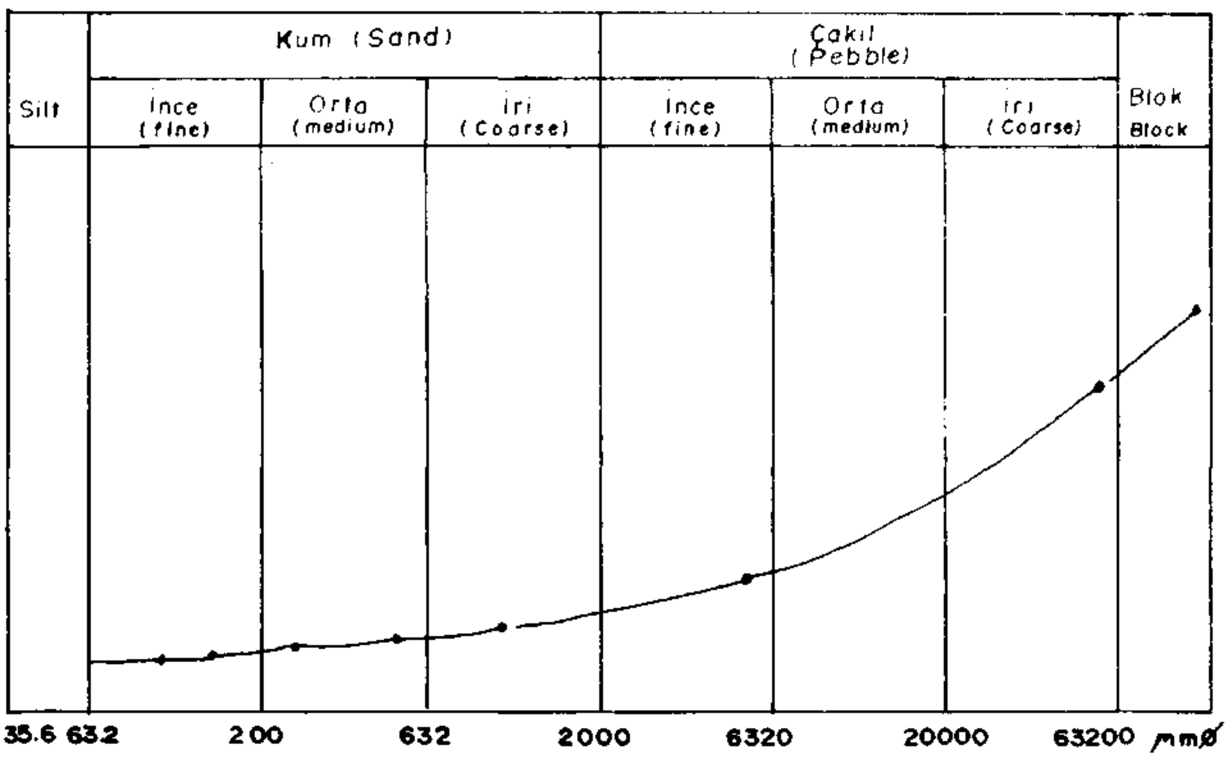


Fig. 3 - Grain size distribution of a sample from adit 2.

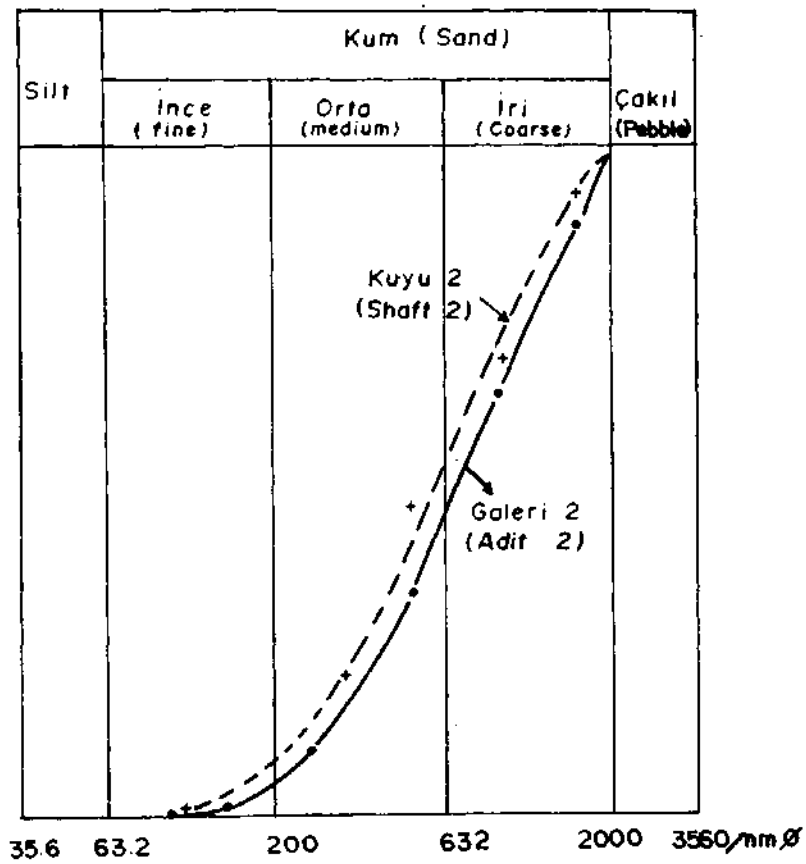


Fig. 4 - Grain size comparisons of sample from adit 2 with that of shaft 2 (between 2.0-0.1 mm.).

tains gold. The samples taken from shaft 2 is composed of 80 % pebble size and 17.6 % sand size material. Figure 4 illustrates that both samples are dominated by medium and coarse size sands.

Heavy mineral distribution

Heavy mineral content of the placer, about 3 %, shows an increase towards the bottom, parallel to gold content. However, heavy mineral content of the lowermost zone, 2 meters in thickness, reaches 13 % (Table 1).

Table 1- Grain size distributions and heavy mineral contents of shaft 2 and adit 2

Sample from shaft 2		*Sample from adit 2*	
Grain size (mm.)	*Heavy mineral (%)*	*Grain size (mm.)*	*Heavy mineral (%)*
1.6 - 1.0	7.5	1.60 - 0.95	0.3
1.0 - 0.63	6.6	0.95 - 0.5	7.7
0.63 - 0.315	12.4	0.5 - 0.25	12.9
0.315 - 0.2	2.2	0.25 - 0.147	4.5
0.2 - 0.1	1.7	-	-

In addition, heavy minerals are largely concentrated within 0.63 mm.-0.315 mm. size fraction (Table 1).

Heavy mineral types

An unprocessed sample taken from the placers was first sieved through 630 mm- 200 mm, 200 mm - 63 mm, and 63 mm and approximately 200 grains of each fraction was counted. The result is illustrated in Table 2.

Table 2- Mineral distribution of placers

	Grain size		
Mineral	*630-200 μm (%)*	*200-63 μm (%)*	*63 μm< (%)*
Opaque	40	25	20
Chromite	.1	-	1
Pyroxene	8	15	3
Amphibole	10	10	8
Calcite	2	2	Trace
Zircon	-	0.5	1
Turmaline	-	Trace	0.5
Rutile	-	Trace	0.5
Garnet	3	2	1
Epidote	15	20	20
Quartz+Feldspar	20	25	45

Besides, some concentrations were prepared to search for PG (platinum group) minerals. Those grains which were suspected to be any type of platinum group minerals were assayed by scanning electron microprobe. The results showed several combinations of Cr, Fe, Cu, Ni, Si, S, Ti, Pb, and Sn for these grains. Based on these combinations, some grains could be chromite, ilmenite, and awaruite but some remains very difficult to identify. Weisser (1988) determined some grains as some types of PGMs comprising a solid solution of Pt and Fe, osmiridium and rutheniridium. Some of these grains contain rounded gold inclusions.

Table 3 - Heavy mineral and gold distribution in the lowermost 60 cm. of shaft 2

Grain size (mm.)	*Heavy mineral content (%)*	*Number of gold grains*
> 1.6	2.5	2
1.6-1.0	13.3	8
1.0-0.63	0.7	5
0.63-0.315	19.4	9
0.315-0.2	2.9	-
0.2-0.1	1.3	-
< 0.1	6.4	-

Origin of gold

Quartz veins, trending NE-SW and NW-SE and varying in thickness from mm. to 4-5 m., occur in the drainage area. Some gold grains can be seen by naked eye in these quartz veins. Electron microprobe analyses of 5 grains, each with 3 readings, from the quartz veins are given in Table 4 (Weisser, 1988).

Table 4 - Electron microprobe analyses of gold grains in a quartz vein

		Elements %											
Sample	*Analyse*	*Au*	*Ag*	*Fe*	*Hg*	*Cu*	*S*	*Bi*	*Sb*	*Te*	*As*	*Se*	*Total*
	1	91.84	7.22	0.11	-	0.09	0.05	0.27	-	-	-	0.01	99.60
1	2	91.83	7.13	0.62	0.17	0.15	0.03	0.08	-	-	-	-	100.02
	3	91.95	7.02	0.19	0.09	0.07	0.04	-	0.01	0.01	-	0.01	99.40
	4	83.69	15.9	0.08	-	0.02	0.03	0.32	0.01	0.03	-	-	100.07
2	5	90.67	7.56	0.06	0.15	0.05	0.03	0.31	-	0.03	-	-	98.87
	6	91.58	7.37	0.12	0.08	0.08	0.03	0.31	-	-	0.01	-	99.58
	7	92.14	6.84	0.01	-	0.04	0.03	0.03	-	-	-	-	99.08
3	8	91.38	6.76	0.37	0.14	0.29	0.08	0.01	0.04	0.03	-	-	99.11
	9	91.39	7.02	0.52	0.08	0.44	0.10	0.15	-	-	-	-	99.71
	10	91.66	6.99	0.05	0.13	0.13	0.04	0.09	-	-	-	-	99.10
4	11	92.06	6.65	0.26	0.09	0.73	0.05	-	0.02	0.04	-	-	99.90
	12	91.43	6.95	0.28		0.25	0.05	-	-	0.01	0.01	-	98.99
	13	92.36	6.98	0.08	0.07	0.10	0.04	0.15	0.03	-	-	-	99.81
5	14	92.52	6.82	0.22	0.03	0.16	0.04	0.13	0.01	0.02	-	-	99.94
	15	91.93	7.03	0.28	0.13	0.47	0.06	-	0.02	-	-	-	99.91

Gold content of these grains range from 83.69 % to 92.52 % with an average of 91.23 %. Ag values vary between 6.65 % and 7.56 %, except a point reading of 15.89 %, with an average of 7.02 %, indicating rather low values. Hence, gold in the quartz veins appears to have high fineness expressed as [(Au/Au+Ag)1000 of 923]. Besides, Cu and Fe occur at the equal amounts. S, As, and Te yield very low values. Low Ag values indicate a secondary precipitation for gold below the water table (Mann, 1984; Webster and Mann, 1984). Very low Te values provide evidence for oxidation (Antweiller and Campbell, 1982). In addittion, low Ag, high Cu, Bi and Pb values indicate high temparature formation conditions for primary gold deposition (Antweiller and Campbell, 1977).

Electron microprobe assays carried out on placer gold grains indicate similar range of fineness (900-950) to that of vein gold (Bergman, 1988). Besides, gold redeposited below the water table shows secondary growth. Therefore, gold in the placers was largely derived from quartz veins, less from listwaenites and shear zones.

CONCLUSIONS

Drilling, aditing, shafting and trenching carried out on placers revealed considerable amount of reserves and delimited the lowermost section, approximately 2 m. thick, of placers to be of economic interest. Gold content increases parallel to heavy mineral content, especially in 0.63 mm.-0.315 mm. size fraction. Heavy minerals identified in the placers correlate well with these in surrounding rocks. Gold in placers show same size and fineness as gold in quartz veins. In addition, some gold was derived from listwaenites and shear zones. Density of sampling is not sufficient due to unsuccessful sampling by drilling. Thus, Any drilling method successfully applied to similar type of placers should be sought and be applied to the area of interest for more representative sampling.

ACKNOWLEDGEMENT

This study was generally realized within the framework of Turkish-German joint project. Grain size analyses were carried out by the author in Germany, the graphics were prepared by Dr. H. Haude. The author is thankful to all who put their great contributions on this paper.

Manuscript received October 3,1991

REFERENCES

Antweiller, J.C. and Campbell, W.L., 1977, Application of gold compositional data to mineral exploration in the United States: J. Geoch. Explor.,v.8,p. 17-29.

———and————1982, Implications of the compositions of lode and placer gold: T.G. Theodore et al. (Eds.), Geology and gold mineralization of the Gold Basin- Lost Basin mining districts Mohave country, Arizona, U.S.G.S. Prof. Pap., 1361, p. 245-264.

Bergman, H.B., 1988, Gold/PGM placer prospecting and exploration in the Kazıkkaya area, Eastern Anatolia, Turkey, Archives, no. 102096, 60 p. (unpublished), BGR-Hannover.

Çağlayan, A. and Kral, K., 1980, Ağrı-Taşlıçay ve Kars-Kağızman civarının jeolojisi: MTA Rep. 6785 (unpublished), Ankara.

Haude, H., 1989, Exploration von seifengold in Terrassenschotien hei Kazıkkaya, provinz Kars, Türkei: Archives no. 105867, 72 p. (unpublished), BGR-Hannover.

Mann, A.W., 1984, Mobility of gold and silver in lateritic weathering profiles: some observations from western Australia: Econ. Geol., v.79, p.38-49.

Molly, E.W., 1955, Zaraphane-Kazıkkaya altın prospeksiyon raporu: MTA Rep. 2334 (unpublished), Ankara.

Webster, J.G. and Mann, A.W., 1984, The influence of climate, gcomorphology, and primary geology on the supergene migration of gold and silver: J. Geoch. Expl., v. 22, p. 21 -42.

Weisser, T., 1988, Erzmikroskopische und mikroanalytischc untcrsuchungen von Au-und PGM-Kömem aus dem Ortakale Dere, provinz Kars, Türkei: Archives no. 40066, 7 p. (unpublished), BGR-Hannover.

Mineral Res. Expl. Bull., 113, 73-86, 1991

GENESIS OF BAUXITE BEARING IRON ORE DEPOSITS FROM PAYAS (HATAY) DISTRICT

Şükrü KOÇ* and M.Ali DEĞER**

ABSTRACT. - In the study area, a unit composed of dolomite and dolomilic limestone of Lower Triassic-Lower Jurassic age forms the base. This unit up to 400 m. thick is conformably overlain by Lower Cretaceous units represented by limestone and dolomilized limestone. These limestones which also host mineralization arc conformably overlain by Senonian olisloslromal sequence. A sequence consisting of conglomerate, sandstone and limestone, that is of Middle Miocene age conformably overlies the olisloslromal fades. The Upper Pliocene sediments occurring over extensive flatnes areas rest conformably upon all of the units in the study area. Mineralization in the region occurs as lenses between the Lower Crelaccous limestones and Senonian limestones. Ore bodies lie on lop of limestones characterized by common dissolution cavities and brecciated in places and on top of sandstones in other places. Ore microscopic studies reveal that main ore minerals arc maghemite, hematite and goethile. Mineral paragenesis also includes berthierine, diaspore, quartz and calcile. Massive, granular, colloidal and oolitic textures are observed in ores. On the basis of sedimentary petrographic studies, three types of mineralization in which massive, granular and combined massive and granular textures arc dominant could be recognized. Each type is characterized by dissolution cavities and microkarstification features. Geologic, ore microscopic and sedimentary petrographic studies provide evidence that these deposits have originally developed on top of a gentle topography by long-lived atmospheric effects and subsequently washed away and broken up and eventually formed by infilling of regional karstic cavities by transported material.

INTRODUCTION

The workers who have studied in the present area and its surroundings (Fig. 1) report a great number of ferruginous bauxite and bauxite bearing iron occurrences. However, the opinions on the origin of these occurrences in the region are contradictory.

Some workers (Riches, 1913) attribute the formation of ore occurrences to alteration of basalts, while others (Pilz, 1939; Ami, 1941; Romicux, 1942) consider them to be terra rossa type of bauxites. Krupp (1959) concluded from his studies that ore bodies occur in conformable with thick limestone scries and furthermore it is controversial whether influx of metal bearing solutions into the environment and mineralization occurred concurrently with sedimentation or not. Rouzand (1910) and Petrascheck (1965) point out that the solutions which arc enriched in Fe and Al, released by alteration of basic rocks were transported and finally precipitated in hollows of limestones. Some other authors (Brennich, 1956; Akçay and Hasan, 1974) claim that the formation of ores may be explained by transport of residual enrichments that developed over basic and ultrabasic rocks and subsequent precipitation in sedimentary basins. Erten et al. (1971) relate the ore occurrences in the region to a laterilic phase containing high Al_2O_3- Elgin (1975) regards the Payas iron occurrences as sedimentary deposits hosted in the Upper Cretaceous limestones.

Apart from these studies, various general geologic and mining geologic surveys are known to have been conducted in different parts of the Amanos mountains (Wippern, 1964; Hatay, 1967; Alan, 1969; Arda, 1972; Aslaner, 1973; Çoğulu, 1974; Yalçın, 1980; Selçuk, 1981; Tekeli and Erendil, 1986; Aksay et al., 1988).

The main purpose of this paper was to establish the genetic relations of ore forming metallic elements with surrounding rock units and also to propose a model by which geological events that have been effective on the present day setting of ore occurrences may be explained in connection with theserclationships.

The study area is located to the east and southeast of Payas subdistrict of 15 km. north İskenderun town, Hatay province. Along 15 km. north-south direction, 8 km in easj-west direction of the area is located on 1:25 000 scale topographic maps of Antakya O-36 a_3, b_4, c_1, d_2.

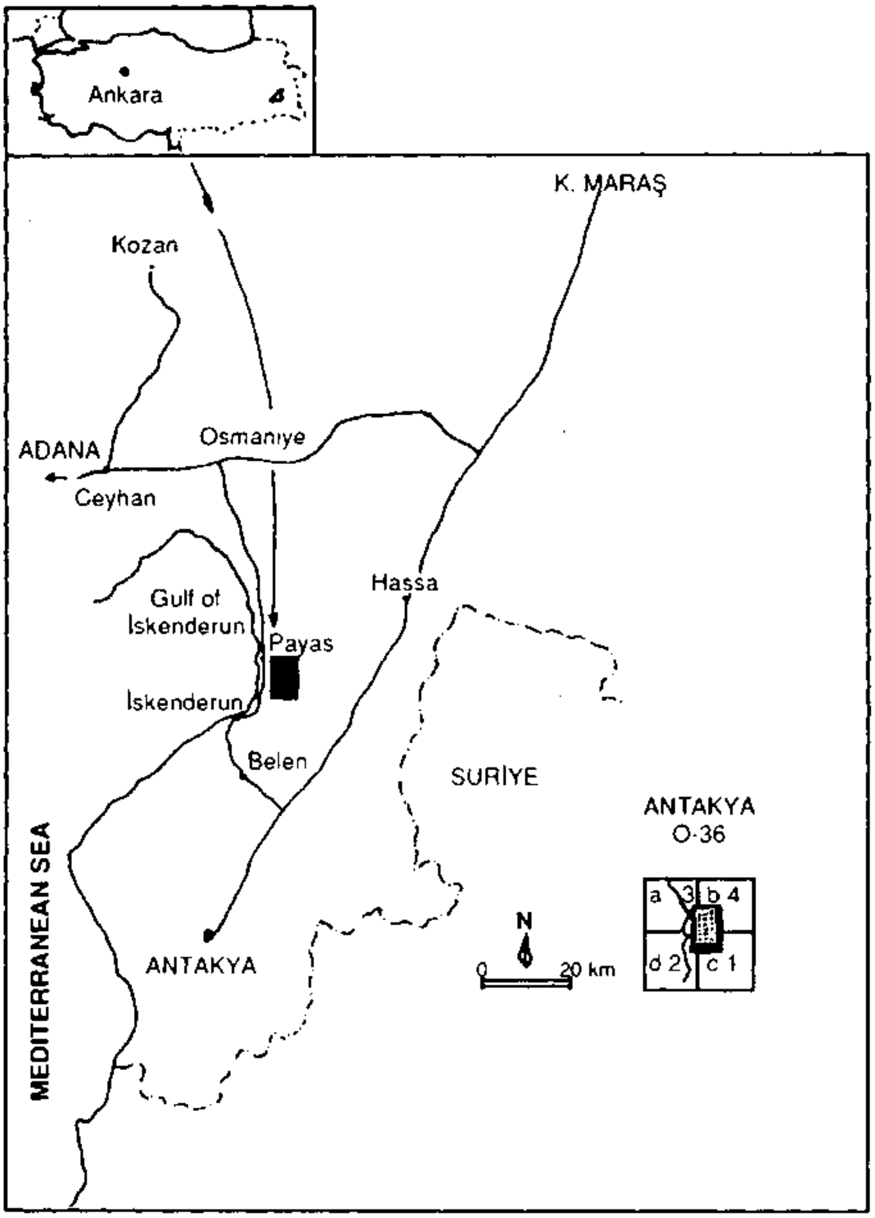


Fig. 1 - Location map

REGIONAL GEOLOGIC SETTING

The regional geologic information was compiled from the studies of Aksay et al. (1988) and Alan (1969). A generalized columnar section from the Amanos mountains is given in Figure 2. According to this section, the Paleozoic formations lie beneath the Amanos mountains range constituting a part of the Arabian platform. The relationships between these units are conformably stated.

The Paleozoic sequences of clastic sediments are conformably overlain by the Mesozic carbonate sequences.

During the Upper Cretaceous the sequencer of the Arabian platform are overlain by the Amanos olistostrome and Kızıldağ ophiolite which was emplaced during early Upper Cretaceous Campanian-Maestrichtian age.

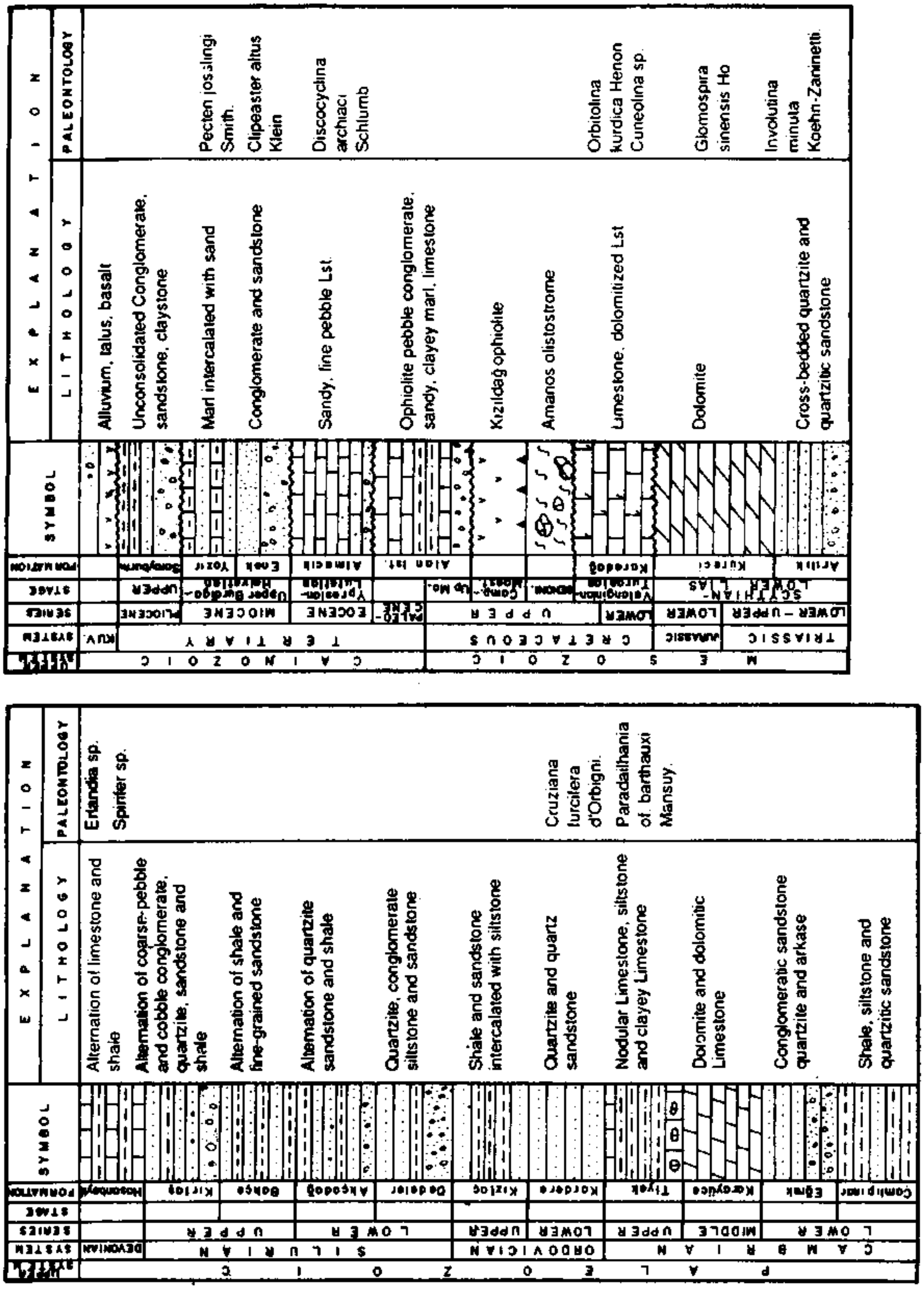


Fig. 2- Generalized columnar section of the Amanos range (after Aksay et al., 1988).

Following the emplacement of ophiolite, a sedimentary sequence called the Alan limestone was deposited. This sequence begins with ophiolite derived pebble conglomerate of Macstrichtian age and continues upward with abundant fossilliferous sandy limestone, clayey limestone and marl strata. The latter sequence is conformably and transitively overlain by a Paleocene sequence of clayey limestone and limestone stratums.

The Alan limestone is conformably overlain by the Almacık limestone of Lower Middle Eocene age. Following this unit, Miocene age Enek formation consisting of conglomerate sandstone and abundant-fossil-bearing limestone and with the Yazır formation consisting of marl commonly intercalated with sand horizon, are overlain unconformably. The Palcocene sequence called the Sarayburnu formation conformably rests upon all the units below. This unit consists of unconsolidated conglomerate, sandstone and claystone.

The occurrences which indicate the Quaternary units in the region arc, basalts that exposure over a very extensive area, talus and alluvial deposits.

Regional tectonic features were compiled from the studies by Ketin (1959). The Amanos mountains structurally form an anticline. Fold axis trends NNE-SSW and the strata on the limbs strike NE-SW.

In the region, the Cambrian terrain was affected by Caledonian orogeny. Triassic strata were shaped by tectonic movements that occurred during the time interval between Triassic and Albian. The Karadağ limestones of Cretaceous age were affected by the Subhercynian phase of Alpine orogeny. Furthermore, the ophiolite nappes gained their present day settings by the affects of this phase. Afterwards, they have emerged above the sea level and have been subjected to erosion by the affects of the same phase and as a result, ophiolitc derived pebble conglomerates of Macslrichtian age have been transgrcssively deposited over serpentinites.

Strata of Maestrichtian age emerged above the sea level by folding during the Laramian phase (Upper Cretaceous-Eocene) and were subjected to erosion. As a result of this. Eocene conglomerates were disconformably deposited above the older units.

The majority of the Taurus range emerged above the sea level by the end of Oligocene. As a result of this, the Miocene sequence began with a thick basal conglomerate. Uplifting and folding occurred again at the end of Miocene. Intense deformation and particularly faulting took place during the Upper Miocene and Early Pliocene.

The Amanos range gained its present day morphology by vertical faults. These faults, one of the most prominent structural elements in the region fundamentally trend N-S, N45°-75°E and N4()°-7()°W.

STRATIGRAPHY OF THE STUDY AREA

The stratigraphic features of the mapped area (Fig. 3) are given in Figure 4. The rock units exposed in the vicinity of Kargıcak and called the Küreci limestone (Alan, 1969) are of Lower Triassic Lower Jurassic age (Aksay et al., 1988). This unit, conformably overlying the Anlık quartzite that occurs outside the study area, consists predominantly of dolomite and less amount of dolomitic limestone. This sequence gray to dark gray, thin, medium or thick bedded and locally massive, contains some levels made up of cherty bands, yellow-brown dolomitized limestone, and interbeds of dark gray shale.

Strata are repeated upwards through the Küreci dolomite. Strata of the lowermost section are dolomitic limestones containing ostracoda, pelloid, pyrite and quartz. This section grades upwards into laminated limestone that is more intensely dolomitized, and dolomite. Breccias that are generated by dissolution of evaporiles are common within the dolomites.

This unit, up to 400 m. thick, is unconformably overlain by the Karadağ limestones. This unit, of Lower Cretaceous age (Aksay et al., 1988), known as the most common lithology within the study area, is represented by limestone and dolomitized limestone. It occasionally, contains interbeds of siltstone and shale.

Even though the Karadağ limestone looks as if it overlies conformably the formation below, it is suggested that it rests unconformably upon the same formation on the basis of the fact that bauxite occurrences are found at some horizons between these two units in the vicinity of Islahiye (Gaziantep), outside the mapped area.

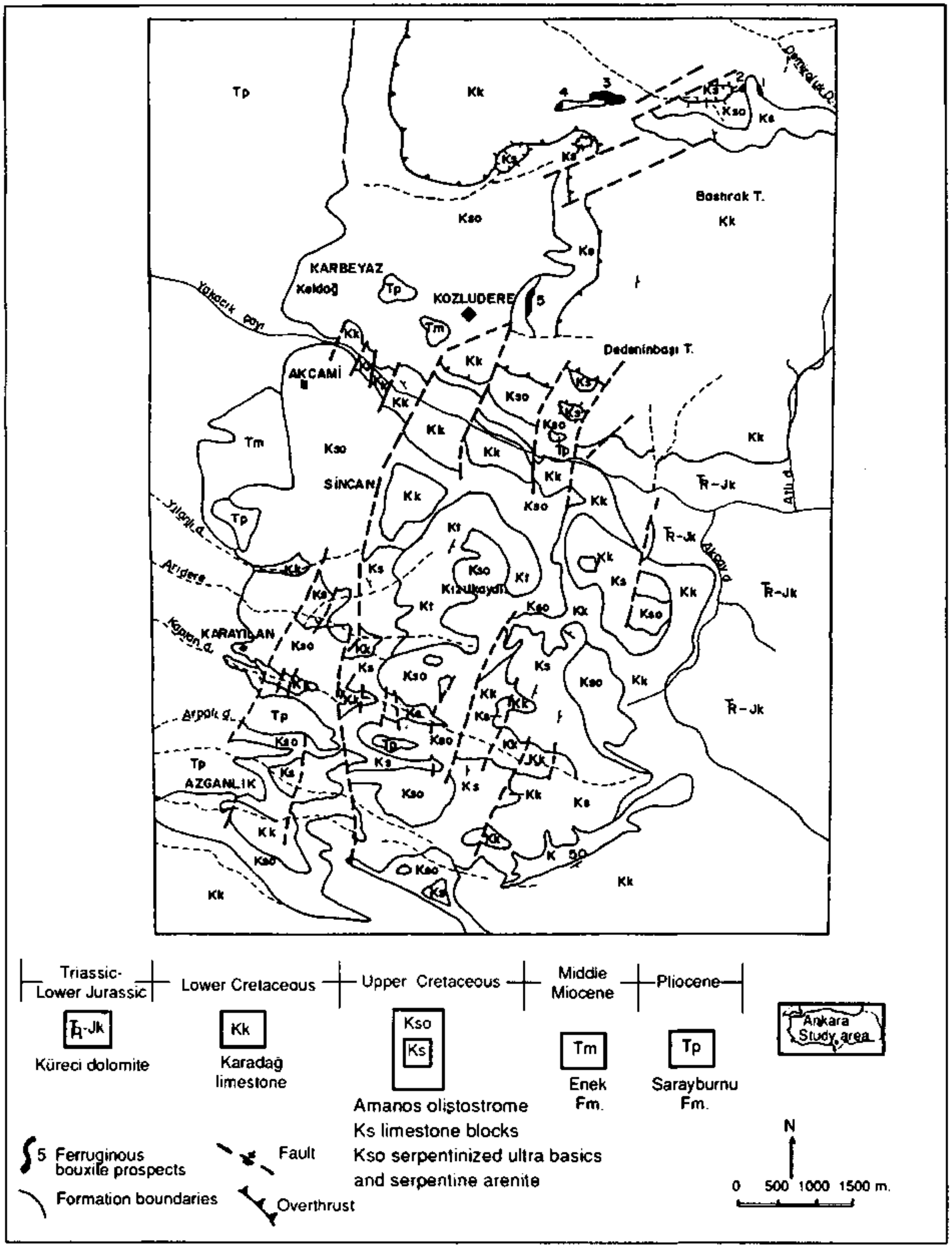


Fig. 3 - Geologic map of the study area and locations of sample groups.

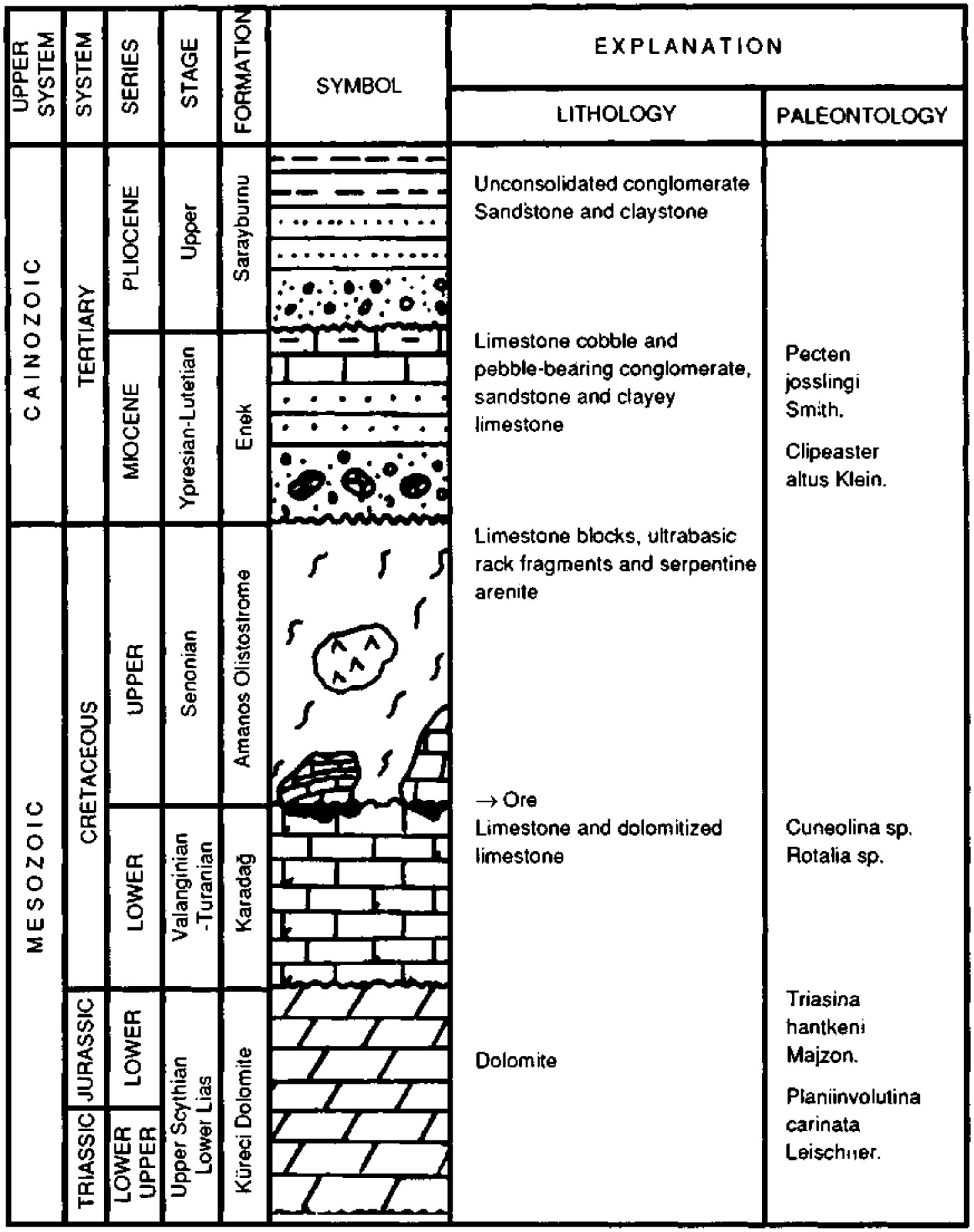


Fig. 4 - Columnar section of the study area.

The limestone and dolomitic limestone that constitute this unit are thinly to moderately and locally massively bedded and include a variety of karstic features. They are seen as thin channels in some places and as deep hollows in others (Plate I, fig. 2). The limestones that have breccial character immediately below the ore bodies are cemented by calcite.

The Karadağ limestones that host mineralization is unconformably overlain by the Senonian olistostromal sequence.

The olistostromal sequence is composed essentially of limestone blocks of varying size, fragments of serpentinized ullrabasic rocks and serpenlinc arenite.

The serpentine arenite that makes up the groundmass of the sequence is light green to greenish-gray colored, thinly laminated and foliated. The serpentinites have undergone dynamothermal metamorphism as the overlying blocks of limestone have slowly moved over them and as a result, schistose textured lenses that seem to be totally serpentinized ultrabasic rock have formed in the upper levels of the serpentinite (Plate I, fig. 3).

The fragments of serpentinized ultrabasic rocks seen around the An stream are massive in appearance at the base. Microscopic studies reveal that this rock contains serpentine minerals (chrysotile, antigorite) displaying fibrous texture, relics of serpentinized pyroxene and opaque minerals (Plate II, fig. 1).

The limestones belonging to the olistostromal sequence are seen in various forms.The most common ones are those which rest upon the serpentinites. A completely argillized crushed zone about 1 m. thick lies between the serpentinites and these limestones. Folding has occurred within limestones along these horizons by deformation and the lowermost levels of these limestones have gained schistosity by the effects of metamorphism that has been produced during the movement of limestones over serpentinites. The study of thin sections from these gray colored and thinly bedded limestones reveals that the rock consists mostly of calcite and also contains recrystallized calcite and quartz.

In some places, the schislose limestones are also seen above the levels of sandstone, and ankeritic limestone, all of which cover the ore bearing zones. The thickness of the ankeritic limestones ranges from 1 to 3 m. Here, a regular transition from the ore body toward the schistose limestone is observed (Plate II, fig. 2). This limestone that occurs adjacent to all of the ore occurrences with the exception of Fındık Yaylası-I, consists of calcite ranging in size from 0.02 to 0.15 mm., locally displaying pressure twinning and contains minor intergranular quartz and infiltration of iron hydroxide (Plate n, fig. 3).

Some of the limestone blocks belong to gray colored, thickly to massively bedded limestone that overlies both the serpentiniles and schislose limestones. These rocks displaying cataclastic lexture consist of calcite that ranges in size from 0.05 to 0.3 mm., locally displaying pressure twinning, and containing clay minerals in very small amounts and quartz.

A part of limestones belonging to the Amanos olistostrome is seen as lenticular bodies within serpentinites. These rocks arc gray to dark gray, thin bedded and exhibit schistosity. They consisl essentially of calcite and minor quartz.

Besides those mentioned above, recrystallized limestone blocks are found within serpentinites. These dark gray and black limestones are massive and dolomitic in composilion.

On the basis of idenlified fauna such as *Globigerina* sp. and *Globotruncana* sp. from gray colored horizons of these limestoneblocks, that are found above serpentinites, an Upper Crelaceous age is assigned to these limestones.

Another unit which constitutes the olistostromal sequence is sandstone levels overlying and underlying the Findik Yaylası-I ore. These levels that are yellow and 2-3 m. thick consist of quartz grains ranging in size from 0.03 to 0.1 mm. and from 0.4 to 1.0 mm. and contain feldspar, tourmaline, zircon, chloritized biotite, carbonate minerals and minor limonite.

The depositional age of olistostromal sequence has been dated based on the ages of limestone blocks that rest upon and intervene in serpentiniles. These blocks are of Albian-Aptian age in the vicinity of Osmaniye, in the north (Arda, 1972), Coniacian-Campanian age near Kızıldağ (Aslaner, 1973) and Upper Cretaceous age in the study area. On the basis of this evidence, the unit is of Senonian age.

The Enek formation of Middle Miocene age that is exposed in the southwestern part of the study area (Aksay et al., 1988) unconformably overlies the Senonian olistostrome. A conglomeratic level, rich in very coarse and fine pebbles of limestone and serpentinite lies al the base of this sequence. The limestones are of Senonian age and display schislosity. Fine pebbles are rounded, whereas very coarse ones are angular. Grains are cemented by a carbonate mineral. The overlying sandstone are coarse grained arid thin bedded. Abundant altered serpentinite, quartz and iron oxide were identified within these sandstones. The uppermost levels of the sequence are characterized by thin bedded, light, gray limestones.

The porous conglomerate, unconsolidated sandstone and clayslone, all of which arc Upper Pliocene in age (Dubertrct, 1953). arc exposed in extensive flat areas overlying conformably the older units.

TECTONICS

The study area was highly affected by the Subhercynian phase of the Alpine orogeny. Following the emplacement of ophiolite during this period, the olistostromal sequence was emplaced during the Senonian (Ketin, 1959).

The serpentinites gained schistosity under high pressure which has been generated in response to slow movement of limestone blocks that were transported into the environment during the emplacement of olistostrome over the serpentinites. Mcanwhile, the basal parts of detached blocks of Senonian limestone gained schistosity as well. A calaclastic texture was developed in some blocks of limestone above serpentinites.

The major faults in the study area arc N20° - 30°E-trending and N60° - 70"E-trending normal faults with vertical displacements. The older units were exposed due to these faults that developed at the end of Miocene.

MINIM; GEOLOGY

Field observations

The mineral occurrences in the region are found as lenses between the Lower Cretaceous limestones and Senonian limestones. In some places, the ore bodies are underlain by sandstones, whereas in other places, they are underlain by limestones including common dissolution cavities and having a breccia character. On the other hand, they arc overlain by yellow sandstones interbedded with hematite in some places and by yellow ankeritic limestones in other places. These overlying horizons that are found only as 2-3 m. long zones are covered by gray colored limestones of Senonian age whose lowermost parts display schistosity.

Most of the mineral occurrences are found around the Paşanın Eğreği Yaylası. In addition, ore prospects near such localities as Sarıyokuş, Mağarabaşı, Fındık Yaylası, I. Fındık Yaylası - II and Kozludere were also studied (Fig. 3).

The mineral occurrences near the Paşanın Eğreği Yaylası are hosted by brecclated limestones in which widespread dissolution cavities developed. These limestones form the upper levels of dark gray thick bedded limestones of Lower Cretaceous age. Mineralization occurs as massive bodies in some places and as conglomeratic masses in others. Its grain size is up to 20 mm. Massive bodies contain specularite. Ore bodies are overlain by yellow ankeritic cryptocrystalline limestones that grade into gray schistose limestones (Plate II, fig. 2, 3). The Lower Cretaceous limestones are overlain by serpentinites and Senonian limestones 20 m. cast of ore bearing zone (Fig. 5).

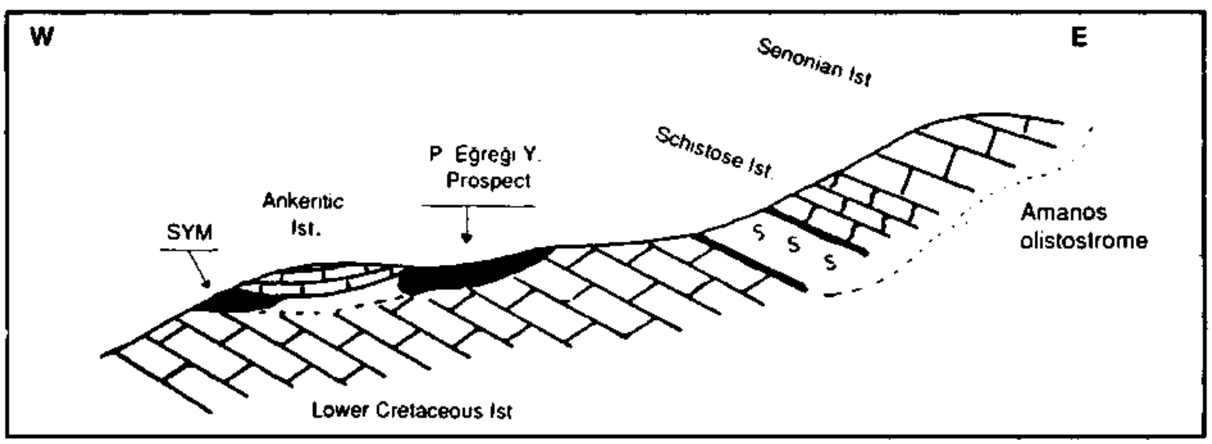


Fig. 5 - Sketch cross section of ore occurrences from Paşanın Eğreği Yaylası and Sarıyokuş Mağarabaşı Mevki (SYM).

The Sarıyokuş Mağarabaşı prospect is in the same position as the above mentioned mineral occurrence (Fig. 5). However, ore from this prospect display schistosity. When broken by hammer, it splits readily into thin sheets. Flaky grains of hematite are macroscopically seen in a pinkish red matrix.

The Fındık Yaylası-I prospect differs from the other ones that is overlain and underlain by sandstones intercalated with hematite. Mineralized body has, locally a massive character and locally conglomeratic and breccial character (Fig. 6; Plate III, fig. 1).

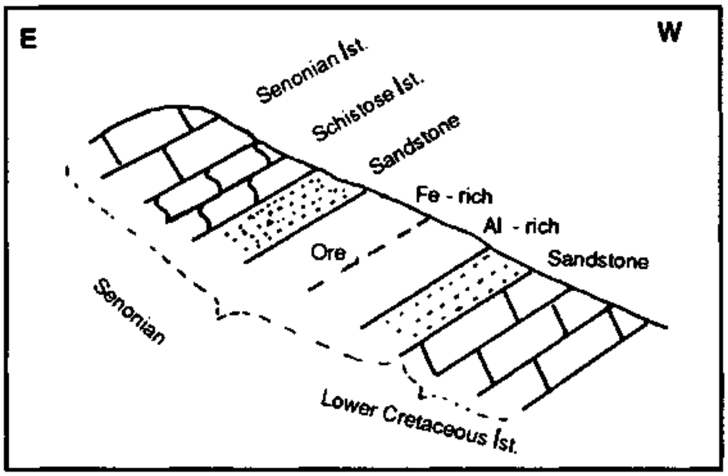


Fig. 6 - Sketch cross section of Fındık Yaylası-I ore occurrence.

The Fındık Yaylası-II prospects consist mostly of limonitized hematite. Mineralization is underlain by the Lower Cretaceous limestones and overlain by a yellow ankeritic zone 2-3 m. thick and gray schistose limestone. The serpentinites arc exposed about 10m. to the south of mineralized bodies (Fig. 7).

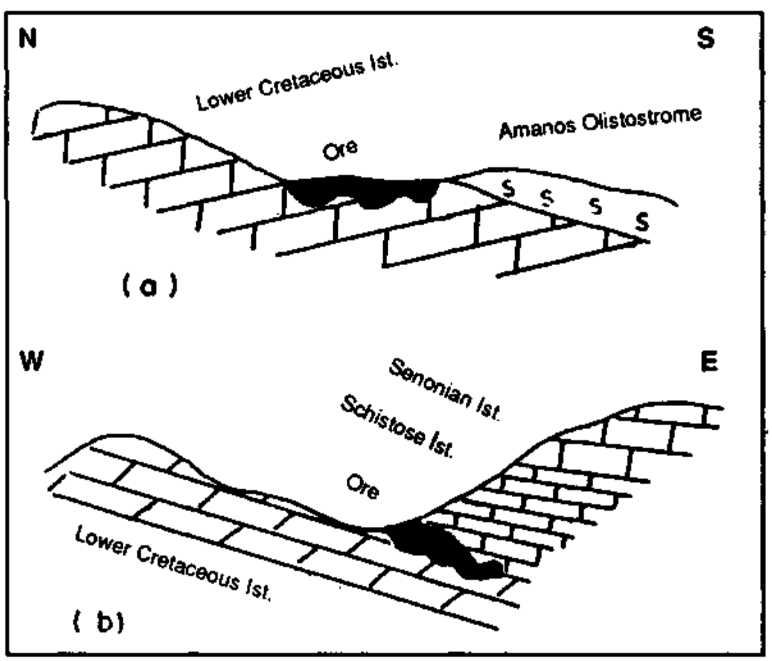


Fig. 7 - Sketch cross section of Fındık Yaylası-II ore occurrence.

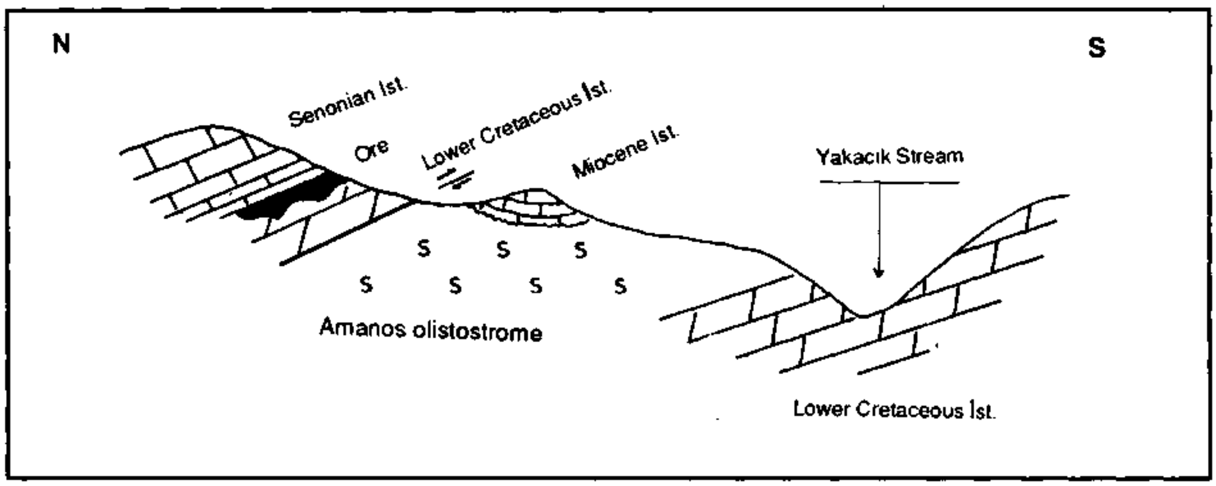


Fig. 8 - Sketch cross section of Kozludere ore occurrence.

The Kozludere occurrences lie as bands between the Lower Cretaceous limestones and Senonian limestones. Here, the same yellow ankeritic zone occurs in transition to the overlying gray limestone.

Ore microscopic studies

The ore microscopic studies of mineral occurrences from the above mentioned five different districts indicate slightly diverse paragenetic, structural and textural relationships among them. X-ray diffractograms of samples from these districts were utilized in addition to ore microscopic studies in establishing these relationships.

Some polished sections of samples that characterize different mineral occurrences were examined under the ore microscope in order to get the mineral paragenesis. On the basis of these studies, maghemite, hematite, specularile, goethite and rutile were determined in paragenesis. Non opaque minerals were examined through the thin sections of ore samples and X-ray diffractograms. They include carbonate, quartz, berthierine, diaspore and rock fragments (serpentinite). Furthermore, some studies concerning the textural features of mineral occurrences have been done in order to provide evidence that may expose the origin of mineralization. Granular and colloidal textures arc observed in all mineral occurrences except those found around the Fındık Yaylası where oolitic texture is dominant.

Hematite -Hematite is the dominant mineral of samples and mainly displays colloidal texture (Plate III, fig. 2). Colloidal texture is formed by infilling of voids from the rims of mineral or observed as being of cocarde type. Hematite is found as single crystals or aggregates surrounding rounded or angular grains (Plate III, fig. 3).

Nucleus is composed of either rock fragments or fossil remnants. Colloidal precipitates that have occurred in small vugs form radiating aggregates in larger vugs that have originated from coalescense of smaller ones. Ferruginous clay or goethite bands are seen as parallel to the rims of minerals in ores displaying radial texture. A clayey matrix composed mainly of berthierine occurs between hematite grains found as space filling or cocarde.

Apart from colloidal forms, hematite is also found as grains or oolitic bands. Hematite grains range in size from 540-770 to 40-80m.m.or may be even smaller. Hematite which is mostly converted into goethite displays relict texture (Plate IV, fig. 1,2).

That hematite is observed in variable tonality of color and younger hematite crystals appear as cutting older ones may provide evidence that hematite formed at least in two stages in that environment.

Hematite that envelopes ooliths displays indistinct anisotropy in grayish tints.

Hematite is abundant in ferruginous bauxitic clays which arc commonly seen as matrix material. These minerals which arc readily identifiable by its reflection colors and anisotropic features are found as very tiny (2.50 to 4.0 mm.) acicular crystals (Plate IV, fig. 3) or grains having irregular shape (8-16 mm). Unsorted xenomorphic grains of hematite are relict minerals (relict texture) of goethitization. Most of the grains are converted into goelhite along their rims (Plate V, fig. 1).

Although in hand specimens, hematite is seen as rounded pebbles of varying size, embedded in a brownish red matrix, the ore microscopic studies clearly indicate that it also constitutes the matrix of smaller pebbles which display granular texture. These pebbles are made up of lithic fragments, ferruginous bauxitic clays, goelhite, hematite and fossil particles. The vast majority of hematitic matrix is converted into goethite in varying degree and a zoned texture develops in sections where this conversion occurs from the rims inward. In contrast, a mottled (spotted) texture (white and gray) develops in sections where it occurs from the interior parts outward. One can see that matrix composed of hematite locally includes vugs and they are filled with ferruginous clays.

Maghemite. _ It is found in varying amount in all samples and observed particularly in ores displaying oolitic texture (Plate V, fig. 2). Maghemite which is lighter gray than goethite and somewhat darker gray than hematite and seen as euhedral crystals (triangular, quadrangular) is found as very tiny grains (24-80 microns). Very minute maghemite crystals are more readily distinguished from co-existing ferruginous clay minerals and goethite which display yellow, yellowish red and brownish red colored internal reflections by their isotropic appearance between crossed nicols. Maghemite from the samples displaying granular texture is found as disseminated throughout the matrix (Plate V, fig. 3). In contrast, maghemite from the samples displaying oolitic texture occurs both as surrounding the ooliths and as arranged parallel to the exterior surfaces of them within the zones of ooliths and between them. It is also shown that some ooliths are fractured and maghemite grains form along these fractures. Besides, some ooliths that don't include any maghemite are present in some portions of the samples. (Plate VI, fig. 1).

Goelhite. _ Goethite, present in all the samples, is found in two different forms. Grains composed wholly of goethite and those displaying relict texture is formed by partial conversion of other minerals (Plate VI, fig. 2). Although some goethite minerals from the samples displaying granular texture are larger in size (385 to 700 microns) than hematite and maghemite, they may also occur as smaller and larger grains. These larger goethite crystals, that are readily identifiable by their yellow, brownish internal reflections, are replaced by a matrix which has given rise to break up of them. Smaller goethite grains that resulted from this break up as well as maghemite grains are dispersed through the matrix at random.

The reflection colors of goethite which formed by conversion of hematite show varying tints of gray, depending on the degree of conversion. This case may be accentuated by the fact that hematite shows bluish gray-white anisotropy and goethite has brownish red internal reflection between crossed nicols.

Particularly, the grains which do not comprise any maghemite were completely converted into goethite in the samples displaying oolitic texture.

The samples contain specularite in minor amount and very scarce rutile other than these main ore minerals.

Matrix. _ The matrix of ores displaying granular texture is composed of berthierine, a kind of chamosite having a clay structure. Moreover, a sample from Fındık Yaylası-I contains diaspore in addition to berthierinc in the matrix. Most of the conglomeratic pebbles forming granular texture arc cemented by hematite. The matrix is composed of quartz, ankerite, chlorite and carbonates in addition to these main constituents. Besides, abundant fossil is also present in the matrix as seen in the mineral occurrences.

X-Ray analyses:

Hematite, goelhite, maghemite, berthierine and diaspore were identified by X-ray analyses in the laboratories of Union of Turkish Cement Manufacturers.

Sedimentary petrography:

Microscopic studies reveal thai three types of ore can be pelrographically recognized. These are granular, massive and combined granular and massive ores.

Granular ore comprises well rounded grains of hematite, and limonite. Some of these grains are found as intergrown Zones. They have fairly massive internal structure. Angular ore grains accompanying these grains locally show internal structure even if weakly developed (Plate VI, fig. 3; Plate VII, fig. 1). Some of these grains arc derived from highly altered serpentine (Plate VII, fig. 2).

Massive parts of massive ores or massive granular ores appear to be intcrgranular matrix. Numerous fissures developed throughout these parts (Plate VII. fig. 3). In places, they are found as parallel and oblique to one another. They are filled with calcite, microcrystalline quartz (Plate VIII, fig. 1) and even calcite mixed with bauxite minerals (diasporc) (Plate VIII, fig. 2). In addition, these massive parts include dissolution cavities and microkarst features (Plate VIII, fig. 3). Most of microkarst features are preserved as dismembered masses. Several massive ores contain quartz, sand up to 20-30 % in proportion. Quartz sand is arranged as weak bright alignments within the ores or dispersed throughout them.

CONCLUSIONS AND DISCUSSION

1. Maghcmite, hematite and goethite as iron ore minerals, berthierine and diaspore as bauxite mineral were identified from the samples collected.

- Maghcmite found as cuhedral crystals is dispersed throughout the matrix and contained within the ooliths.

- As a matrix hematite found in large amound and also observed as granular.

- Gocthite, formed as a weathering mineral, is mostly found as single grains together with hematite.

- Berthicrine is found both as a matrix material and also observed in the ooliths, body.

2. Oolitic, granular (conglomeratic) and colloidal textures were recognized through the textural studies.

- In the case of oolitic texture, ooliths show an orientation with respect to long axes. Some oolitic grains have broken up and new zones of ooliths have developed around the old oolitic fragments. Some ooliths consist of maghemite and hematite, while the others are completely converted into goethite. The matrix is very scarce around the oolitic grains and these grains arc found as one on top of the other. Maghemite grains are not only arranged within the envelopes of ooliths, but also aligned in conformance with the slopes of the outer surfaces of the ooliths.

- Two types of conglomeratic ore can be recognized from the samples displaying granular texture. The primary ore later made up the grains of the secondary ore. The primary ore in which hematilic malrix is dominant consists of well rounded grains.

- Colloidal texture is developed by hematite and goethite. Colloidal tcxture which develops as open space filling from the rims also formed as being of cocarde type that resulted from deposition around a nucleus.

3. Abundant transported fragments of Miliolidae were identified from all the samples.

The ore microscopic sludies and lypes of texture idenlified suggest that mineralization occurred in shallow sea environments or karstic vugs. It is known that ooliths are shallow sea formations formed in environments devoid of cool currents in part depending on wave and current actions and may also develop in karstic vugs. On the other hand, both granular and colloidal textures which arc common may shed light on transportation of iron into sedimentary environment. The fact that maghemite grains are found as angular fragments indicates that transportation occurred for a short distance. In contrast, colloidal textures document that some iron was transported as colloids. Intergrown conglomerate textures seen from some samples indicate the presence of two types of mineralization. A pre exisling conglomeratic ore makes up the grains of a late stage conglomeratic ore. This evidence may indicate two different depositional environment. The fact that some oolitic fragments make up the nucleus of late stage ooliths may reflect that a pre existing oolith has broken up during the transportation and been involved in the formation of oolith as nucleus in new environment. However, having regard to the fact that this type of ores displaying granular texture can develop in karstic hollows and other available geological data, the mechanism of formation may be clearly understood.

PLATES

PLATE -I

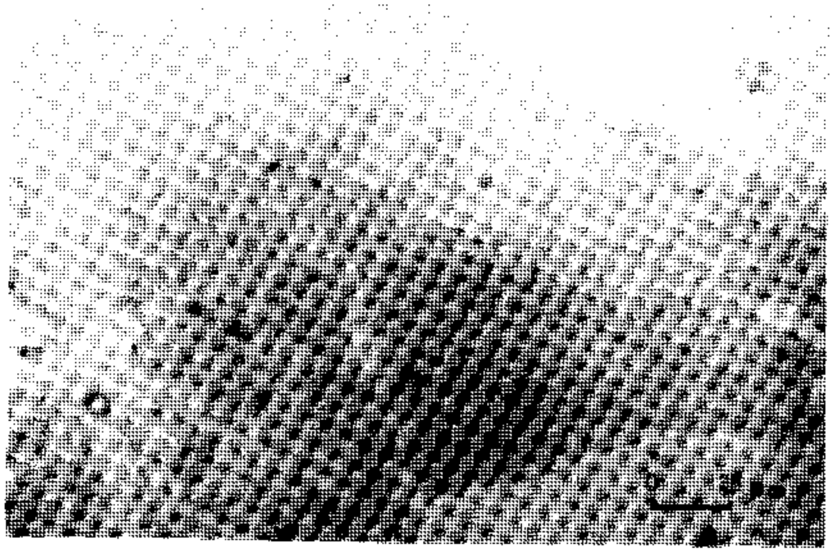
Fig. 1- Karadağ limestones including karst features.

Fig. 2- Calcite grains displaying pressure twins from Karadağ limestones.

Fig. 3- Serpentinites displaying schistosity.

1

2



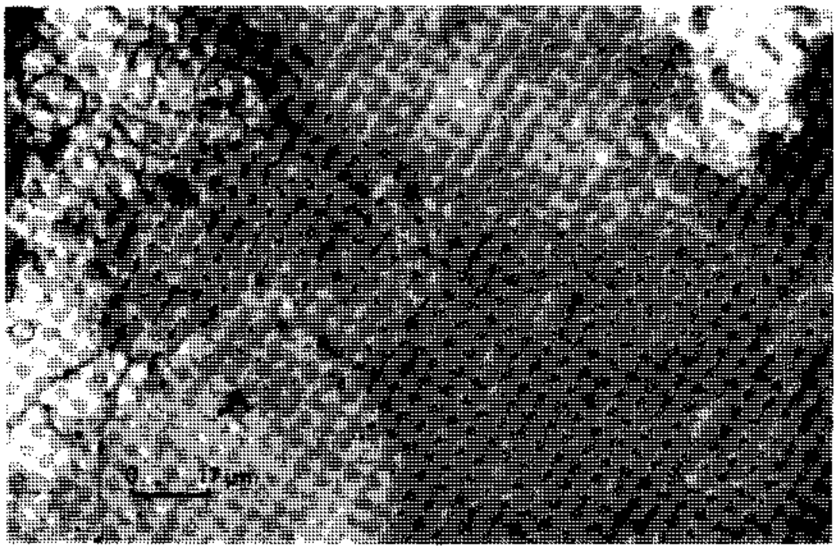
3

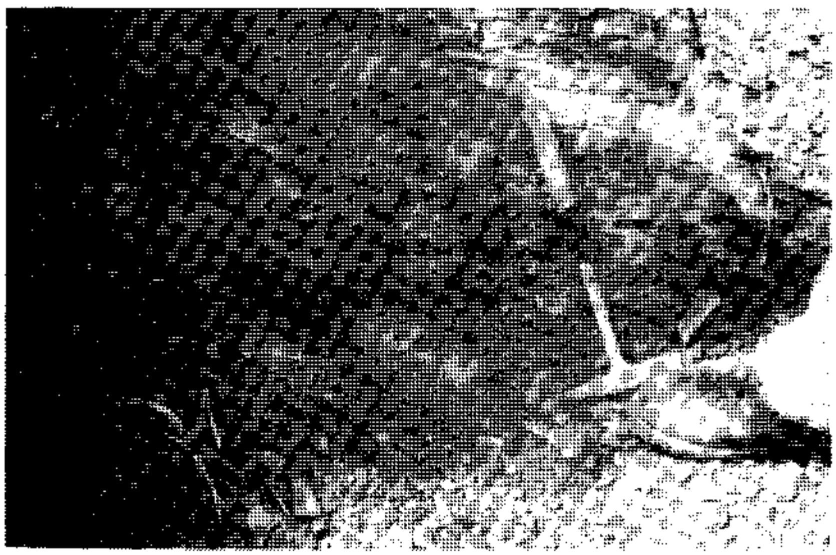
PLATE - II

Fig. 1- Pyroxene and serpentine minerals of serpentinized ultrabasics.

Fig. 2- Ankeritic limestone overlying ore horizons.

Fig. 3- Ankeritic limestone.

1


2


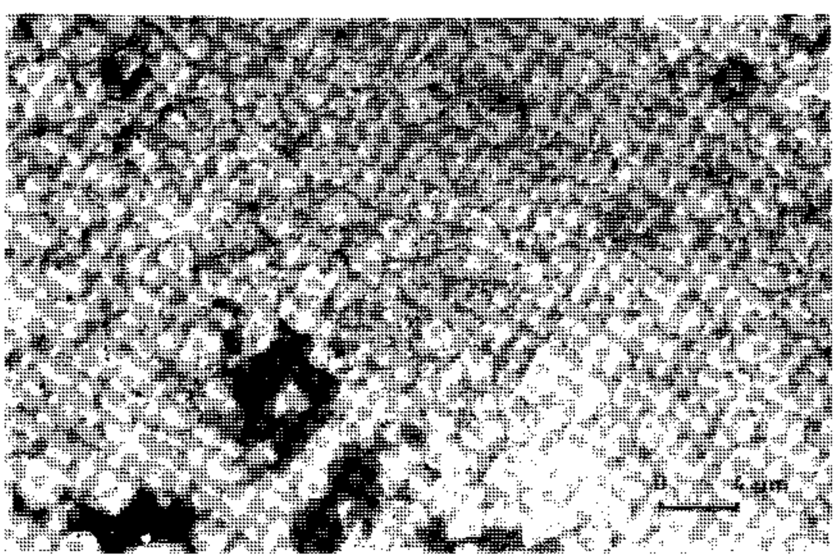
3


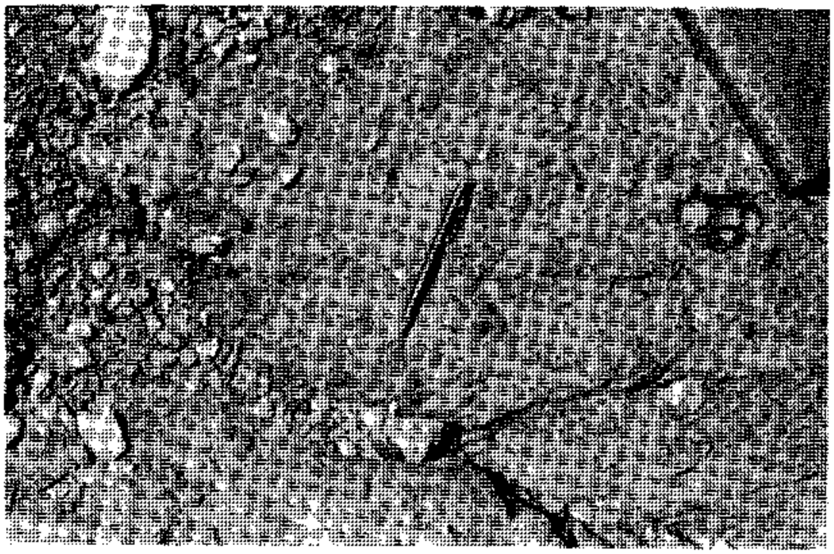
PLATE - III

Fig. 1- Ferruginous conglomerate from Fındık Yaylası.

Fig. 2- Colloidal texture within ore minerals.

Fig. 3- Hematite grains surrounding rounded and angular grains.

1



2

3

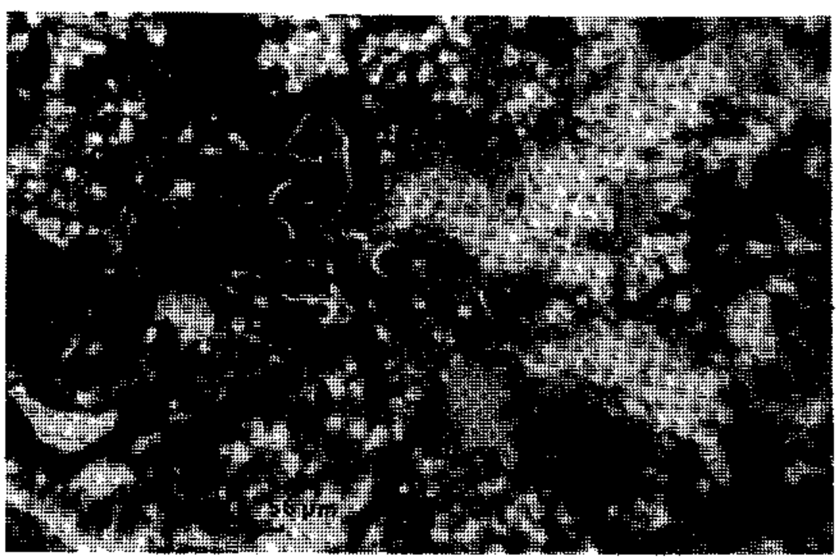


PLATE -IV

Fig. 1- Hematite displaying relict texture (white: hematite, gray: goethite).

Fig. 2- Goethitized hematite grains.

Fig. 3- Hematite grains shown as acicular crystals.

1

2

3

PLATE - V

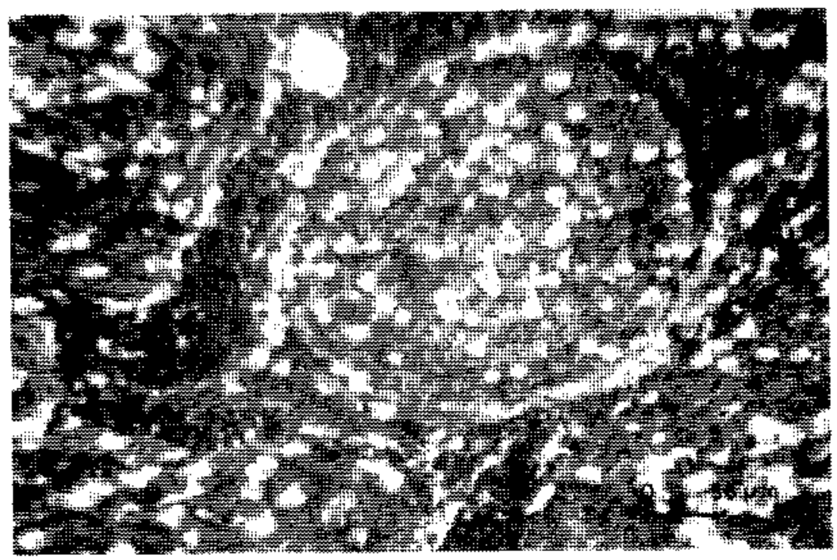
Fig. 1 - Hematite goethitized along its rims.

Fig. 2- Maghemite grains (while) surrounding and within ooliths.

Fig. 3- Maghemite grains within matrix.

1

2



3

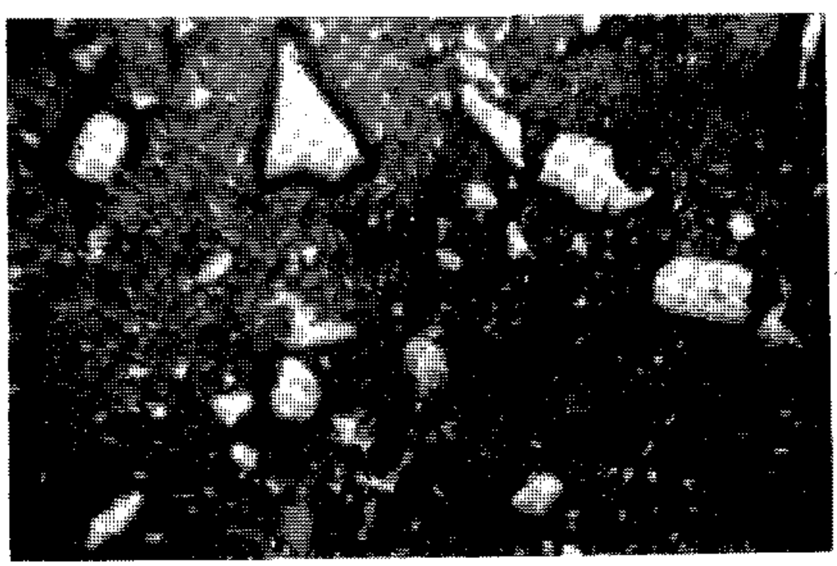


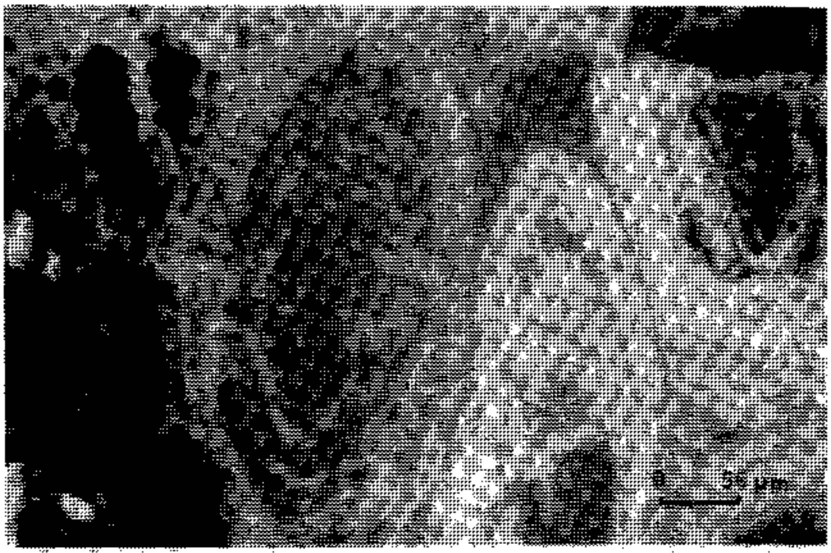
PLATE - VI

Fig. 1- Goethilized ooliths without maghemite.

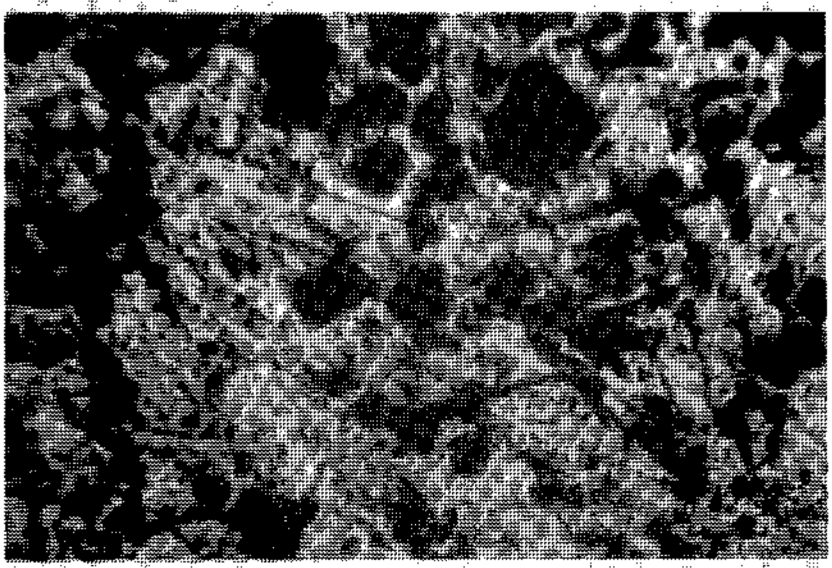
Fig. 2- Goethite minerals (gray) displaying relict texture and Lath-shape hematite grains (white).

Fig. 3- Well-rounded hematite grain.

1



2



3

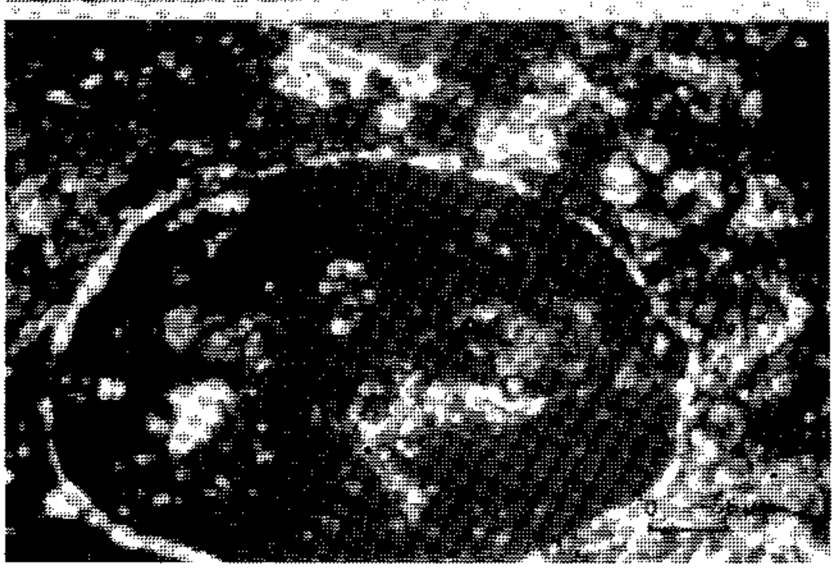


PLATE - VII

Fig. 1- Angular hematite grain.

Fig. 2- Altered serpentine fragment (light).

Fig. 3- Fissures through hematite matrix (black).

1

2

3

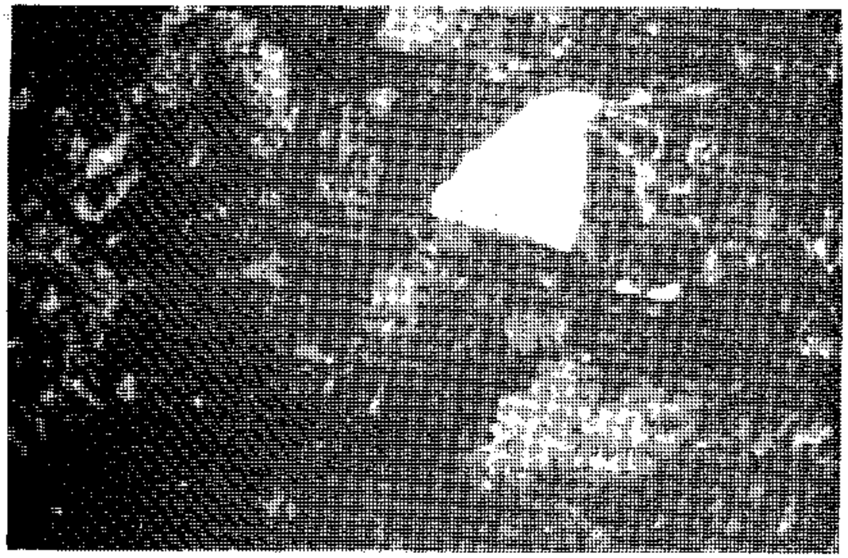
PLATE - VIII

Fig. 1- Limonilized grains within hematite matrix (black) and microcrystalline quartz grains surrounding them.

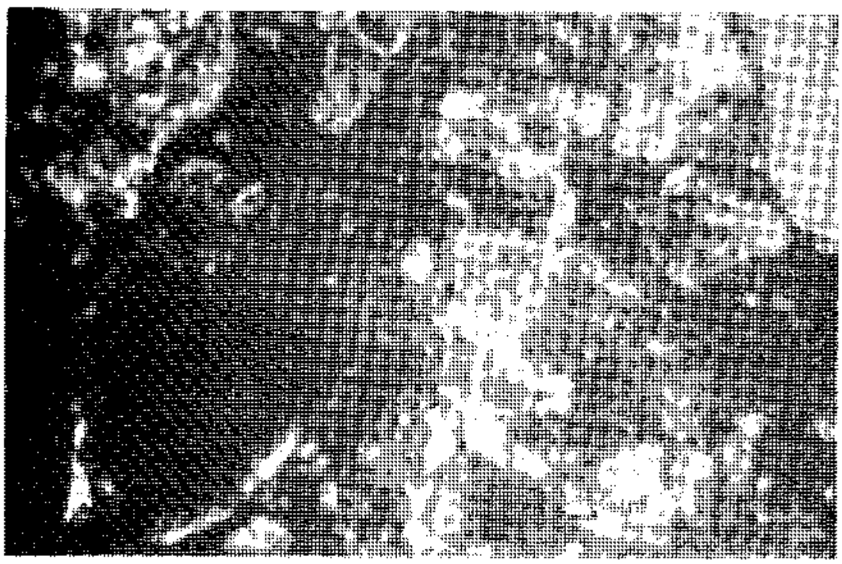
Fig. 2- Diaspore minerals as aggregates within hematite matrix (black).

Fig. 3- Black grain including karst features within hematite matrix.

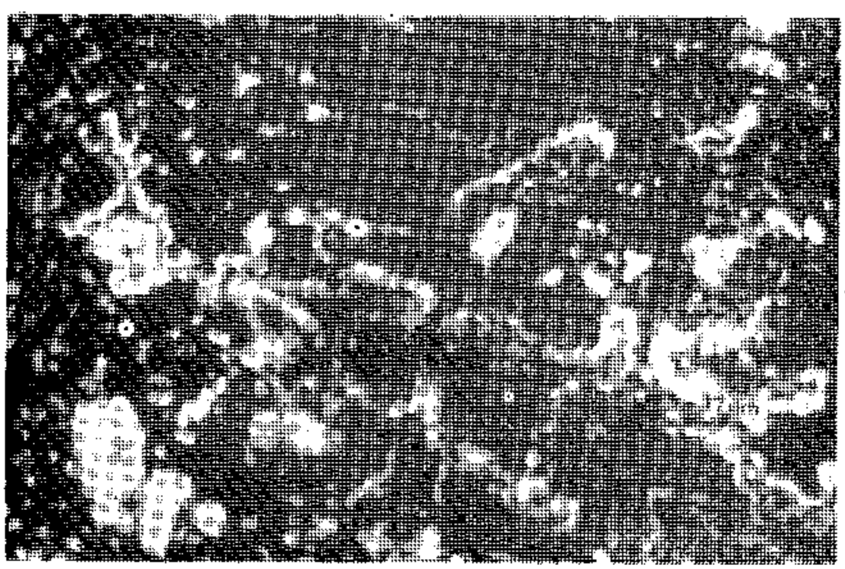
1



2



3



Sedimentary pctrographic features support that mineral occurrences were formed as a result of transportation. Roundness is possibly a result of this transportation process. Some ore material has probably become colloids in a transporting agent by break up of grains during the transportation. This resulted in the formation of matrix forming massive ore. A great number of microfissure systems and microkarst features seen throughout the ores reflect that these ores were probably subjected to atmospheric effects after their secondary emplacement. These fissures that arose as a result of drying under atmospheric conditions were later filled with CaCO3 of meteoric waters and gave rise to the formation of carbonate matrix. Diaspore and possibly oder bauxite minerals probably formed in this stage. Furthermore, quartz sand and sandstones cemented by hematite reflect the uplifting and subsequent erosion of the source area by faulting tectonics during the emplacement of ore.

All these observations support that mineral occurrences have a deposilional character, subjected to atmospheric effects. This may be regarded as karstic deposition. These deposits which developed on top of a gentle topography by long lived atmospheric effects were washed away or broke up and eventually filled the regional karstic hollows during some probable interruptive periods (waning of precipitation depending on climatic changes, etc).

ACKNOWLEDGEMENTS

The writers thank Dr. Sencer İmer, General Director of TDÇİ for providing all kinds of supports throughout the field studies, Dr. Ibrahim Çopuroğlu, Manager of Laboratories of General Directorate of MTA for assistance in both preparing and examining thin sections and polished sections and Associate Prof. Dr. Baki Varol, instructor of Faculty of Sciences, Ankara University for assistance in sedimentary petrographic studies.

Manuscript received October 15,1991

REFERENCES

Akçay, Y. and Hasan, İ., 1974, Antakya İli Hassa-Dörtyol vc Gaziantep İli Islahiye ilçelcri hematilli boksit zuhurlarının prospeksiyonu: MTA Rep., 6309 (unpublished), Ankara.

Aksay, A.; Tekeli, O.; Ürgün, B.M. and Işık, A., 1988, Amanoslar'ın Palcozoyik Birimleri ve Mesozoyik Platform Karbonat İstifleri: MTA Rep., 8312 (unpublished), Ankara.

Arda, O., 1972, The Geology and Petrology of the Northern Amanos Mountains, Southern Turkey: Doktora tezi, Sheffield Üniv., 123 s. (unpublished).

Ami, P., 1941, Türkiye'de halen malum bulunan boksit yatakları: MTA Bull., 2, 23, Ankara.

Aslaner, M., 1973, İskenderun-Krıkkhan Bölgesindeki Ofiyolitlerin jeoloji ve petrografisi: MTA Publ., 150,78 s., Ankara.

Atan, O.R., 1969, Eğribucak-Karacaören (Hassa)-Ceylanlı-Dazevlcri (Kırıkhan) arasındaki Amanos Dağlarının jeolojisi: MTA Publ., 139, 85s., Ankara.

Brennich, G., 1956, Maden Arama Ltd. Şirketine ait yarmalar yapılmış demir madcni sahası: MTA Rep., 2466 (unpublished), Ankara.

Çoğulu, H.E., 1974, Hatay Bölgesindeki Ultrabazik Tektonitler ve Tabakalı Peridolitler: MTA Bull., 83, 185-192. Ankara.

Dubertret, L., 1953, Geologie das roches vertes du nod-ouest de la Syrie et du Hatay (Turquie): Museum National d'Historie Naturelle, VI.

Elgin, I.A., 1975, İskenderun Demir ve Çelik Fabrikalarının doğusundaki boksitik demir cevherleri yatakları hakkında rapor: İSDEMİR-H.M. 48 (unpublished), İskenderun-Hatay.

Erten, H.; Doğan, M.Z. and Özbayoğlu, G., 1971, Payas Bölgesindeki alüminalı demir cevherlerinin teknolojik araştırılması: TÜBİTAK Rep.. 210 (unpublished), Ankara.

Hatay, N., 1967, Islahiye-Hassa Bölgesi boksit zuhurları hakkında geçici rapor: İSDEMİR-H.M.C.-52 (unpublished). Hatay.

Ketin, İ., 1959. Türkiye'nin orojenik gelişimi: MTA Bull., 53. Ankara.

Krupp, F., 1959, Rohstoffe-Untersuchung Eisenerzvorkommen Turkei: Etibank Rep., 1018, Ankara.

Petraschcek, W.H., 1965. İskenderun havalisindeki Payas boksitik demir cevherleri: MTA Bull., 65, 21-25, Ankara.

Pilz, R., 1939, İslahiye ve Payas mınukaları boksit yatakları hakkında yapılan rapor: MTA Rep., 821 (unpublished), Ankara.

Riches, EJ., 1913, Kurudağ ve Karasu demir madeni nihai raporu: MTA *Rep.,* 455 (unpublished), Ankara.

Romieux, J., 1942, Hatay'da yapılan istikşaf raporu: MTA Rep., 1426 (unpublished), Ankara.

Rouzand, T., 1910, Payas-Kuzguncuk hematit yatağı: MTA Rep., 455 (unpublished), Ankara.

Selçuk, II., 1981, Etude geologique de la partie meridionale du Halay (Turquie): Doktora tezi, Cenevre Univ. 116 s. (unpublished).

Tekeli, O. and Erendil. M., 1986. Kızıldağ Ofiyolitinin (Hatay) jeoloji ve petrolojisi: MTA Bull.. 107, 33-48. Ankara.

Wippem. 1964. Islahiye-Payas boksit yatakları: MTA Rep., 1127 (unpublished). Ankara.

Yalçın, N., 1980, Amanosların litolojik karakterleri ve Güneydoğu Anadolu'nun tektonik evrimindeki anlamı: Türkiye Jeol. Kur. Bull. 23, 21-30. Ankara.

Mineral Res. Expl. Bull., 113, 87-92, 1991

GEOLOGY AND ORIGIN OF CLAY DEPOSITS AT ORTA (ÇANKIRI) AREA

Asuman G. TÜRKMENOĞLU*; Orhan AKIMAN*; Serdar AKER* and Ayla TANKUT*

ABSTRACT. - Kaolinitic clay layers interbedded with lignite seams are observed in the Orta (Çankırı) area. In order to reveal the genesis of these clays, geological, mineralogical, petrographical and micromorphological studies were carried out in the vicinity of the clay deposits and in their surrounding country rocks. Rock samples were examined by means of optical microscope, X-ray powder diffractometer and scanning electron microscope. Kaolinitic clays were formed in the clayey and silly Orta formation of Pliocene age. These elastics were transported and deposited by streams in a lacustrine environment located on a paleotopographic depression. The country rocks providing detritic materials which mainly consist of smectite comprise pyroclastic rocks (Kepezinkaş, formation) and lava flows (Naltepe basalt). In addition to this, some data indicating the development of smectite related to the authigenic processes were also obtained. It is concluded that the clay layers were formed by the transformation of smectite to kaolinite in an acid swamp environment.

INTRODUCTION

In this paper the results of the studies on the clays of Orta (Çankırı) area have been used to determine the geologic origin and mineralogic characteristics of the clay deposits occurring within the provincial boundaries of Ankara and Çankırı were dealt with in this paper. Kaolinite-rich clay layers interbedded with low quality lignite seams are found within a depositional basin surrounded by volcanic and pyroclastic rocks in Orta area. According to Has and others (1977) these clays are covered by a blanket of alluvium occupying an area of almost 80 km2 between the villages of Kalfat, Kırsakal, Sakarcaören, Bastak, Hasanhacı, Büğdüz and Kanlıca. Orta town is located at the center of this area (Fig. 1). Lignite bearing kaolinitic and bentonitic clay deposits are encountered both in Cretaceous flysch and in the tuffs of Miocene Pliocene age in the Çankırı basin. Clays of Orta area belong to the latter group (Turgut and Altınay, 1979). Limestones of Early Mesozoic age, andesitic pyroclastics, and, andesitic basaltic lavas and tuffs of Miocene age constitute the basement rocks for the formations involving lignite seams (Has and others, 1977).

According to Kartal (1978) clays at Orta area were transported by streams and settled in lakes surrounded by acidic volcanic rocks. Their quality was further improved by the activity of humic acid in the environment. The genesis of bentonites and kaolinite rich clays (tonsteins) interbedded with lignite is still controversial (Loughnan, 1978). However, the idea of in situ bentonilization of volvanic ash followed by the transformation of bentonite to tonstein in an acid environment has recently gained importance depending on the chemical, mineralogical and micromorphological investigations (Senkayi and others, 1984; 1987).

For the purpose of better understanding of the geologic origin and of the factors controlling the mineralogy of clays found at Orta area located in the Çankırı basin, detailed geologic, mineralogic and petrographic investigations were carried out in the study area lying within the boundaries of the topographic maps of G30 dl-d2-d3 and d4 at the scale of 1:25.000. Alteration products of the country rocks providing detritic materials for the depositional basin were also studied in detail. Clay mineralogy studies were carried out in the Department of Geological Engineering, Middle East Technical University by means of a JEOL-JDSX-100S X-ray powder diffractometer. Micromorphological examination was performed by using CAMBRIDGE Stcreoscan scanning electron microscope in the Department of Metallurgical Engineering.

GEOLOGY OF THE STUDY AREA

The distribution of rocks having different lithologies within the study area is shown in Figure 2. Lava flows, pyroclastic and epiclastic units constitute the basement rocks of the area. The cover rocks including lignites and interbedded clays of Orta region crop out at the south of the study area. In general, these rocks are overlain by the alluvial deposits of the Devrcz creek and only exposed along the Karabalçık valley at which clay samples were collected from a small quarry (Fig. 1).

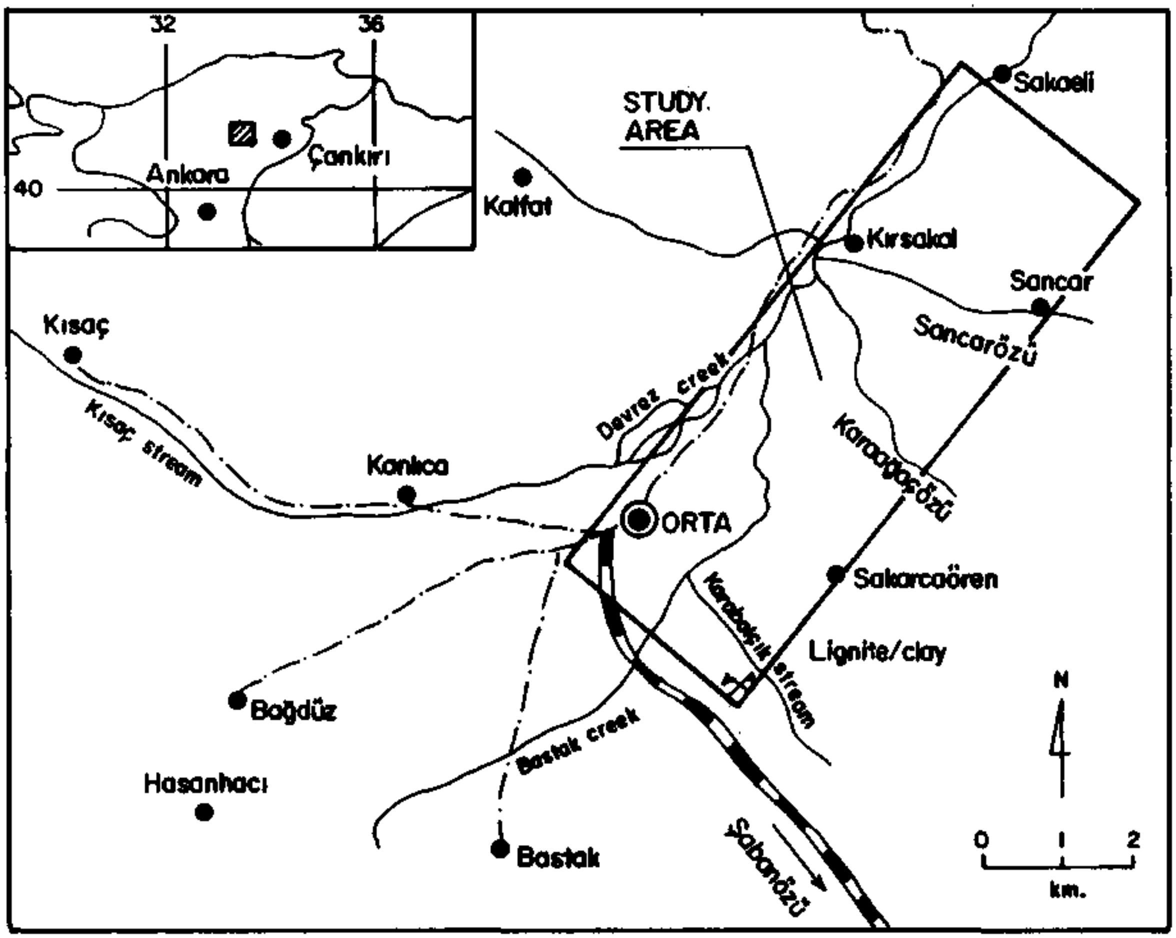


Fig. 1 - Location map of the study area.

A generalized stratigraphic column comprising the basement and cover rocks is shown in Figure 3, based on the field studies, laboratory work and earlier investigations (Akyürek, 1981; Akyürek and others, 1984).

Basement rocks

Basement rocks consist of Sancar andesite, Devrez formation, Kepezinkaş, formation and Naltepe basalt of Upper Miocene age (Fig. 2 and 3).

Sancar andesite. _ Sancar basaltic andesite forms the oldest unit and has a very narrow outcrop within the study area. Its lower boundary is not observed and the relationship with the overlying epiclastic unit (Devrez fm.) is not well established (Fig. 3). Sancar andesite has dark color and exhibits porphyritic texture. Plagioclase and pyroxene are the main minerals embedded in a glassy groundmass. Palagonitc is a common alteration product causing the greenish appearance of the rock. This unit can be correlated with the Kurtsivri volcanics of Akyürek (1981).

Devrez formation. _ This unit outcrops along the Sancarözü stream valley (Fig. 2). It has a normal upper boundary with Kepezinkaş formation but is overlain unconformably by Naltepe basalt. Devrez formation has a dark color and consists of subroundcd fragments derived from Sancar andesite and other volcanic rocks. It is an epiclastic unit rich in clay cement. This unit can be correlated with the Hancılı formation described by Akyürek (1981).

Kepezinkaş formation. _ This unit has a widespread occurrence in the study area (Fig. 2). There is an angular unconformity between the Kepezinkaş formation and the overlying Naltepe basalt (Fig. 3). It has white color and exhibits various

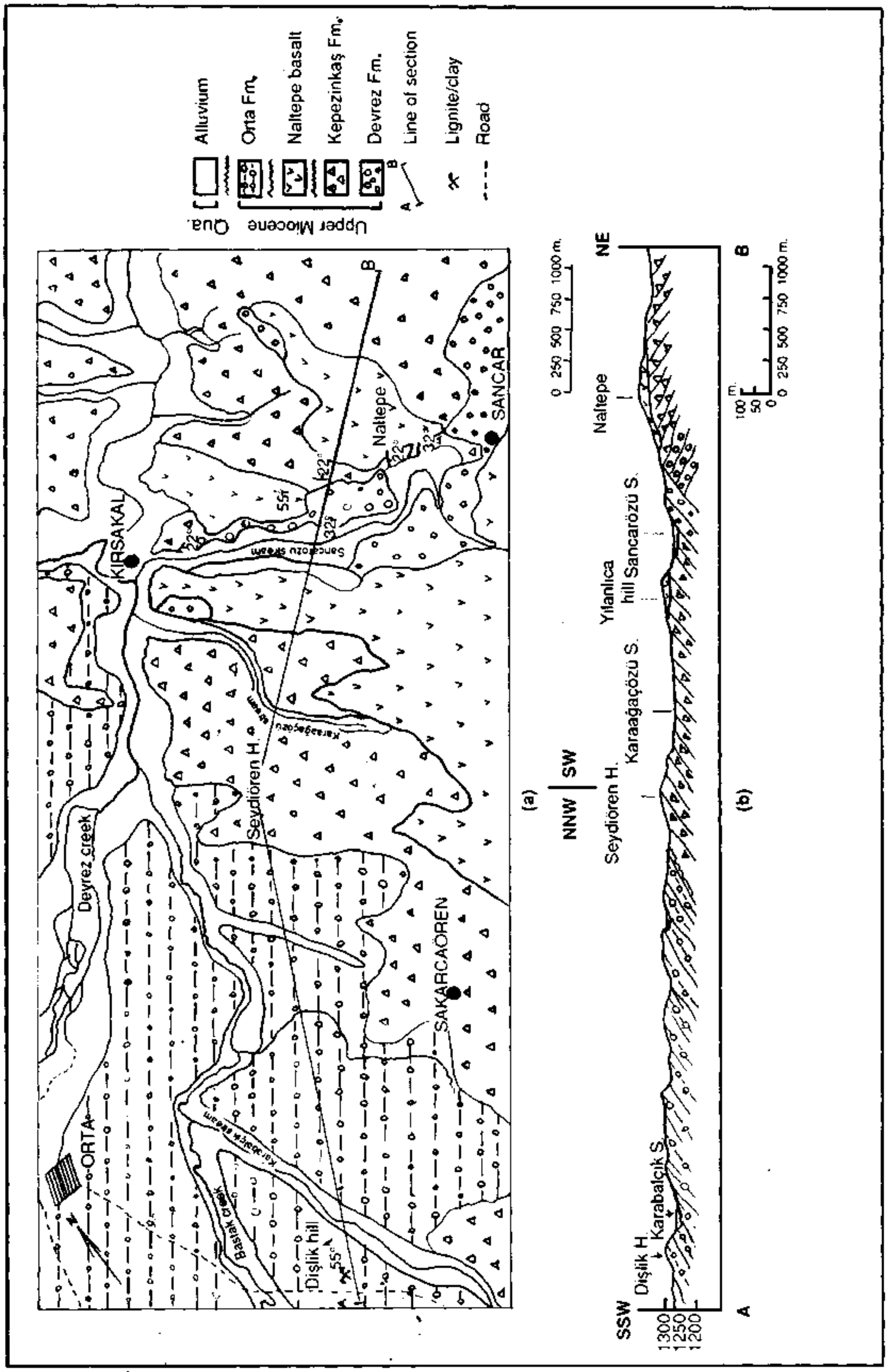


Fig. 2 - a- Geologic map of the area between Orta-Kırsakal-Sancar-Sakarcaören. b- Geologic cross-section.

lithologies such as conglomerate, tuff, dolomitic limestone and marl. Tuff has andesitic composition and is rich in volcanic glass shards. In addition, quartz, biotite, sanidine, volcanic rock fragments and pumice are common. Agglomerate consists of dark colored basalt, pink colored andesite and basaltic andesitc (Sancar andesite) fragments. Dolomite is identified in the samples from lacustrine limestones interbedded in this unit. Kepezinkaş formation is analogous to the Eregez agglomerate (Akyürek, 1981).

Naltepe basalt. _ All of the hills in the study area are covered by this unit (Fig. 2). It has an unconformable relationship with the overlying Orta formation (Fig. 3). It is dark colored massive and vesicular, olivine, pyroxene and plagioclase are the common minerals. Volcanic glass is present in the groundrriass. The vesicles are lined with green colored secondary minerals. The Naltepe basalt can be correlated with Aydos basalt of Akyürek (1981).

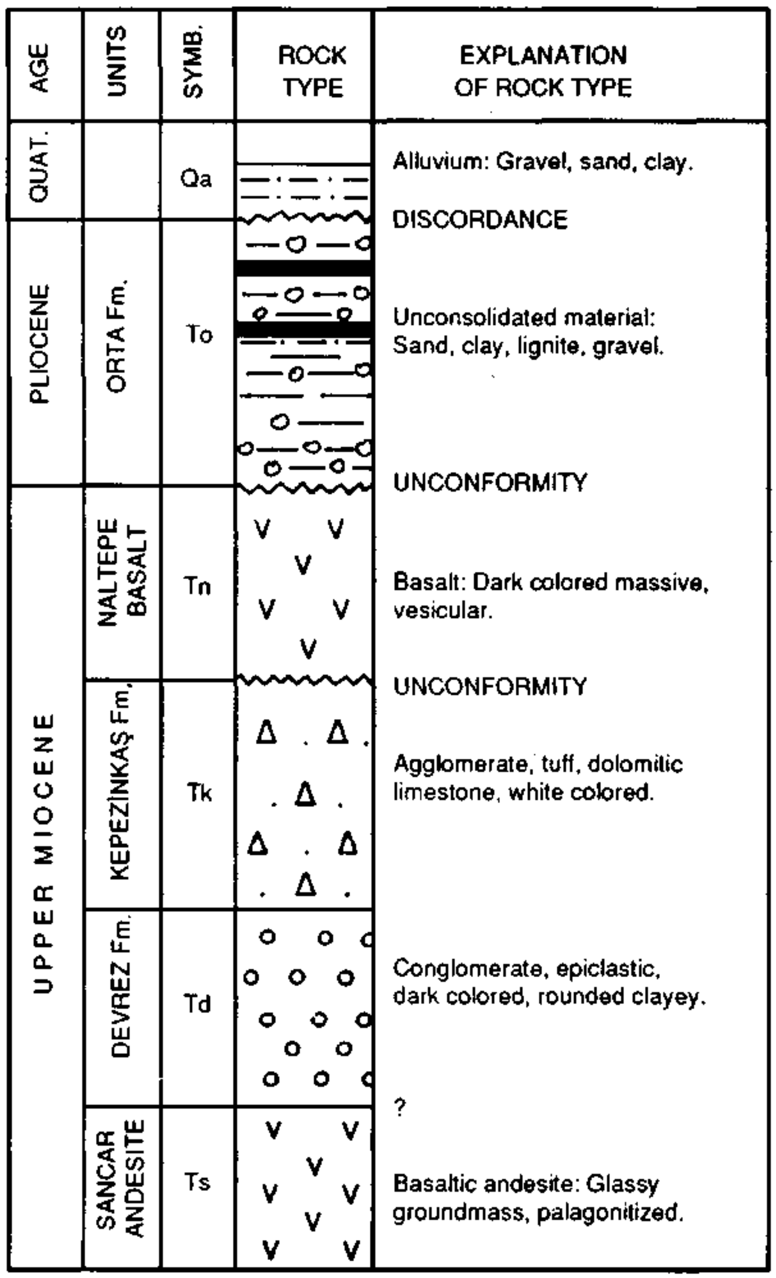


Fig. 3 - Generalized stratigraphic columnar section of the study area (not to scale).

Cover rocks

Cover rocks consist of Pliocene Orta formation and Quaternary alluviums (Fig. 2 and 3).

Orta formation. _ This unit unconformably overlies the basement rocks while it is disconformably overlain by the alluviums of Devrez creek. It consists of layers striking in the N 80° W direction and dipping 32° SW when observed from the section at the valley of Karabalçık stream. At the uppermost part of this exposure red colored soil and silt is observed. Varying thicknesses of the light brown to white colored clay and lignite layers lie underneath of this upper horizon. Lower part of the section contains 1.5 m. and 30 cm. thick upper and lower lignite seams which are underlain by 1 m. and 15 cm. thick clay layers, respectively. Clay rich horizons of the formation include macro plant fossils. Orta formation is found to be equivalent of Büyükyakalı formation of Akyürek (1981).

Alluvium. _ The alluvium composed of loose gravel, sand and clay occupying large areas in the valleys formed by Devrez creek and its tributaries, represents the youngest unit in the study area (Fig. 2).

MINERALOGY AND ALTERATION PRODUCTS

In addition to the geological investigations, a detailed study of mineralogic features and the determination of alteration products of basement and cover rocks were required in order to understand the genesis of the clay deposits at Orta area. According to the general stratigraphic relations, the Orta formation unconformably overlies the lava flows and pyroclastic materials which arc thought to be the products of Upper Miocene volcanism. There is no clear evidence of volcanic activity in Oligocene within the study area.

A worldwide close relationship exists between the kaolinite and bentonitic clay layers interbedded with coal and lignite, and the pyroclastic products of volcanic activity. Based on mineralogic and chemical evidences, Senkayi and others (1984, 1987) and Zielinski (1985) suggested that such clays originate through diagenesis of pyroclastic material in a lake and swamp environment. The existence of quartz, biotite, sanidine, cristobalite and glass shards all of volcanic origin coupled with their textures and alteration products indicate this kind of geologic origin.

Mineralogic and morphologic properties of clays

Clay exhibit abundant fossils in thin section (Plate 1; fig.1). Their study with the scanning electron microscopy displayed porous and tubular fossils associated with clay minerals having enhedral crystal morphology (Plate I; fig. 2, 3). According to Ercüment Sirel (oral communication, 1990) they are believed to be diatoms. Similar fossils have been identified in the diatomaceous earth from the Emmiler-Hırka (Kayseri) Neogene basin (Uygun, 1976). 7.16 Ao peak in the X-ray powder diffraction patterns of the Orta clay samples indicated that the clay mineral is kalinite. Badaut and Risacher (1983) suggest that poorly crystalline authigenic Mg-smectite may develop on the surfaces of diatom frustules in salt waters of some Bolivian lakes.

Alteration products of the basement rocks

Alteration products of the Kepezinkaş, formation and Naltepe basalt having widespread occurrences in the study area were investigated in detail. In thin-sections, opal-CT is observed as infilling material within the vesicles of tuffs from Kepezinkaş formation Plate II, fig. 1, 2). Precipitation of opal-CT from silica rich solutions is most probably occurring while the alteration of volcanic glass causes a pitted surface (Plate II; fig. 3). Electron microscope observations reveal the presence of smectite within these depressions (Plate II; fig. 4, 5) Plagioclase crystals in tuffs also alter and clay minerals from on their surfaces (Plate II; fig 6).

Basaltic glass in the groundmass of Naltepe basalt alters to palagonite and carbonate minerals to give rise to a banded texture (Plate III; fig. 1). In hand specimens green colored alteration products occupy the inner walls of vesicles. Palagonite surfaces have a botryoidal appearance under the electron microscope (Plate III; fig. 2).

Serpentinization of olivine crystals and carbonate formation from orthopyroxene are also a common phenomenon Feldspar crystals, however, arc generally fresh.

RESULTS

Orta clay deposits originated from the kaolinization of transported clay material by the effect of water in a Pliocene lake swamp environment. Major source of clays transported by streams into the depositional basin is the smectite rich soil developed by the alteration of volcanic and pyroclastic rocks surrounding the lake. This conclusion is further supported by the transformation of volcanic glass into smectite in the tuffs of andesitic composition. Evidences are also obtained implying the authigenic growth of some smectite crystals from the surfaces of diatom frustules. The model of smectite to kaolinite transformation during diagenesis is favored by the lack of textures which otherwise would indicate that these lignite interbedded clay deposits originated through in situ alteration of air-fall tuff.

ACKNOWLEDGEMENTS

This paper presents a part of the results of a research project AFP 88-03-09-03 which is sponsored by the Middle East Technical University. The authors' thanks are due to Prof. Dr. Ali Koçyiğit, Bünyamin Akbaş and Behçet Akyürek for their valuable discussions on the geology of the area. They also acknowledge Ercüment Sirel's contributions to the paleontological problems.

Manuscript received June 26,1990

REFERENCES

Akyürek, B., 1981, Ankara melanjının kuzey bölümünün temel jeolojik özelllikleri: İç Anadolu'nun Jeolojisi Sempozyumu, TJK 35. Bilimsel ve Teknik Kurultayı, 41-45, Ankara, Turkey.

———; Bilginer, E.; Akbaş, B.; Hepşen, N.; Sunu, O.; Soysal, Y.; Dağer, Z.; Çatal, E.; Sözeri B.; Yıldırım, H. and Hakyemez, Y., 1984. Ankara-Elmadağ-Kalecik dolayının temel jeoloji özellikleri: Jeol. Müh., 20, 31-46.

———; Akbaş, B. and Dağer, Z.. 1988, 1:100.000 ölçekli açınsama nitelikli Türkiye Jeoloji haritaları serisi, Çankırı E 16 paftası: MTA Jeoloji Etütleri Dairesi yayınları, 22 p. Ankara, Turkey.

Badaut, D. and Risacher, F., 1983, Aulhigenic smectite on diatom frustules in Bolivian saline lakes: Geochim. et Cosmochim. Acta, 47, 363-375.

Has, F.; Sezer, C; Özgen, S.; Demirok, Y.; Erdoğan, M, Sağıroğlu, A. and Alemdaroğlu, T., 1977, Çankırı-Orta linyit sahası fizibilite araştırması: Vol. 1, MTA Rep. 6077 (unpublished), Ankara, Turkey.

———;———and Özgen, S., 1978, Çankırı-Orta linyit sahası: Vol. 2, MTA Rep. 6127 (unpublished), Ankara, Turkey.

Kartal, G., 1978, Orta Anadolu ateşkili alanları: Jeol. Müh., 6, 45-48.

Loughnan, F.C., 1978, Flint clays, tonsteins and the kaolinite clay rock facies: Gay Miner, 13,387-400.

Senkayi, A.L.; Dixon, J.B.; Hossner, L.R.; Abder Ruhman, M. and Fanning, D.S., 1984, Mineralogy and genetic relationship of tonstein, bentonite and lingitic strata in the Eocene Yagua formation of east-central Texas: Clays and Clay Minerals, 32, 259-271.

———; Ming, D.W.; Dixon, J.B. and Hossner, L.R., 1987, Kaolinite, opal-CT and clinoptilolite in altered tuffs interbedded with lignite in the Jackson Group, Texas: Clays and Clay Minerals, 35, 281-290.

Turgut, A.T. and Altınay, A., 1979, Çankırı-Şabanözü ve Orta ilçeleri civarındaki linyitli sahaların jeolojik raporu: MTA Rep. 7017 (unpublished), Ankara, Turkey.

Uygun, A., 1976, Geologie und dialomit-vorkommen des Neogen-beckens von Emmiler-Hırka (Kayseri-Türkei): Dissert doktor., Universitat Bonn, 136 p.

Zielinski, R.A., 1985, Element mobility during alteration of silicic ash to kaolinite a study of tonstein; Sedimentology, 32, 567-579.

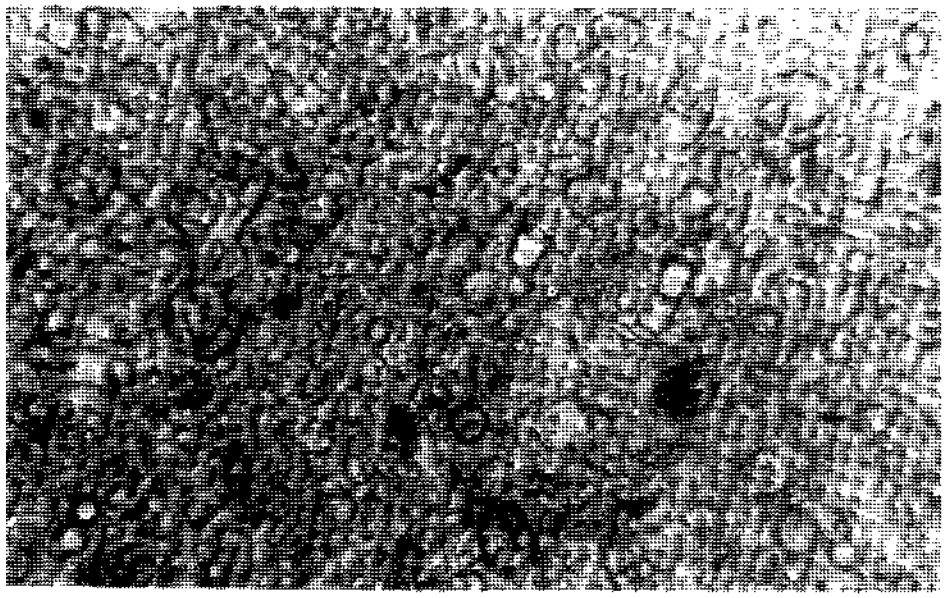
PLATES

PLATE-I

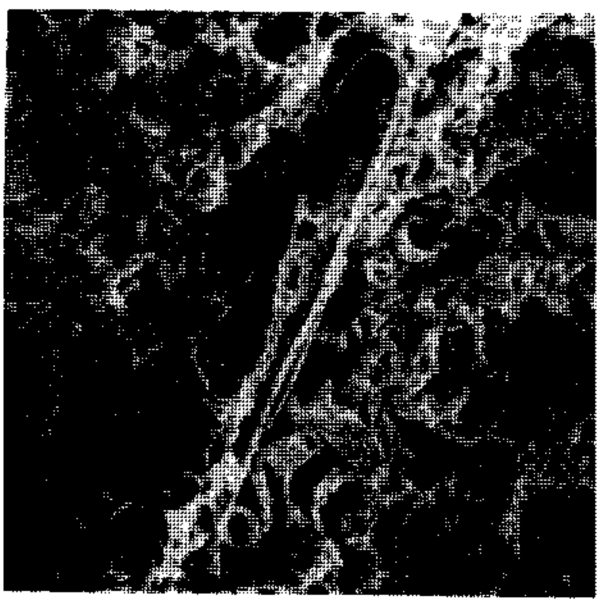
Fig. 1 - Photomicrograph showing fossils in clays (plane polarized light, X25).

Fig. 2- Scanning electron microscope view of an unusual fossil type (X 700).

Fig. 3- Scanning electron microscope view of diatoms and clay crystals (X 1600).



1



2

3

PLATE-II

Scanning electron micrographs of tuffs:

Fig. l-Opal-CT(X900).

Fig. 2- Close-up view of opal-CT (X 4500).

Fig. 3- Solution pits from volcanic glass (X 1800).

Fig. 4- Smectite crystals formed within the volcanic glass (X 900).

Fig. 5- "Cornflake" morphology of smectite (X 4500).

Fig. 6- Kaolinization on the surface of plagioclase crystal (X 1800).

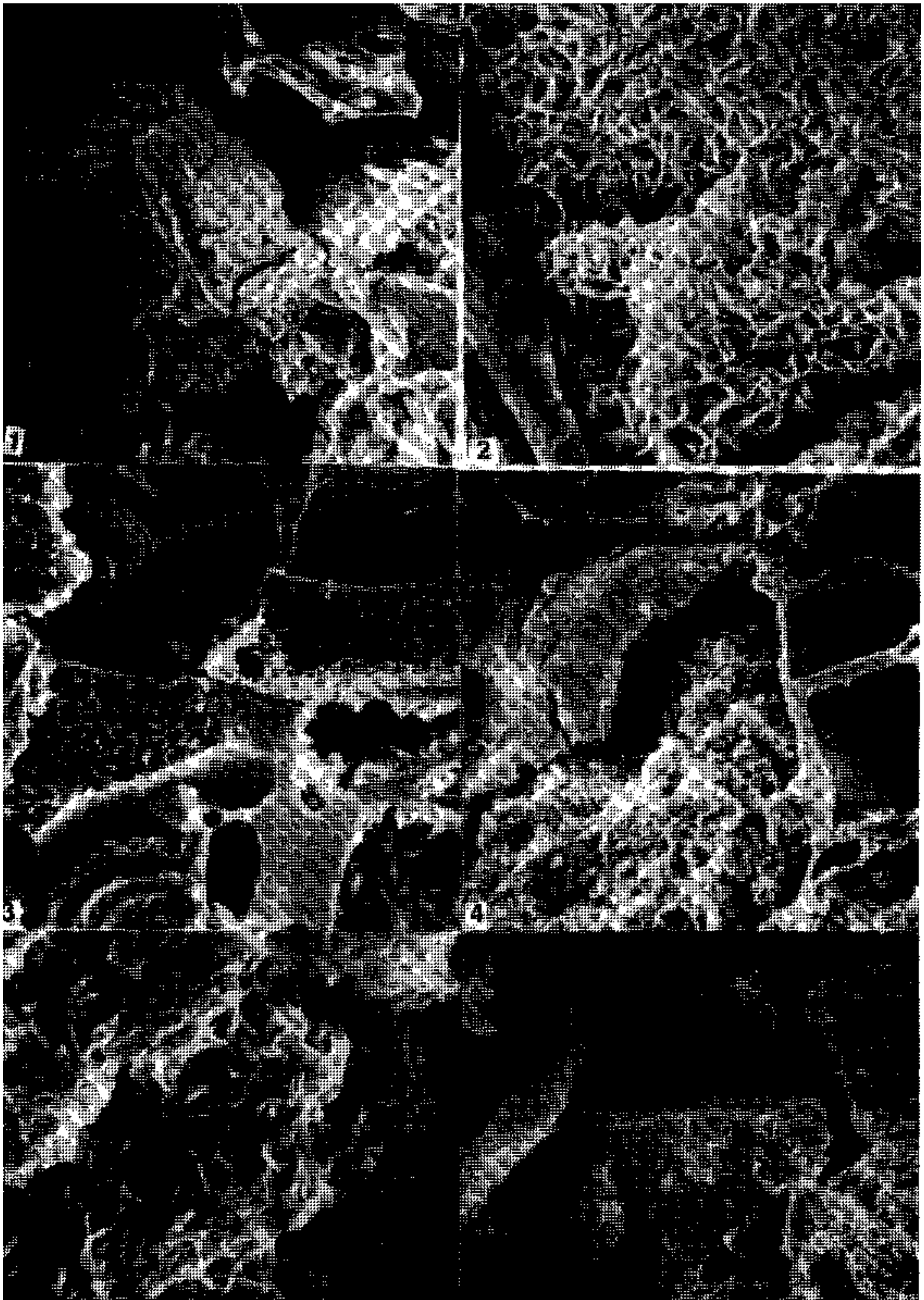


PLATE-III

fig. 1- Photomicrograph showing the palagonization in Naltepe basalt (plane polarized light, X 10).

fig. 2- Scanning electron micrograph showing fresh volcanic glass (black) and botryoidal morphology of palagonite within a vesicle (X400).

THE GEOLOGY OF THE SIVAS-D1VRİĞİ-TAŞLITEPE IRON PLACER AND ITS MINING

Hüseyin ÖZTÜRK***

ABSTRACT— Taşlıtepe iron ore plaser occurrences was deposited during the Pliocene time which is the oldest placer than the other ones at the region. It displays fairly well belonging to colluvial fan deposition features. Fragmenial ore material that has moved down from mountainside by the influence of gravity will lend to accumulate at the foot of the slope. The basement rocks consist of crystalized limestones Mesozoic age, serpantinized ultrabasics Upper Cretaceous age, siyenite-monzonite plutons Paleogene age and conglomerale-mudstone Miogcne age. Taşlıtepe iron placer overlains these basement rocks with angulary unconformity and it is overlain by the river deposits with unconformably. But placer was faced with these river deposits by oblique strike slipe faulting events of plio Quaternary age. These river deposits arc exposed at the high position as a 400 m. from the actually river level as a result of quickly uplift of the region recently. Sedimentologicial, structural and morphologicial datas of the placers indicate that placer materials has been transported from southwest toward northeast route. It is thinked that there was a primary deposit at the siyenite serpantine contact although there isn't any primary deposit at present. Source deposits of the placer has finished due to erosion effects from Pliocene to present. 600.000 tons measured ore and 400.000 tons probably ore total 1.000.000 tons iron ore was determined in the light of the eight drilling holes at the placer. The content of the iron mineral which is martite in the placer varies from 1 ton 1.3 tons per cubic metre. Approximately 200.000 tons martite Containing % 62 Fe was produced from the placer in 1989.

UPPER CRETACEOUS (MAESTRICHTIAN) BENTHIC FORAMINIFERA FAUNA IN THE OSMANİYE (ADANA) REGION

Niyazi AVŞAR****

ABSTRACT— In this paper general information is presented on the regional stratigraphy on the base of the data gathered by studying the bentic foraminifera present in the Upper Cretaceous (Macstrichtian) sediments of the Osmaniye (Adana) region. Mesozoic ophiolite unit forms the basement in the region. Middle-Upper Maestrichtian sediments which include clayey and micritic limestones disconformably overlie the ophiolite. In this clayey limestone bentic foraminiferas such as *Lofiusia morgani* Douville, *L. baykali* Meriç, *L. oktayi* Meriç, *L kahtaensis* Meriç, *Orbitoides medius* (d'Archiac), O. *triangularis* Checcia-Rispoli, *Omphalocyclus macroporus* (Lamarck), *Siderolites calcilrapoides* Lamarck and *S.* cf. *denticulatus* Douville have been identified. At the top Miocene sediments overlie the Middle-Upper Maestrichtian sediments with an unconformity.

Mineral Res. Expl. Bull., 113, 93- 102, 1991

HYDROCARBON POTENTIAL OF THE KAHRAMANMARAŞ AND ELBİSTAN AREAS

Yüksel ÖNEM*

ABSTRACT. - The Taurus mountains, which developed in the conjoining zone of the Anatolian and Arabian Plates, underwent a disruption between Bolkar mountain and Engizek mountain. This can be explained by the fact that the area was traversed and transformed by two major strike-sup faults situated at Mersin-east Bolkar mountain-Kayseri in the west and Antakya (Hatay)-Elazığ-Bingöl in the east In fact, the east-west oriented 200 km. wide area, covering the gulf of İskenderun and the northern pan of Adana, was compressed and deflected as far as the north of Sarız and the Arabian Plate was dislocated prior to the faulting, and moved circa 120 km. inside Anatolia. Linked to this movement, the Miocene Nappe cover was dragged too far in the exactly opposite direction, i.e., to the south, and changed the original form of the mountain sequence. This relocation resulting from tectonic activities has emphasized, from the viewpoint of the settling of the formations belonging to the Arabian Plate, the importance of the area north of Bolkar mountain-Engizek mountain line or the Taurus sequence and defined the hydrocarbon potential of Elbistan region. As to the Kahramanmaraş area, the fact that the oil-producing formations of the Southeast Anatolia are found in this also, it continues to be an important objective.

INTRODUCTION

My first investigations relating to the Kahramanmaraş area took place in 1980 on behalf of a private oil company. At the beginning I made the 1:25.000 scale geological map of the area extending from Kahramanmaraş to the foot of Engizek mountain. Apart from having steeper flanks, these anticlines, covered with Eocene-age limestones, exhibited no difference from the known structures of southeast Anatolia. The limestone cover is directly underlain by the Karadut formation. This configuration can be seen clearly in the faulted zones south of Ahırdağı anticline.

During the said investigation and the field trip I made later to the northwest of Kahramanmaraş, I noticed that the autochthon formations were, as many geologists have observed and arc aware of, formations belonging to the Arabian Plate and this led to my hypothesis regarding the hydrocarbon potential of the region. The Elbistan plain which is covered by the Miocene Nappe, has, along with the Kahramanmaraş area, become an important objective.

The most important question regarding the Kahramanmaraş area was whether or not the target levels of southeast Anatolia existe here also. The data on which Figure le was based, shows clearly that the formations existing extensively in the northwest and in the south of Kahramanmaraş definitely support the positive view regarding the Kahramanmaraş area. As to the extension of the structures observed on the surface and below the surface this was proven by the seismic profile MS-101 taken by Placid Oil Company in 1986.

The important questions concerning Feke, Saimbeyli, Sarız, Afşin and the Elbistan areas, located north by northwest of the Kahramanmaraş area, was how far and in what manner had the Arabian Plate advanced. Kahramanmaraş and its vicinity has been the subject of study since 1975 from the viewpoint of continental movements related to the Anatolian and Arabian Plates. However, none of those investigations (Perinçek, 1979; Yiğitbaş, 1980; Perinçek and Özkaya, 1981; Yılmaz, 1981; Tekeli and Erendil, 1986; Tarhan, 1986; Yoldemir, 1990; Yılmaz, 1990; Çemen et al., 1990. Kozlu and Fourcade, 1990; Günay et al., 1990) has brought forth a clear view or picture regarding the thrust zone, although they have furnished data and advanced opinions in connection with the various tectonic phases and depositional environments between the two plates. Consequently, our views regarding the thrust line between the plates and the situation of the present Arabian Plate are based, jointly, on our field observations, MTA data (MTA, 1961, 1962) and further studies we have conducted.

GENERAL GEOLOGY

The thick sedimentary cover which extends over the surface of Southeast Anatolia is the northwestern part of the large sedimentary cover of the Arabian trough. It is bounded by the Taurus mountains in the north.

Kahramanmaraş, Feke, Saimbeyli, Sarız and the Elbistan region is the northern most part of the Arabian basin, and its autochthon formations belong to the same plate.

At the north of the Taurus mountain, there is the Anatolian Plate of which Pre-Cambrian and Paleozoic aged formations are metamorphosed and probably originate from different sources.

Except the Thrace basin, oil has not been discovered within the sediments deposited on the Anatolian Plate and such a possibility is remote. The Taurus mountains which are a part of the Alpin Orogenic Belt between the Alps and the Himalayas, is a mountain chain formed as a result of the squeezing of the sediments/magmatic materials of the Tethyan Sea between the Arabian or African Plate and the Anatolian Plate beginning in the Cretaceous time. Two important tectonic movements both going forward to the south opened and ended during this Taurus Orogeny, the first one is the Upper Cretaceous gravity slide and the second is the Miocene Nappe.

The anticlines of the Kahramanmaraş area are formed by the Eocene age limestones, and they form high mountain chains in the east-west direction. The synclines between these mountains/anticlines have been filled by the coarse elastics of Miocene age.

Those materials which form mixed and rough topography at the north of the Kahramanmaraş area, beginning from the Engizek mountain, belong to the Miocene Nappe formations, and they are mostly ophiolites and also metamorphic blocks (Yılmaz and Yiğitbaş, 1990) carried from the Anatolian Plate. It is accepted that the Tertiary and older formations under this nappe cover belong to the Arabian Plate outside of the thrust zone.

Allochthon rock bodies belonging to the Upper Cretaceous gravity slide and/or Miocene Nappe, and also autochthon formations of the Arabian Plate exist as a blend in the south of the Kahramanmaraş area (Fig. 2).

STRATIGRAPHY

It is different to define stratigraphy of the Kahramanmaraş area before the Midyat formation. At two small overlapping zones in the south of the Ahırdağı anticline the Karadut formation is exposed in small dimensional (Fig. 2).On the basis of this, we can with certain say that the Karadut formation started directly after the Midyat limestone section. The thickness of the Karadut formation can not be estimated by field observation. But two sources can be helpful for the thickness and also the lithology of the complex. One of the sources is seismic line MS-101 which only shows the thickness (Fig. 3). The other source is the Haydarh-2 well which was drilled by Türkiye Petrolled Anonim Ortaklığı (TPAO) in 1983,33 km. east of this seismic line, showing both thickness and lithology.

The base of the Karadut formation is not known exactly. But from the sources that have contributed to the preparation of Figure 1 it can be seen that, from the Feke-Saimbeyli-Sarız area to the north and northwest of the Kahramanmaraş area, from the Gaziantep area (including wells) in the south, from the Amanos mountains in the south and southwest, and finally from the Adıyaman area in the cast and southeast of them and also from some surface and subsurface data obtained from the wells and geological maps/measured sections give, in our view, reliable straligraphic information about the Kahramanmaraş area. Thus, the fence diagram that forms Figure 1 represents the lithologic units of this environment, and the stratigraphic section in Figure 4 shows a synthesis depending on that data.

PALEOZOIC

Cambrian

The Cambrian scries that seems to be a typical section in Derik, west of Mardin has a striking resemblance to the Değirmentaş, formation in the Sarız area which was measured by various companies, (also the ones exposed at the Amanos mountains, and the section that outcrops it to a small extent at the Penbeğli-Tutköy area in the west of Adıyaman). Since the Kahramanmaraş area is in the middle of these exposed sections it is highly probable that the same section exists there also.

It is hard to estimate the total thickness of this scries which is composed of the elastics at the base, carbonates in the middle, and again the elastics at the top. It is possible that the thickness of this section may be about 2000 m. (Fig. 1,4).

Ordovician-Silurian

The Ordovician-Silurian sections in the Gaziantep area arc almost the same in lithology as the Bedinan formation; mostly composed of black shales at Derik.

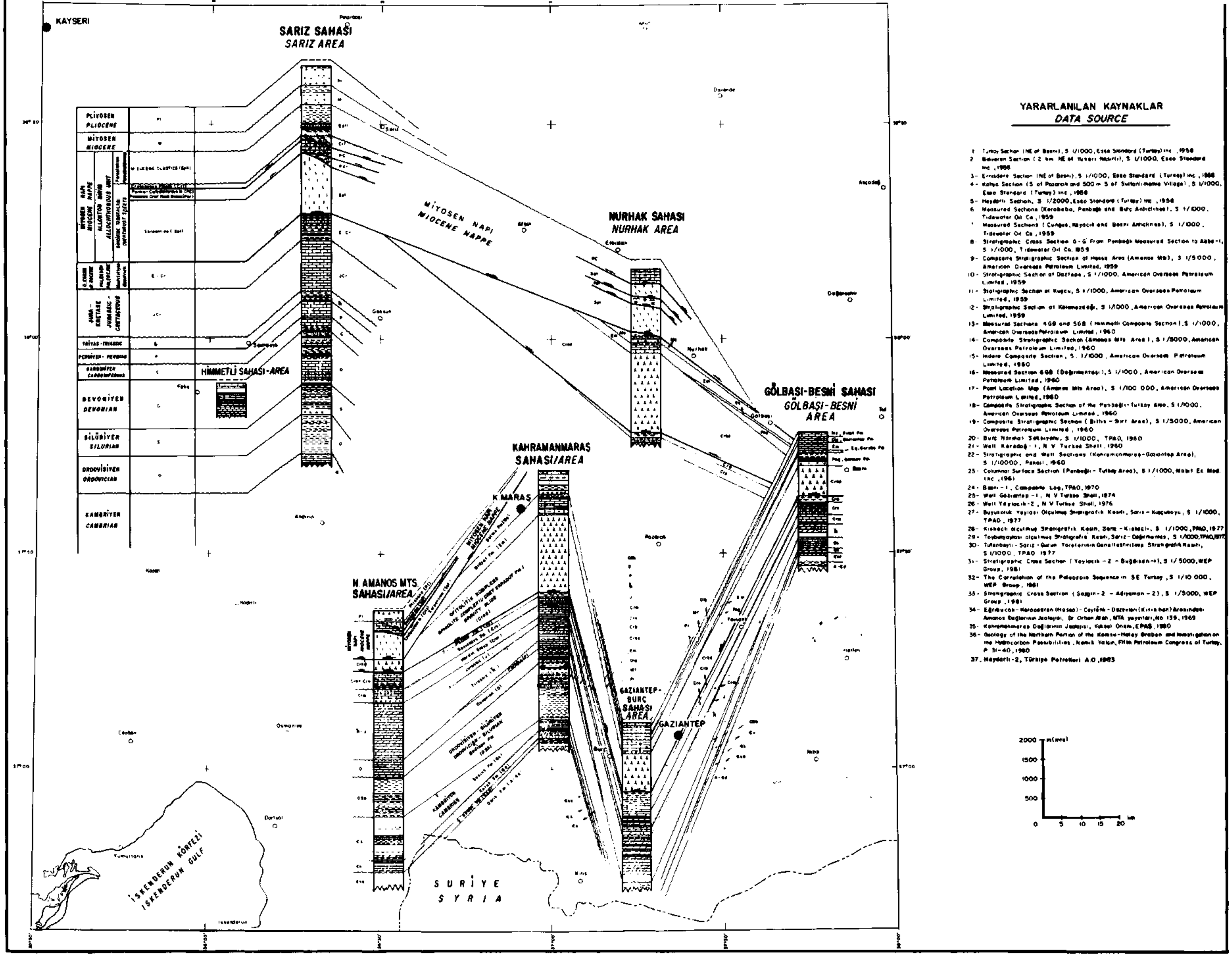


Fig. 1 - The fence diagram of the vicinity of the Kahramanmaraş Area. Scale Hor.: 1:500.000, Ver. 1:50.000.

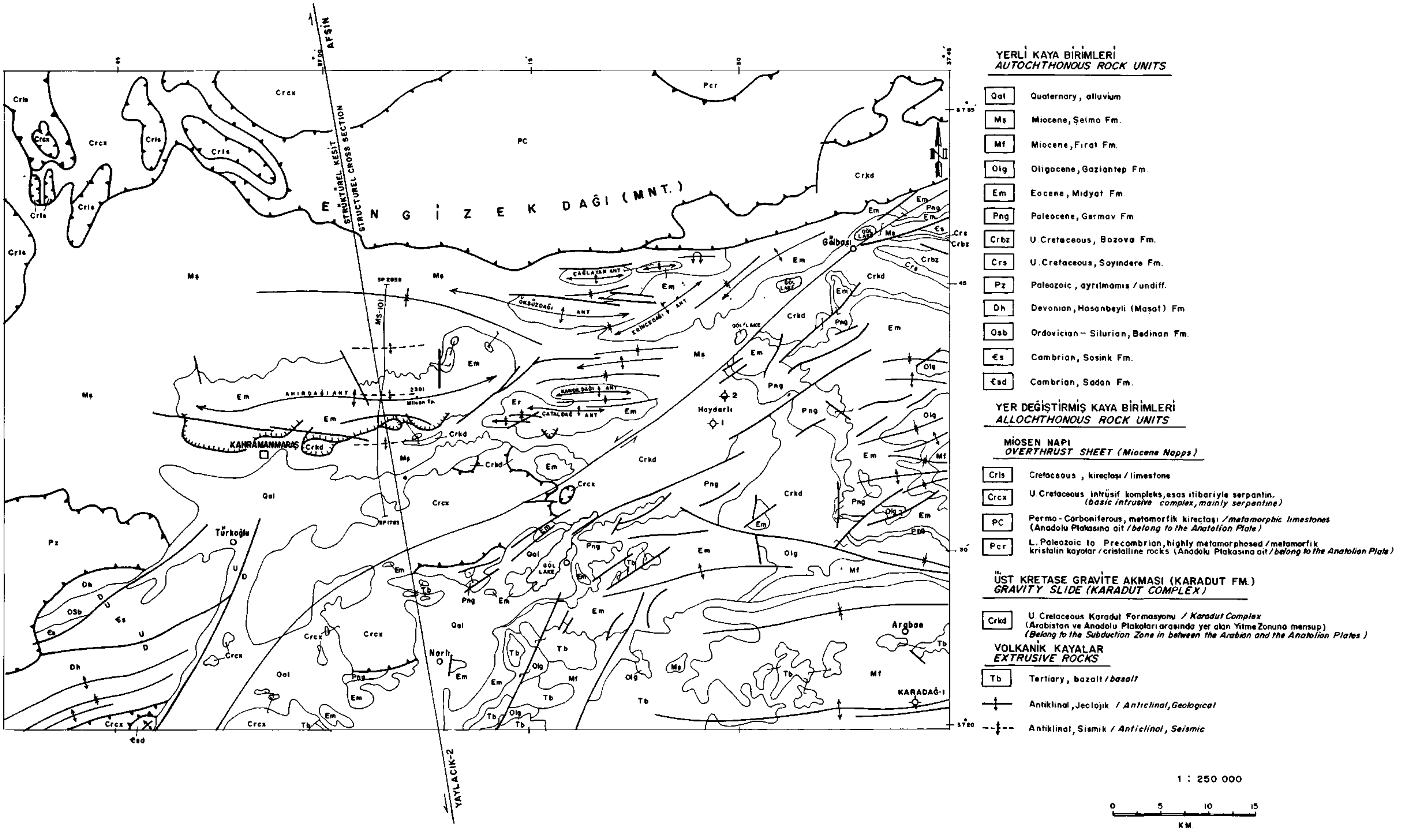


Fig. 2 - Geologic map of the Kahramanmaraş area. Scale: 1:250.000.

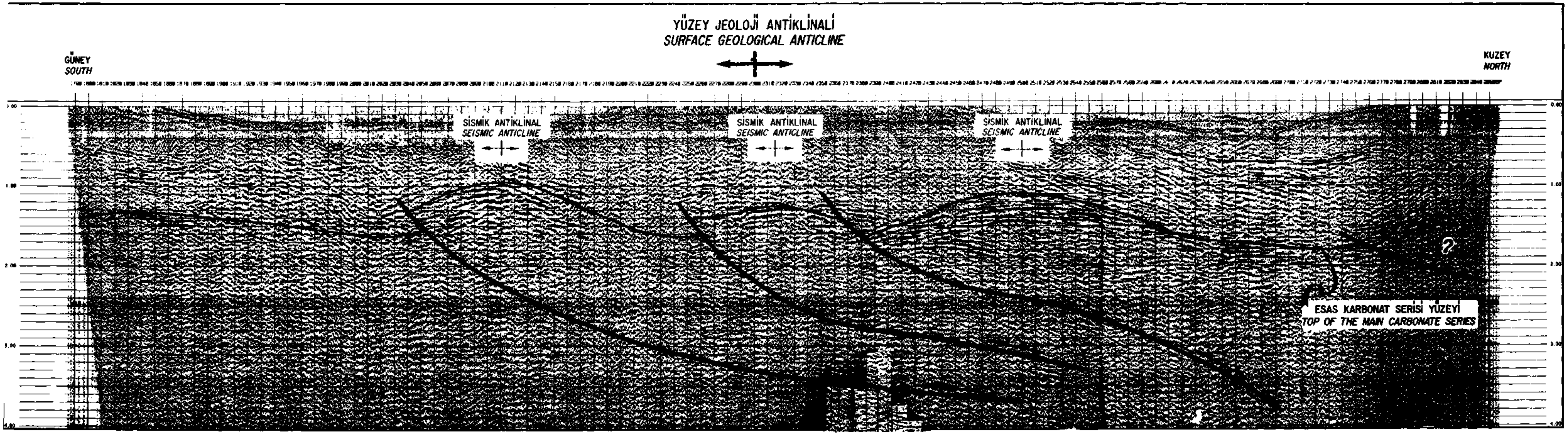


Fig. 3 - Seismic line MS-101.

The same-age section in the Amanos mountains contains the following units (Atan, 1969) at the base of the Kardere formation; mainly quartz sandstone of a coastal facies, the Kızlaç formation; fine-grained sandstone, mudstone and shale deposited in a slowly deepening sea, the Akçadağ formation; coarse elastics believed to be deposited under shallow marine conditions, and at the top, the Bahçe formation; thin-bedded black shales and mudstones believed to have been deposited in a deep sea environment (Fig. 4).

The Ordovician-Silurian section exposed at the Toybuk Yaylası (location in the Sarız area) is formed of shales; 1050 m.; calcareous shales; 310 m. a coarse clastic member; 95 m. sandy shales; 80 m. altogether 1535 m. in thickness according to the measurement taken by TPAO.

The Upper Cretaceous carbonate series overlies the Cambrian section with a large unconformity in the Penbeğli-Tutkoy area. Thus, the younger part of the Paleozoic scries is not exposed there, and it is very difficult to form a clear idea of the thicknesses and the lithologies of the Ordovician-Silurian formations expected in the eastern pan of the Kahramanmaraş area.

Some Ordovician-Silurian formations, however, would be expected in the Kahramanmaraş area because of the thick sections exposed in the Amanos mountains, and in the Sarız area, and observed in the well around the city of Gaziantcp(Fig.l,4).

Devonian

There are no Devonian formations in the Gaziantep, Urfa and Adıyaman areas. This indicates the Devonian formations were eroded at the top and also around the axial zone of the Mardin-Adıyaman uplift.

However. Devonian formations are present in the Amanos mountains. There, it is observed (Alan, 1969), that conglomerates and sandstones (Kırtaş formation) overlie the eroded surface of the Silurian formations and that shale interbedded in a limestone section (Hasanbeyli formation) was deposited in the more stable parts of this area (Yoldemir and Perinçek, 1990). These very fossiliferous limestones belong to the Devonian period according to paleontological data.

Devonian formations are also present in the Feke, Saimbeyli, Sarız areas. At the Toybuk Yaylası location (in the Sarız area) a Devonian section 540 m. thick has been noted by TPAO. The main parts of this section (410 m.) are formed of limestone and 50 m. of sandstone, 50 m. of calcareous shale and 30 m. of shale.

A good sandstone section, although not very thick, between the Silurian shales and the Permian limestones in the Hazro uplift belongs to the Devonian period in age.

If we consider that the Devonian formations exist in the Amanos mountains (Sarız and Hazro areas), then it is highly probable that a Devonian with a similar facies measuring approximately 225 m. of thickness can be found in the Kahramanmaraş area also (Fig. 4).

Permian

There are no Carboniferous layers found in the South and Southeast Anatolia. Also, there are no Permian formations in the Gaziantep and Amanos mountain areas. The Silurian/Bedinan formation underlies the Triassic sequence in the Anl-1 well located 20 km. cast of the city of Gaziantep.

Gaziantep-1 and Yaylacık-2 wells were abandoned in the Triassic formations, but the Permian aged formations are not believed to exist in these locations.

On the other hand, the conditions are different in the eastern pan of the Mardin-Adıyaman uplift, in the Hakkari area, and the northeastern part of the same uplift and in the Hazro area. In the Hakkari area the Permian section at the Belek location has a total thickness of 1080 m.; a shale-sandstone unit at the base of 40 m.; a limestone unit at the top of 1040 m. Also in the Hazro area, a limestone unit at the base, a sandstone unit in the middle, and again a limestone unit at the top together form the Permian section of which is mostly composed of limestone, with a total thickness of about 350 m.

In the Sarız area, (Kıskaçlı location) the Permian section measured by TPAO is formed of shale (150 m. thick) with some interbeds of sandstone at the base which is overlain by limestone above the shale (235 m. thick).

At the Kahramanmaraş area a Permian section with a maximum thickness of 150-200 m. can be expected (Fig. 4).

MESOZOIC

The Mesozoic-age formations that are observed all over Southeast Anatolia as a thick series; will, in all probability, be present in the Kahramanmaraş area also.

Triassic-Upper Cretaceous

Main carbonate series (Triassic-Mardin group). - The carbonate section cut in the Arıl-1 well in the Gaziantep area consists of: basal clastic horizon (Uludere formation of Triassic age); 239 m. in thickness; 696 m. Triassic carbonates; 75 m. Jurassic limestones; and 661 m. Mardin group carbonates. Thus, the total thickness of the Mesozoic series which attain a total thickness of 1671 m., the major part, 1432 m., consists of limestone and dolomite. "Gaziantep-1" well was abandoned after having penetrated 85 m. of Triassic elastics. Above this clastic horizon, 1402 m. Triassic; 496 m. Jurassic; and 467 m. Mardin group was cut and all of them were composed of carbonates. The Jurassic, as compared to "Arıl-1", was found to be thicker and the reason for this is explained as the repetition of the same formation due to a fault. The total thickness of this section is 1700 m. in this area.

"Karadağ-1" well which is 74 km. southeast of the city of Kahramanmaraş was abandoned in the Triassic elastics level after penetration at 76 m. Above this level, it was composed of all carbonates and with in a total thickness of 1239 m. is found a section containing Triassic that is 569 m., Jurassic 145 m., and Mardin group 525 m.

In the Amanos mountain there is a Triassic transgression that is seen after a Permo-Carboniferous discontinuity and this Triassic transgression starts with the Arılık formation that forms the clastic unit at the bottom and has a thickness of 130 m. (Atan, 1969). The Küreci limestone which was deposited under stable conditions, and the upper part belonging to Jurassic (Atan, 1969), lies above it; 235 m. in thickness. The Karadağ limestone, 300 m. in thickness and of Albian-Cenomanian age, overlies the Küreci formation with a basal conglomerate level and an angular disconformity. In summary, the Triassic to Cenomanian section totals 665 m. in thickness in the Amanos mountains area.

Eighty-seven km. east/northeast of the city of Kahramanmaraş in the "Besni-1" well, elastics were encountered below the main carbonate series and were considered as Cambrian in age until the 1980 s. But, during these years, paleonlological determinations made by TPAO showed that this clastic level belonged to the Triassic Uludere formation. The section at Besni-1,455 m. in thickness, is composed of 130 m. of Triassic elastics at the base, 84 m. of Triassic limestone in the middle, and 241 m. of the Mardin group's carbonates at the top.

At the Haydarlı-2 well, which is located 48 km. east of the city of Kahramanmaraş, the main carbonate series was 496 m. thick of this 154 m. was Mardin group (limestone, a thin marl level at the base), 80 m; Areban formation (sandstone, shale) and 262 m.; Triassic-Jurassic limestones.

In the Sarız area there is a very thick carbonate section deposited during the periods Triassic to Cretaceous. The total thickness of the measured section of Triassic (Katarası formation) and Jurassic/Upper Cretaceous (Yüceyurt formation) is more than 1500 m.

After determination of these series-aged Triassic-Upper Cretaceous layers around the Kahramanmaraş area, it is expected that a limestone/dolomite section with a basal clastic unit of approximately 750-850 m. in thickness exists there (Fig. 1,4).

Upper Cretaceous

Argillaceous limestone-marl sequence (Sayındere and Bozova formations). - The section, in the east of Diyarbakır and covering the Mardin group as a thick and monotonous sahale series, is called Germav formation. Many authorities believe that this series is the main source rock in this area.

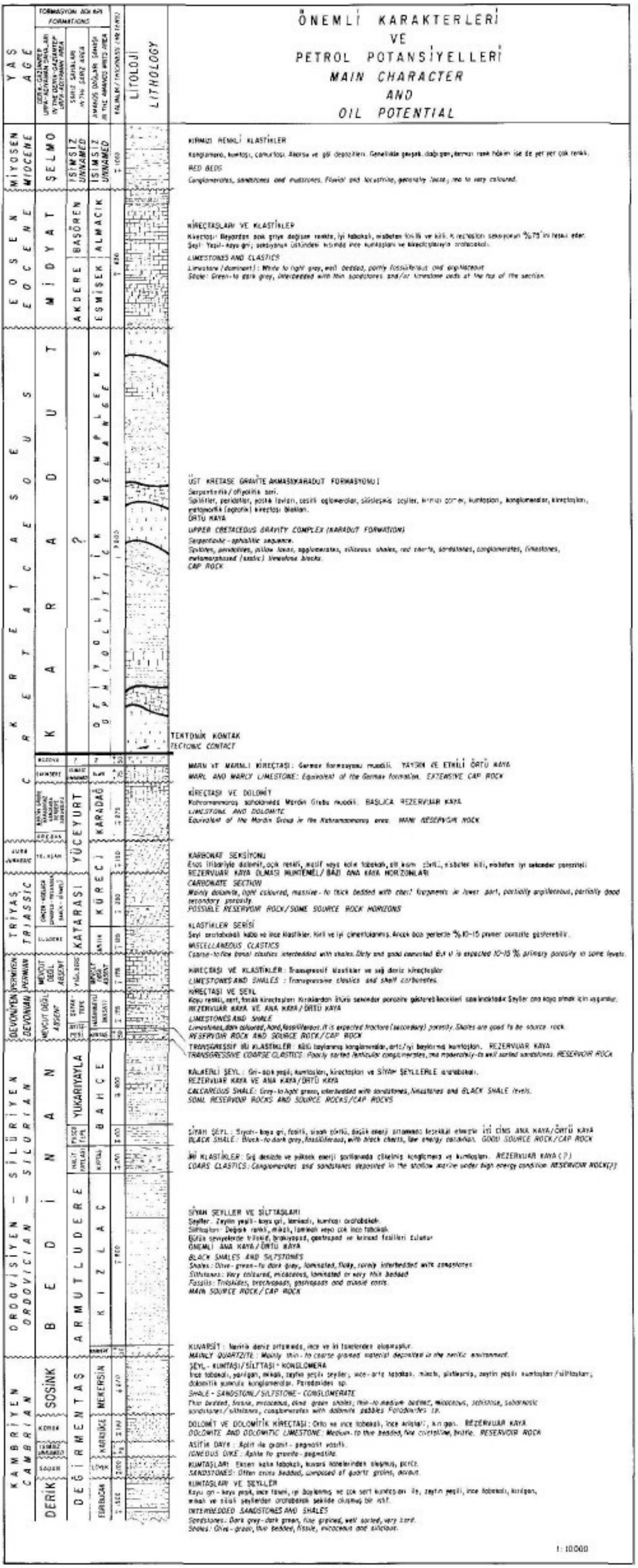


Fig. 4 - Composite stratigraphic section of the Kahramanmaraş area. Scale: 1:10.000.

The monotonous character of this formation in the west of Dıyarbakır has been changing and turning into calcareous shale, argillaceous limestone and marl. The Sayındere formation (argillaceous limestone) and Bozova formation (marl) are two sediment units which are different equivalents of the Germav formation in the Urfa, Adıyaman and Gaziantep areas.

The total thickness of the argillaceous limestone-marl sequence is 1290 m. in the "Suvarlı-2" well; 1208 m., in "Karadağ-1" well; 680 m., in "Arıl-1" well; 544 m., in "Gaziantep-1" well; 509 m., in "Besni-1" well and 283 m. in "Yaylacık-2" well.

Argillaceous limestone-marl sequence is the only unit between the main carbonate series and Upper Cretaceous gravity slide (ophiolitic complex), and it can be surmised that its thickness at the Kahramanmaraş area will be between 100-150 m. and that it will make a good cap rock (Fig. 1, 4).

Gravity slide (ophiolitic complex or Karadut formation). - Karadut formation is a congregation of rocks that were deposited in the Tethys Sea which was sometime inactive but from time to time so active as to become narrower under the actions of both the confronting Arabian and Anatolian Plates. These consist, basically, of these groups; sediments such as shales, limestones, conglomerates and sandstones; basic magmatics that are related to the faults of the bottom of the sea; the large, old (metamorphic), exotic rock blocks that were broken off the Anatolian Plate and had fallen over the other rocks in the sea. This formation that has a mixed lithology moved south during the Upper Cretaceous period when the Tethys Sea was squeezed with time. This active body gained speed due to the slippery character of the serpentinitic blocks and, due to a gravity slide formed a tectonic contact with the Mardin group rocks, reaching areas far to the south (Fig. 5, 6).

At the "Haydarlı-2" well of TPAO, which is 48 km. to the east of the city of Kahramanmaraş, drilling was started in this formation and the thickness was determined to be 1696 m. If we take the erosion of the upper part into consideration, it can be said that the thickness around Haydarlı-1,2 wells should be about 1800 m. The same formation has about 1800-2200 m. thickness in Oluklu, Palanlı, Bölükyayla and Kayatepe wells, all of which are to the north of the Adıyaman oil field.

If we take into consideration that the Kahramanmaraş area was in the north/northwest of Adıyaman before the occurrence of the Antakya-Elazığ-Bingöl strike-slip fault, the thickness of the Karadut formation should be more than that of the Adıyaman area e.g., and be 2000-2200 m. (Fig. 1, 4, 6).

TERTIARY

Except for some limited Karadut outcrops that emerged because of the small overlaps at the south of the Ahırdağı anticline, the Kahramanmaraş area is completely covered up by the formations of the Tertiary age. The anticlines that form high mountains are all covered by thick Eocene limestones. The synclines between them are filled by the elastics of Miocene age (Fig. 2, 7).

Eocene

Midyat formation. - The thick limestone mantle that forms the Midyat formation along the dry stream beds that cut the Ahırdağı and Öksüzdağı anticlines seems to be suitable for investigation of lithology and measurement of the sections. Panoil Oil Company measured these limestone series from the Ahırdağı anticline axis to the Kozludere village. According to the measurements, the total thickness of the emerged part of the formation is 525 m. and it consists of 50 m. clastic level at the base, 365 m. of monotonous limestones in the middle, and 110m. of cherty calcareous shales at the top. Including the uncxposed part of the formation the total thickness would be about 600 m.

In another cross-section line at the Çataldağ anticline the Panoil Oil Company measured 500 m. of thickness. The calcareous shales turn into marls in this area.

A measurement made at the Öksüzdağı anticline up to the Oruçpınarı village showed that almost all of the section is composed of limestone and only a black shale level that includes thin sandstone and limestone bands. The section can be about 600-650 m. in thickness in this anticlinal area.

The thickness of the Midyat formation becomes larger around Erincedağı anticline and may have reached 650-700 m. (Fig. 2, 4).

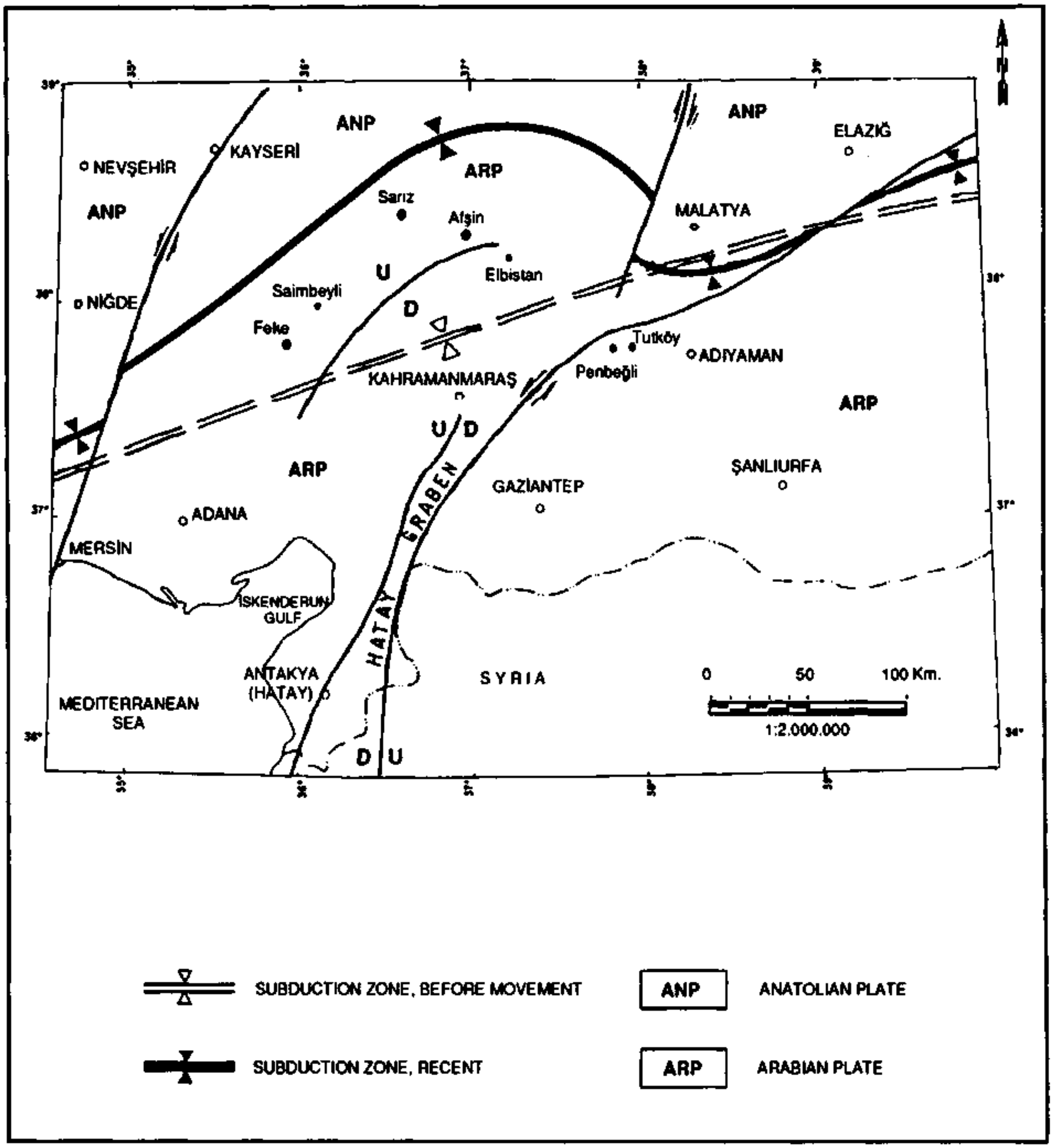


Fig. 5 - Plate movements and displacement of the subduction zone around Kahramanmaraş. Scale 1:2.000.000.

Miocene

Şelmo formation. - Vary coloured elastics as the interbedded shale and sandstone within the synclines and the other deep zones of the Kahramanmaraş area have the same character as the Şelmo formation that is an extensive cover at Diyarbakır-Siirt areas, and that's why it is given the same name. The upper pan of the series is gravelled, and was transformed into uncemented fluvial deposits; this part belongs to the Pliocene in age (Fig. 2, 4).

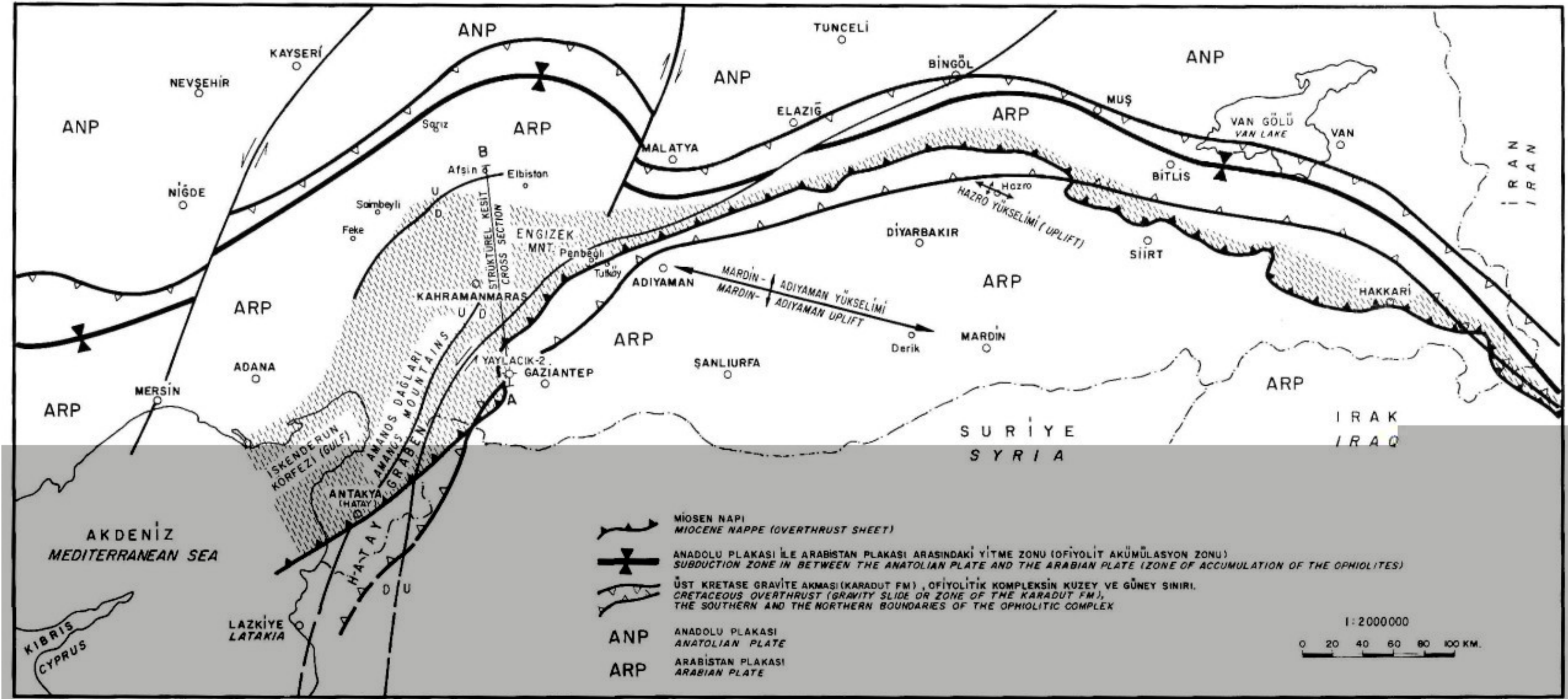


Fig. 6 - Main tectonic features in between the Anatolian Plate and the Arabian Plate in S/SE Turkey. Scale 1:2.000.000.

TECTONIC

The tectonic that is before Alpine Orogeny in Southeast Anatolia has not been investigated carefully because Alpine tectonics dominate the whole region, even the whole of Turkey, in forming the present structure. The developments that started the formation of the tectonic features of the Kahramanmaraş area belong to the final part of the Upper Cretaceous period. The corresponding movements of the Arabian Plate and Anatolian Plate (Kozlu et al., 1991) to the north-south direction forced all the faults and folds to be in the east-west direction. The Taurus mountain and the nappes belonging to them (also the foothills and thrust faults boundaring these at their south side) are all in east-west direction. But the secondary block movements formed structures and faults in varying directions (Fig. 2).

The seismic line MB-101 of the Kahramanmaraş area indicates that the first structures occurred in the Upper Cretaceous layer (Fig. 3). The three separate folds of Cretaceous and older age exist under the fold of the Kahramanmaraş (Ahırdağı) anticline which is at the surface and can only be explained by a tectonic age difference (Fig. 3, 7). It is clear that the forces that dragged the Karadut formation as a gravity slide broke off and folded the lower levels. The same formation was subject to erosion during an important part of the Paleocene. Age at the Middle Eocene period the sea moved in again and the Midyat limestones and coarse elastics, which form the Şelmo formation, were deposited at the surface (Fig. 4).

The last phase of Alpine Orogeny was very strong during the Miocene period. While the young formations were folded for the first time, old and young masses between the two plates was dragged far south, forming the Miocene nappe.

The peaks of the holds of the Upper Cretaceous carbonate sections are 1 to 1.3 msn depth (two way time) in seismic records, and the flanks have a high slope (Fig. 3). For the structures to take their final shapes the forces that formed the Miocene nappe should have had an absolute effect.

The biggest structure of the Kahramanmaraş area is the Ahırdağı anticline which has a length of 32 km. and width of 10 km. This anticline which is about the same size of the big structures of the Middle East is situated north of the city of Kahramanmaraş. This forms a large mountain with a height of 2301 m. at the Milcan hill, and has an east-west orientation. Öksüzdağı and Erincedağ'ı anticlines that exist at the northeast and east are smaller than the Ahırdağı mountain. Çağlayan, Kandildağı, Çataldağ and the other afiticlines follow them (Fig. 2).

There is no doubt that there exists many large anticlines under the Engizek mountain (nappe) cover. But the thickness of the covering mass and hard topography render the area to be beyond economic limitations.

Here we can emphasize a comment that the Elbistan plain that is 60 km. to the south of the subduction zone is a very interesting objective/virgin area. Were a wildcat well to be started on this plain, first the Pliocene series should be cut and next the Miocene nappe should be reached, after that autochthon Tertiary (Şelmo and Midyat formations), and then the Karadut formation should be cut finally, the target zone (main carbonate series) should be reached. The total depth from the surface to the target zone should be about 5000 m.

SOURCE ROCK, RESERVOIR ROCK AND CAP ROCK POTENTIAL

Source rocks

There is an expectation for source rock potential of several formations at Kahramanmaraş area. Starting from the bottom they can be listed as follows:

Armutludere (Kızlaç) formation having about 800 m. of thickness and Ordovician aged, and Pusçutepe formation, which is thought to belong to Silurian, are both source rocks having good qualifications. Also, the dark colored shale levels of the Bahçe formation of Silurian is a source rock.

Upper-Middle Devonian aged Şafaktepe (Hasanbeyli) formation contains shales with pyrite that shows dark colored anaerobic conditions that are precipitated at the quiet sea medium. Dark-colored, very fossiliferous and shale interbedded limestone levels are also source rocks.

Germav formation which is a very thick shale section at Siirt, Diyarbakır, Urfa and Adıyaman areas, and also some shale/carbonate levels of the Triassic age form source rocks of the main carbonate series.

The formations of Paleozoic age are also source rocks for the same carbonate series in one point of view (Fig. 1, 4).

Reservoir rocks

Koruk dolomites which belong to the Cambrian period are the first reservoir level of the stratigraphic column.

According to the field observations of TPAO, the Halityaylası formation which is in the Ordovician-Silurian series is a coarse clastic unit and deposited under high energy conditions however, no evaluation has been made regarding its porosity. Akçadağ formation, which is an equivalent of this series at Amanos mountains, has poor porosity (Atan, 1969). But, these elastics that are deposited between Ashgillian and Landoverian are simply equivalents for the porous Handof-A and Handof-B levels which contain gas and oil that are encountered in the Diyarbakır area. This point is of interest. Wherever they are found in the Kahramanmaraş area as "porous" it is most probable that they will contain hydrocarbons.

In the Sarız area, the upper part of the Silurian is composed of the shale-limestone interbedded section (Yukanyayla formation). In the same deposition period, because the Kahramanmaraş area is very close to the Mardin-Adıyaman uplift, it was higher than Sarız. Because of this, the sandstone levels that are potential reservoir rocks might have developed.

Ayıtepesi formation that belongs to the Lower Devonian is composed of sandstones and limestones which were deposited in the shallow sea during weak-medium energy conditions. When the Devonian sands of the Hazro area are exposed, and contain oil, the Lower Devonian section of the Kahramanmaraş area is most likely be a reservoir rock.

If the Triassic dolomites which form the lower part of the main carbonate series have some evaporitic levels to serve as a rock for every carbonate unit this section may be an important reservoir horizon.

Mardin group carbonates are the most important reservoir objectives of the Kahramanmaraş area. This series which is the reservoir for oil and natural gas of the Southeast Anatolia will be the main target for the exploration wells which are to be planned for the Kahramanmaraş area in the future (Fig. 1, 4).

Cap rocks

For all of the Halityaylası formation and sandstone levels of the Yukarıyayla formation the Silurian shale are ideal cap rocks.

Devonian section has many shale interbeds to serve as a cap rocks for this section's reservoir levels.

The evaporitic bands which can be seen in the Triassic section will also act as a cap rock levels.

Sayındere and Bozova formations are extremely good cap rocks for the Mardin group. Besides this, it should be mentioned that the Karadut formation, which has a complex mass and that contains serpentine blocks and other impermeable rock levels, is a rock in a broad perspective. As a matter of fact, the formations at the south of the boundary of this gravity slide (zero line) have lost their economic values, but flushing to the north of the zero line is prevented because of this formation (Fig. 1,4).

CONCLUSION

Kahramanmaraş area is in the Arabian Plate from which the oil of Turkey is produced; it contains all of its sediments, and has the same structural properties.

It is rich in the source rock, reservoir rock and cap rock. Eventhough a great portion of south and southeastern Anatolia that is at the south of the 0 (zero) line, where the Upper Cretaceous gravity slide (Karadut formation) ended it, lost its economic value because of its being subject to flushing. The Kahramanmaraş area, in my opinion, has not been subject to flushing and hence has protected its economic potential.

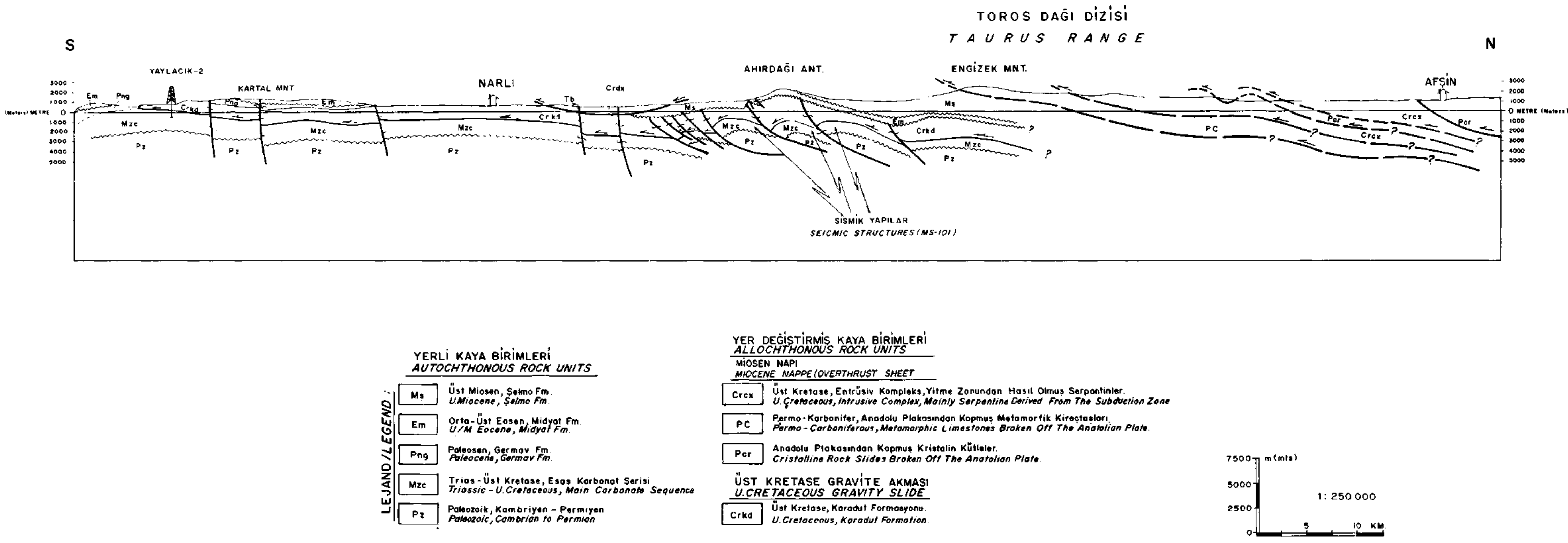


Fig. 7 - Structural cross section through the Yaylacık-2, Ahırdağı anticline (Kahramanmaraş) and Afşin town. Scale 1:250.000.

Previously, it was a serious concern whether or not the anticlines which are seen as mountains at the surface and whose flanks are being represented with limestones, continue at deep/objective levels. In 1986, a seismic line, MS-101, was shot by Placid Oil Company and this proved that the structures do exist under the gravity slide. After more detailed seismic records were taken it is now strongly believed that there might be many more subsurface structures which are ready to be tested within this area.

The wildcat wells would be on the anticlines that are covered by the Midyat limestone, the thicknesses of the sections that are expected to be cut are as follows: Midyat limestone; 150 m., Karadut formation; 2000 m., Sayındere and Bozova formations; 125 m., main carbonate series; 800 m., Permian; 175 m., Devonian; 225 m., Silurian (only Bahçe formation); 525 m.

In view of these thicknesses, in order to reach the Mardin group it will be necessary to drill to 2275 m. If it is necessary to test all of the carbonate series, it would require 3000 m. of drilling program.

In order to test various reservoir levels of Devonian and Silurian/Halityaylası formation it is necessary to drill to 4000m.

At the Haydarlı-2 well with an altitude of 947 m., the Mardin group was reached at minus (-) 738 m. after 1685 m. drilling. At the Ahırdağı anticlinal, a test well would be at approximately plus *(+)* 2250 m. altitude, and the same group would be reached at minus (-) 25 m. which shows that it is 700 m. higher when compared to the Haydarh-2 well and this is a very critical advantage for the target level.

It is clearly known that the Elbistan plain, which is located southeast of Sarız, is composed of Miocene nappe materials. Shortly, the autochthon formations of the Kahramanmaraş, Feke, Saimbeyli and Sarız areas which belong to the Arabian Plate, is the same under the nappe cover of the Elbistan plain. This is not an estimation. It may be that it is a late remembrance of this subject matter. Because of this, the emphasis of the geology of these areas is enough for pointing out the geology and hydrocarbon potential of the Elbistan area.

It is the first time that the Elbistan plain seems to be an objective area for hydrocarbon. If positive results are taken from this point then there may emerge new target areas up to the south of Van lake and places that are nearer to the subduction zone.

ACKNOWLEDGEMENTS

I wish to express my deepest thanks to Oyman Sayer General Manager of Aladdin Middle East Company, and Company Consultant Edward F. Durkee for submitting data pertaining to previous work and for all kinds of help needed to prepare this report; also I extend my thanks to Draftsmen Aydın Tutar and Ruhi Başar of the company for their meticulour drafting.

Manuscript received March 6,1992

REFERENCES

Alan, O. R., 1969, Eğribucak-Karacaören (Hassa)-Ceylanlı-Dazevleri (Kırıkhan) Arasındaki Amanos Dağlarının Jeolojisi: MTA Publ., 139, Ankara.

Çemen, İ.; Perinçek, D.; Ediger, V.Ş. and Akça, L., 1990, Güneydoğu Anadolu'daki Bozova Doğrultu Atımlı Fayı: Üzerindeki İlk Hareket Ters Faylanma Olan Faylara Bir Örnek: Türkiye 8. Petrol Kongresi Bildirileri, Ankara.

Günay, Y.; Fourcade, E.; Dercdurt, J.; Azema, J.; Kozlu, H.; Bellier, J.P.; Cordey, F.; Cross, P.; Wever, P.; De-Enay, R.; Lover, J.P. and Vrielynck, B., 1990, Güneydoğu Türkiye'de Arap Platformunun Kuzey Kenan ve Bu Kenarın Mesozoyik'te Bir Tetis Okyanusal Alanına Geçişi: Stratigrafi-Paleocografya: Türkiye 8. Petrol Kongresi Bildirileri, Ankara.

Kozlu, H.; Fourcade, E. and Günay, Y., 1990, Doğu Toros Bölgesinde Neo-Tetis'in Konumu: Türkiye 8. Petrol Kongresi Bildirileri, Ankara.

Maden Tetkik ve Arama Genel Müdürlüğü, Türkiye Jeoloji Haritası, 1961, 1962, Sivas, Kayseri, Adana, Hatay, Ölçek: 1:500.000.

Perinçek, D., 19796, Interrelations of The Arap and Anatolian Plates: Guide Book For Excursion B, First Geological Congress On Middle East.

———and Özkaya, İ., 1981, Arabistan Levhası Kuzey Kenarı Tektonik Evrimi: Yerbilimleri, 8.

———and Eren, A.G., 1990, Doğrultu Atımlı Doğu Anadolu ve Ölü Deniz Fay Zonları Etki Alanında Gelişen Amik Havzasının Kökeni: Türkiye 8. Petrol Kongresi Bildirileri, Ankara.

Tekeli. O. and Erendil, M., 1986, Kızıldağ (Hatay) Ofiyolitlerinin Jeolojisi ve Petrolojisi: MTA Bull., 107, 33-48, Ankara.

Tarhan, N., 1986, Doğu Toroslarda Neo-Tetis Kapanımıyla ilgili Granitoid Magmanın Gelişimi ve Kökeni: MTA Bull., 107, 95-110, Ankara.

Yiğitbaş, E., 1980, Engizek Dağı (Kahramanmaraş) Dolayındaki Tektonik Birliklerin Petrolojik İncelenmesi: Doktora Tezi, İstanbul Üniversitesi Fen Bil. Enst.

Yılmaz Y. and Şengör, A.M.C., 1981, Tethyan Evolution Of Turkey: A Plate Tectonic Approach: Tectonophysies, Amsterdam v. 75.

————and Yiğitbaş, E., 1990, SE Anadolu'nun Farklı Ofiyolitik-Metamorfik Birlikleri ve Bunların Jeolojik Evrimdeki Rolü: Türkiye 8. Petrol Kongresi Bildirileri, Ankara.

Yoldemir, O. and Perinçek, D., 1990, Güneydoğu Anadolu'nun Batısında (Gaziantep-Adıyaman Arası) Paleosen Yaşlı Graben Oluşumu ve Diğer Tectono-Stratigrafik Bulgular: Türkiye 8. Petrol Kongresi Bildirileri, Ankara.