Mineral Res. Expl. Bull., 116, 1-8, 1994

NEW SPECIES OF RADIOLITIDAE FROM THE BOLU AREA (W. BLACK-SEA) AND KOCAELİ PENINSULA

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ABSTRACT.- Five new species of Radiolitidae from the Maastrichtian of the Bolu area (Western Pontides) and Kocaeli Peninsula, are determined: *Radiolites corporatus* n.sp. *Radiolites simpliformis* n.sp., *Durania carinata* n.sp.. *Sauvagesia sulcata* n.sp. and *Sauvagesia herekeiana* n.sp.

INTRODUCTION

Some rudist genera of the Radiolitidae Gray such as Radiolites Lamarck, Durania Douville and Sauvagesia Choffat have not yet been studied sufficiently in Turkey. Only, some known species of these genera have been described or presented by Bohm (1927), Noth (1931), Kuhn (1933) and Özer (1983) from the central and northwestern Turkey. According to Özer (1988a, 1991), these rudist genera have very wide distribution in the Pontides according to the other regions of Turkey.

The aim of this study is mainly to describe new species of the genera Radiolites Lamarck, Durania Douville and Sauvagesia Choffat from the western Pontides and Kocaeli Peninsula. However, stratigraphic features of the localities with radiolitids are also presented.

STRATIGRAPHY

The late Senonian rudistid formations crop out in some localities of western Pontides such as north of Gökçesu and Bolu, and around Konuralp and Yığılca. These formations are also observed around Hereke in the Kocaeli Peninsula (Fig. 1).

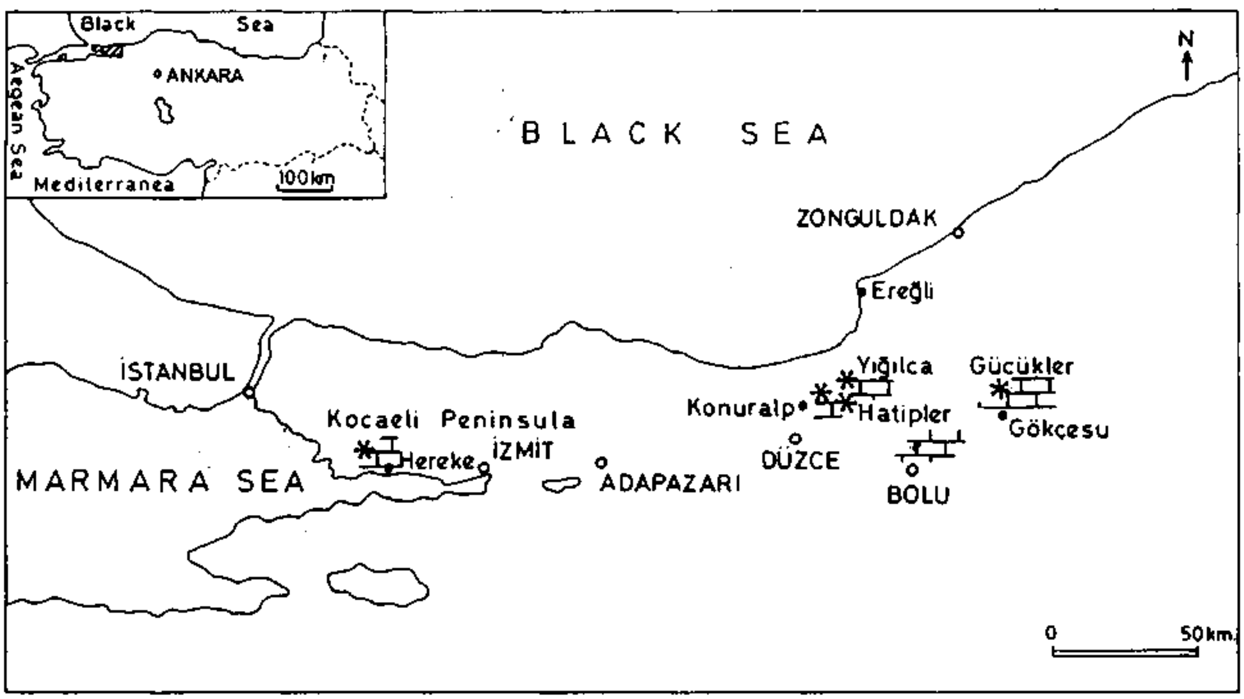

Fig. 1- **Map showing the distrubition of the late Senonian rudistid formations (hachured) and the localities of the new species in western Pontides and Kocaeli Peninsula.**

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The Upper Cretaceous stratigraphy of the western Pontides and Kocaeli Peninsula have been studied by Erguvanlı (1949), Altınlı (1968), Altınlı et al. (1970), Kaya and Dizer (1984a, *b),* Kaya et al. (1986a,b), Özer (1989b) and Özer et al. (1990). Stratigraphic features of the rudistid localities are as follows.

Konuralp and Yığılca localities: In these localities (Fig. 1), the rudists are observed in the Hatipler formation. This formation conformably overlies the unfossiliferous Çamlı formation consisting of sandstones and mudstones (Fig. 2). According to Stratigraphic position of the Çamlı formation in the Upper Senonian sequence, a Late Campanian age has been assigned to it by Kaya et al. (1986a).

The Hatipler formation consists of sandstones, mudstones and rudist bearing limestones. The rudists are very abundant in the northeast of Konuralp and northwest of Hatipler villages, whereas they are sparse around Yığılca. The rudist fauna consist of the forms indicating a Maastrichtian age, as follows: *Hippurites lapeirousei* Goldfuss, *Hippurites colliciatus* Woodward, *Hippurites nabresinensis* Futterej, *Hippurites sulcatoides* Douville, *Vaccinites ultimus* Milovanovic, *Joufia cappadociensis* (Cox), *Joufia reticulata* Boehm, *Radiolites corporatus* n.sp., *Radiolites simpliformis* n.sp., Salvagesia *herekeianan.sp., Durania sp.* and *Biradiolites sp.*

In the Konuralp locality, the specimens of *Hippurites colliciatus* are dominant, and the species *Joufia cappadociensis* and *Joufia reticulata* are also represented by large specimens.

The contact between the Hatipler and the overlying Akveren formations is gradational (Fig. 2). The Akveren formation consists of mudstones, clayey limestones and limestones with planktonic foraminifera indicating a Maastrichtian-Paleocene age (Kayaetal., 1986a).

Gücükler locality: The rudists are very sparse around Gücükler village (Fig. 1). The rudist bearing Gücükler formation rests unconformably on the Kırık-formation. (Fig. 2) consisting conglomerates, and mudstones of Early Triassic age (Kaya and Dizer, 1984 *b).* The rudists are not well pre-

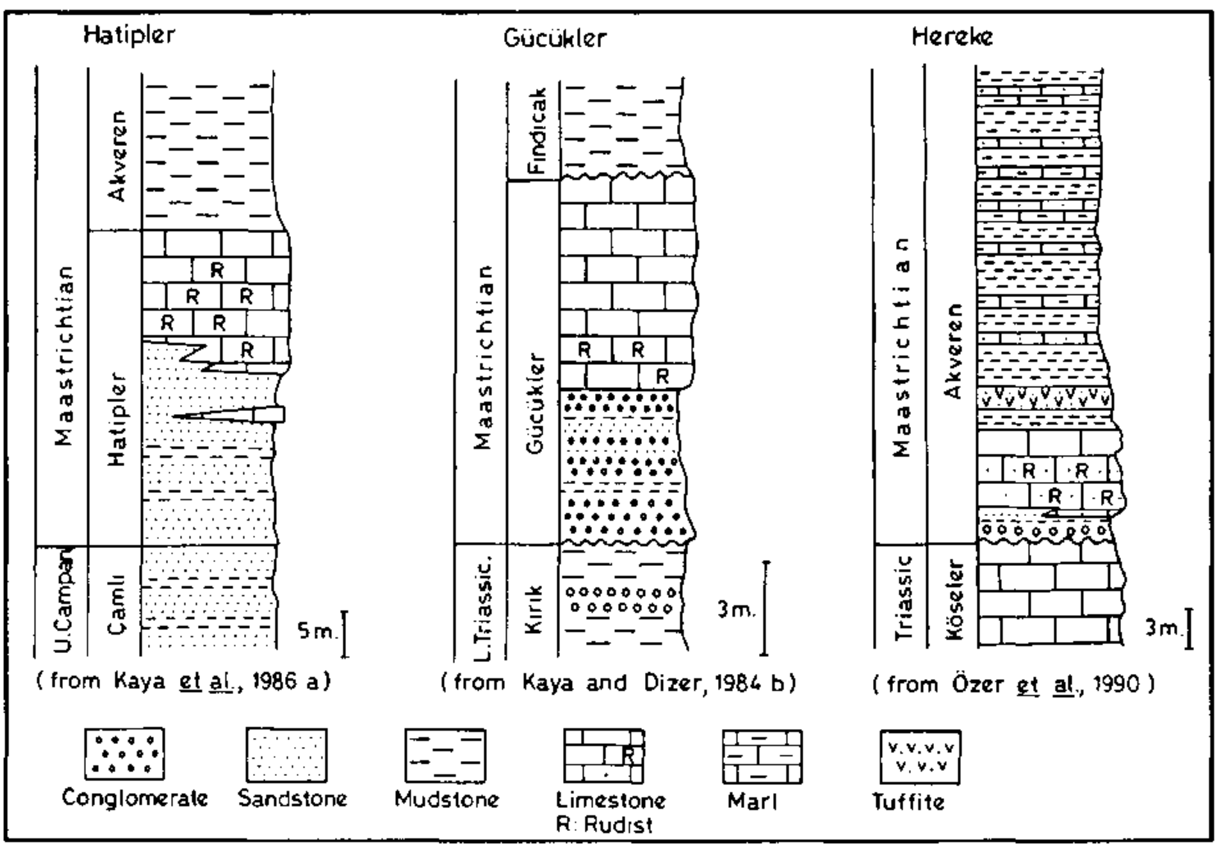

Fig. 2- Columnar sections of the rudistid localities.

served generally are severely fractured. Some rudists such as *Vaccinites loftusi* Woodward, *Hippurites* sp., *Biradiolites* sp., *Radiolites* sp. and the new species *Durania carinata* n.sp. and *Sauvagesia sulcata* n.sp. have been determined. According to Kaya and Dizer (1984b), the age of the Gücükler formation is Maastrichtian because of the presence the benthonic foraminifers such as *Orbitoides medius* d'Archiac and *Siderolites calcitropoides* Lamarck.

The Gücükler formation is overlain unconformably by the Fındıcak formation (Kaya and Dizer, 1984b) of Maastrichtian Paleocene age.

Hereke area: The rudists are very abundant in this area (Özer, 1988b, 1992; Özer et al., 1990) and they are observed in the Akveren formation lying directly on the Triassic rocks (Fig. 1, 2). The basal section of the Akveren formation consists of red conglomerates, bioclastic limestones, rudist bearing sandy limestones and mudstones presenting facies changes. The upper section of the formation is made of marls and mudstones with planktonic foraminifera indicating a Maastrichtian-Paleocene age (Kayaetal., 1986b; Özer et al., 1990).

The rudist bearing limestones include *Hippurites lapeirousei* Goldfuss, *Hippurites nabresinensis* Futterer, *Hippurite? cornucopiae* Defranee, *Vaccinites braciensis* Sladic-Trifunovic, *Vaccinites ultimus* Milocanovic, *Pironaea ti*macensis,Milovanovic, *Joufia cappadociensis* (Cox), *Sabinia klinghardti* Böhm, *Pseudopolyconites ovalis* Milovanovic, *Miseia hekimhanensis* Karacabey-Öztemür, *Gorjanovicia* sp., *Plagiopthycus* sp., *Bournonia* sp., *Sauvagesia* sp., *Sauvagesia herekeiana* n.sp. and *Radiolites simpliformis* n.sp. which indicate probably and Early Maastrichtian age.

PALEONTOLOGY

Class: BIVALVIA

Order: Hippuritoida Newell, 1965

Super family: Hippuritacea Gray, 1848

Family: Radiolitidae Gray, 1848

Subfamily: Radiolitinae Gray, 1848

Genus: Radiolites Lamarck, 1801

Radiolites corporatus n.sp.

(Plate I, fig. 1-4)

Material: One sample with lower and upper valves and one sample with partly preserved upper valve.

Derivation of name: *corporatus*- because of the valve's being massive and strong.

Holotype: Pl. I, fig. 1, 2, 4, sample no: PK 19, the laboratory of Dokuz Eylül University, İzmir.

Diagnosis: Lower valve cylindrical, massive and big. Outer lamellae thin, upturned towards the upper part of the valve densey undulating around the periphery of the valve. Lamellae are represented by a wide curve on the ventral side only. Siphonal bands concave. Interband slightly bulge and very wide. Ligamental ridge thin, long and truncated at the top. Upper valve conical and inclined towards the cardinal area.

Description: The lower valve is cyclindrical, massive, big and 85 to 90 mm in length. The diameter in the commissure is approximately equal to the length of the valve. Outer lamellae are thin, upturned towards the upper part of the valve and regularly and densely undulating around the whole periphery of the valve. Lamellae are formed partly bulge irregular costae. Outer lamellae represent only a wide undulation in the ventral side of the valve which results also an undulation at the commissure line (Plate I, fig. 2). The siphonal bands are clearly observed and concave. Posterior band (S) is marked with a 15 mm wide groove and it is wider than the anterior band (E). Interband (I) is slightly convex, very wide (35 mm) and it consists of the lamellae which upturn towards the upper part of the valve. The shell wall of the valve is prismatic and consists of irregular, small and polygonal cells. The thickness of the pristamic layer is not same everywhere; it is 30 to 35 mm between the cardinal area and ventral region, whereas only 15 to 20 mm in the siphonal region (Plate I, fig. 3). Ligamental ridge is thin, long (7-8 mm) and it is truncated at the top. The teeth are not same size and well observed. The myophores are partly preserved.

The upper valve is conical, inclined towards the cardinal area and 28 mm in height (Plate I, fig. 1,4). The surface of the valve is ornamented by the cyclic growth lamellae.

Discussion: The new species somewhzt resembles *Radiolites crassus* Polsak by the conical upper valve, short and big lower valve (Polsak, 1967). But it differs from *R. crassus* Polsak by the concave siphonal bands, thin lamellae, long ligamental ridge and evidently a massive valve.

The new species presents some similarities to *Radiolites sauvagesi* (d'Hombres-Firmas) by the structure of the siphonal bands (d'Orbigny, 1847; Toucas, 1909; Polsak, 1967); however it distinguishs from *R.sauvagesia* (d'Hombres-Firmas) by the undulation of the commissure line, the shape of outer lamellae in the ventral side of the lower valve and especially short and massive lower valve.

Type locality: Holotype northeastern Konuralp (Bolu), paratypes northwestern Hatipler and Konuralp (Bolu).

Type level: Maastrichtian.

Radiolites simpliformis n.sp.

(Plate II,fig. 1-3)

Material: One sample with lower and upper valves and three lower valves.

Derivation of name: Because of the very simple structure of the siphonal region and outer lamellae.

Holotype: Plate II, fig. 2, 3, sample no: PY 12, the laboratory of Dokuz Eylül University, İzmir.

Diagnosis: Lower valve conical. Outer lamellae in horizontal position throughout the periphery of the lower valve. Siphonal region with very simple structure. Siphonal bands widely concave. Interband slightly convex.

Description: The lower valve is conical and 105 mm in length in the holotype. The diameter is 80 to 90 mm and circular. The outer lamellae are horizontal throughout the periphery of the valve (Plate II, fig. 1, 2). The siphonal region is of a very simple difficulty structure and narrow (35 mm). The bands can be observed with (Plate II, fig. 1). The siphonal bands (S and E) are slightly concave and approximately of the same size. Interband is 16 mm wide, and it is represented by a slightly bulge undulation. Interband is less wider than the siphonal bands. Outer layer consists of small and polygonaj.cells. This layer is thinner in the ventral and dorsal side than those of the cardinal area and siphonal zone (Plate II, fig. 3). Ligamental ridge is thin, short, truncated and slightly widen at the top. The teeth and myophores are not preserved.

The upper valve is flat and smooth.

Discussion: The new species resembles to *Radiolites mamillaris* Matheron by the shape of the siphonal bands (Matheron, 1842; Parona, 1912; Polsak, 1967). But, it differs from this species by the less developped siphonal bands and horizontal position of the outer lamellae. The new species can be compared by the shape of the outer lamellae with *Radiolites sauvagesi* (d'Hombres-Firmas) which is determined by Polsak (1967, Plate 35, fig. 4). However, it differs from this sample by the very narrow and very simple structure of interband and less development of the siphonal bands.

Type locality: Holotype Yığılca (Bolu), paratypes Hereke (Kocaeli) and Konuralp (Bolu).

Type level: Maastrichtian.

Genus: Durania Douville, 1908.

Durania carinata n.sp.

(Plate III, fig. 4-6)

Material: One sample with lower and lower valves and one lower valve.

Derivation of name: Because of presence of a caren in the ventral side of the lower valve.

Holotype: Plate III, fig. 4-6, sample no: PG 4, the laboratory of Dokuz Eylül University, İzmir.

Diagnosis: Ventral side of the lower valve with an outer caren as longitudinal costae. Posterior siphonal band slightly convex. Anterior band smooth or less convex. Interband bulge and separated form siphonal bands by a groove which is more narrow and more deep. Siphonal area of the upper valve plicated.

Description: The lower valve is conical, short and 30-35 mm in langth. The diameter is 60 mm in the commissure. The surface of the valve has mostly been eroded; however, around antero-ventral side a few thin and longitudinal costae can be observed. Posterior band is slightly convex, 15 mm in width and ornamented with 8-10 longitudinal and very thin costae. Anterior band is smooth or less convex and ornamented with 6-8 thin and longitudinal costae. This band is twice as narrow as the posterior band (Plate III, fig. 4, 6). Interband is separated from the siphonal bands by a narrow and deep groove (Plate III, fig. 6). An outer caren of the ventral side of the valve is characteristic for the new species. This caren is rather bulgy as a longitudinal costae around commissure and shows a triangular transverse section (Plate III, fig. 5, 6). The outer layer consists of irregular prismatic cells. These prisms are radially elongated along the inner part of the shell wall. The thickness of the outer layer is 20 mm in the cardinal area, whereas it is very thin in the siphonal region. Ligamental ridge is not developed. The teeth and myophores are very well preserved (Plate III, fig. 6). The anterior tooth and myophore are more developed than the others.

The upper valve is slightly convex and smooth. The siphonal region is plicated and it contains a slightly bulgy and wide costae corresponding to the posterior band of the lower valve. Interband is represented by a deep and narrow groove (Plate III, fig. 4, 5).

Discussion: *Durania carinata* n.sp. differs from all of the known species of the genus by the structure of the siphonal area and especially by the presence ventral caren.

The new species can be compared with *Durania gaensis* (Dacque), *Durania ruanensis* (Choffat) and *Durania spadai* Parona by the shape of the interband (Choffat, 1891; Dacque, 1903; Douville, 1910; Parona 1911 a, 1912; Polsak, 1967). However it differs from these species by the structure of the siphonal bands.

Type locality; Holotype and paratype Gücükler (Bolu).

Type level: Maastrichtian.

Genus: Sauvagesia Choffat, 1986

Sauvagesia sulcata n.sp.

(Plate III, fig. 1-3)

Material: One sample with lower and upper valves and one lower valve.

Derivation of name: sulcata -because of the groove type shape of the posterior siphonal band.

Holotype: Plate III, fig. 1-3, sample no: PG 11. the laboratory of Dokuz Eylül University, Izmir.

Diagnosis: Posterior band groove. Anterior band and interband flat. Transverse section of the valve oval.

Description: The lower valve is conical and about 60 mm in lenght. The diametre of holotype is 45x66 mm. The transverse section of the valve is oval (Plate III, fig. 3). The surface of the valve is eroded, so, the ornamentation is not clearly observed. But, the dorsal side of the valve contains a few thin costae. Posterior band is narrow, 7 mm in width and a deep groove at commissure (Plate III, fig. 1-3). Posterior band is probably ornamented with a few thin costae. Anterior band is flat, and it has very thin costae. Interband is also flat. The wideness of the bands is approximately equal. The shell wall consists of regular polygonal cells. Ligamental ridge is thin, 2 mm in length and enlarged at the top.

The upper valve is flat or silghtly convex and smooth (Plate III, fig. 2).

Discussion: The new species shows resemblances to *Sauvagesia turriculata* Catullo and *Sauvagesia stachei* Polsak by the shape of the posterior siphonal band (Catullo, 1838; Parona, 1911b; Polsak, 1967; Civitelli and Mariotti, 1975). But, it differs from these species by the ornamentation of the anterior band, by the shape of the interband and by well developed the lower valve's being.

Type locality: Holotype and paratype Gücükler (Bolu).

Type level: Maastrichtian.

Sauvagesia herekeina n.sp.

(Plate I, fig. 5, 6; Plate II, fig. 4)

Material: One sample with lower and upper valves and one lower valve.

Derivation of name: herekeina -from Hereke where the specimens have been found.

Holotype: Plate I, fig. 5, 6, sample no: KT 36, the laboratory of Dokuz Eylül University, İzmir.

Diagnosis: Lower valve conical. Posterior band and interband flat. Anterior band slightly concave. Lower valve ornamented with longitudinal and regular thin costae.

Description: The lower valve is conical (Plate I, fig. 5). The lenght of the lower valve is about 65 mm. The surface of the lower valve is ornamented by a few slightly bulgy costae which is about 1 mm in width. The costae are separated by shallow longitudinal grooves. Some costae 2-3 mm in width are also observed. Posterior band is flat. Anterior band is broadly concave. These bands are ornamented with 10 thin longitudinal costae and limited from their edges with the bulge and a wide costae (Plate I, fig. 5). The width of the bands is about 18 mm and nearly in the same size. Interband is flat, 8 mm in width and ornamented by 8 thin costae. The shell wall consists of irregular prism. The thickness of the shell wall is not same everywhere; it is 18 mm in the cardinal and siphonal region, whereas only 8 mm in the ventral side (Plate I, fig. 6). The siphonal bands are represented with the wide curves at the inner side of the shell wall. An anterior pseudopillar which separated from the prismatic layer by an oblique lam, are observed (Plate I, fig. 6; Plate II, fig. 4). Ligamental ridge is short and triangular. The teeth are partly preserved.

The upper valve is flat and smooth.

Discussion: The new species can be compared with the species *Sauvagesia tenuicostata* Polsak, *Sauvagesia sharpei* (Bayle) and *Sauvagesia nicasei* (Coquand) by the ornamentation of the lower valve (Bayle, 1857; Coquand, 1862; Douville, 1891; Polsak, 1967; Pons, 1977; Civitelli and Mariotti, 1975). It differs from *S.tenuicostata* by the flat and smooth upper valve, by the conical lower valve, by the width of the interband and posterior band, by the shape of the anterior siphonal band and by the thickness of the shell wall. It differs from other species by the flat interband; the interband of *Sauvagesia nicasei* is convex, whereas concave in *Sauvagesia sharpei* (Pervinquiere, 1912; Polsak, 1967).

Sauvagesia herekeiana n.sp. shows much resemblance to *Sauvagesia ginestousi* Pervinquiere by the structure of the siphonal area; but it differs from this species by the equal width of the siphonal bands, by the marked and wides interband and by the shape of the ligamental ridge.

The anterior pseudopillar of the new species can be compared with those of *Eoradiolites davidsoni* (Hill) and some of the species of the genus Miseia Patrulius (Hill, 1893; Douville,. 1909; Milovanovic, 1938; Patrulius, 1974; Karacabey-Öztemür, 1979; Özer, 1992). But, these pillars are not really pseudopillars observed in the species (Milovanovic, 1938) of the subfamilly Lapeirousiinae Kühn.

Type locality: Holotype Hereke (Kocaeli) and paratype Konuralp (Bolu).

Type level: Maastrichtian.

ACKNOWLEDGEMENT

The author thanks to O. Kaya (Dokuz Eylül University) who collected some rudist samples around Yığılca and Gücükler.

Manuscript received May 14, 1992

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PLATES

PLATE -I

Fig. 1-4-*Radiolites corporatus* n.sp.

Fig. 1 - Lower (VI) and upper (VS) valves, view of the siphonal region, X 0.6, holotype, No. PK 19, Konuralp (Bolu).
S- posterior siphonal band
I- interband

Fig. 2- Lower and upper valves, ventral side, X 0.7, holotype. Note wide ondulation of the lamellae and also the ondulation of the commissure (arrow).

Fig. 3- Transverse section of the lower valve passing below 20 mm of the commissure, X0.6, paratype, No. PH 6, Hatipler-Konuralp (Bolu). Note the thickness of the prismatic layer in the cardinal area.
L- ligamental ridge
B, B'- teeth of the upper valve
S, E- siphonal bands
I- interband

Fig. 4- Upper view of the upper valve, X0.6, holotype. Upper valve is indined towards the cardinal area.

Fig. 5-6- *Sauvagesia herekeiana* n.sp.

Fig. 5- Lower and upper valves, view of the siphonal region, X1, holotype, No. KT 36, Hereke (Kocaeli).

Fig. 6- Transverse section of the lower valve passing below 15 mm of the commissure, X1, holotype. Note the anterior pseudopillar (arrow) separated from the prismatic layer by an oblique lam.

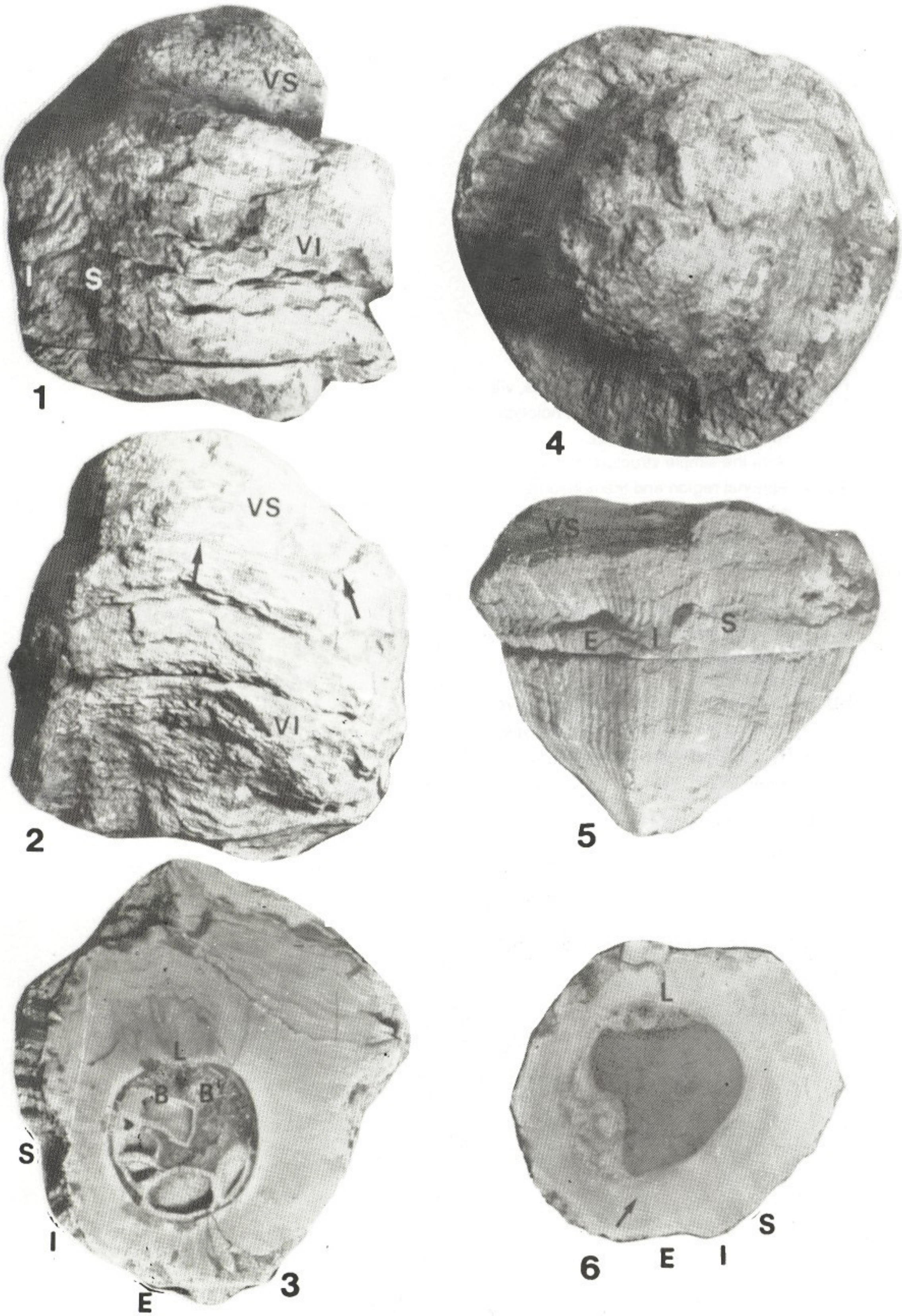
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PLATE -II

Fig. 1 -3-*Radiolites simpliformis* n.sp.

Fig. 1- Lower (VI) and upper (VS) valves, vie of the siphonal region, X0.7, holotype, No. PY 12, Yığılca (Bolu).
Note the simple structure of the siphonal region and the horizontal position of the outer lamellae.
S,E- siphonal bands
I- interband

Fig. 2- Lower and upper valves, ventral side, X0.7, holotype. Compare the position the outer lamellae with the fig. 1.

Fig. 3- Transverse section of the lower valve, commissure unknown, X 1, paratype, No. KT 34, Hereke (Kocaeli).
L- ligamental ridge

Fig. 4- *Sauvagesia herekeiana* n.sp.

Transverse section of the lower valve, commissure unknown, X1, paratype, No. PK. 23, Konuralp (Bolu).
Note the anterior pseudopillar (arrow).

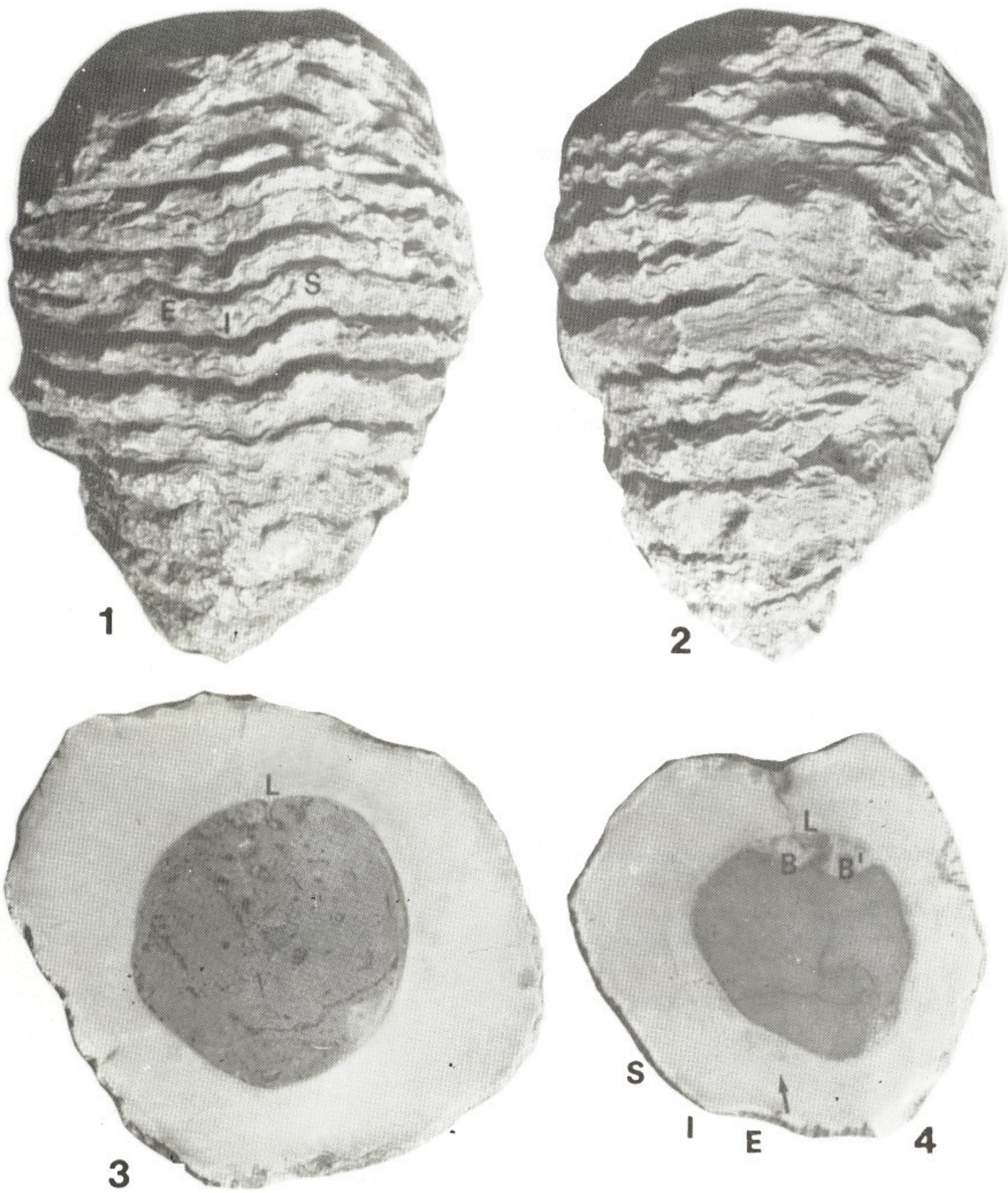

1
S
E
I
2
3
L
4
L
B
B'
S
I
E

PLATE -III

Fig. 1 -*3-Sauvagesia sulcata* n.sp.

Fig. 1- Lower (VI) and upper (VS) valves, view of the siphonal region, X1.2, holotype, No. PG 11, Gücükler-Gökçesu (Bolu).
S, E- siphonal bands.
I- interband.

Fig. 2- Upper view of the upper valve, X1, holotype. Note the deep grove of the posterior band.

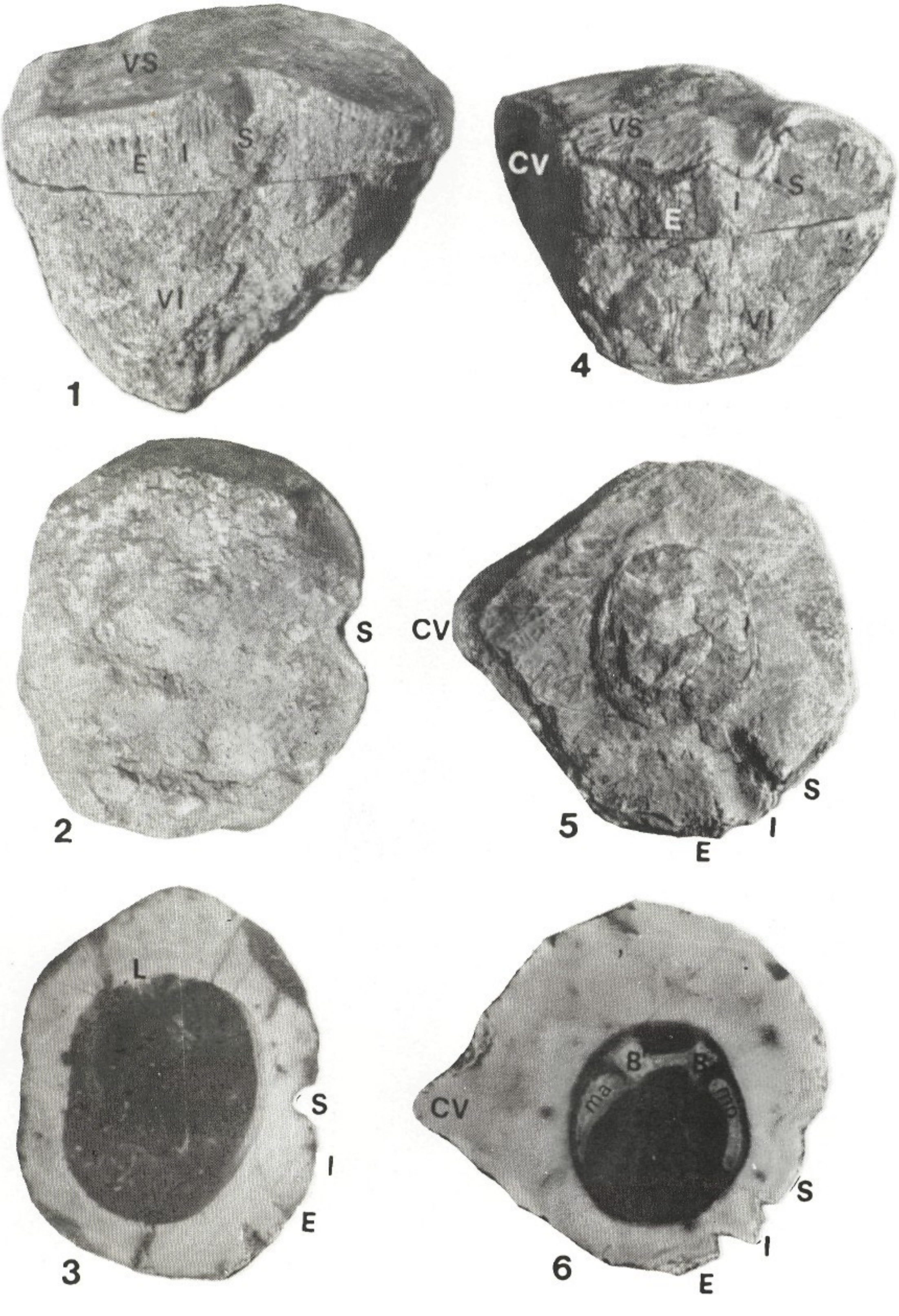
Fig. 3- Transverse section of the lower valve passing below 10 mm of the commissure, X1, holotype.
L-Ligamental ridge.

Fig. 4-6- *Durania carinata* n.sp.

Fig. 4- Lower and upper valves, view of the siphonal region, X1, holotype, No. PG 4, Gücükler-Gökçesu (Bolu).
CV-ventral caren.

Fig. 5- Upper view of the upper valve, X1, holotype. Lower valve is partly observed.

Fig. 6- Transverse section of the lower valve passing below 10 mm of the commissure, X1, holotype.
Note the structure of the siphonal region.
B, B'- teeth of the upper valve
ma, mp-myophores.


1
VS
E
I
S
VI
2
S
3
L
S
I
E
4
CV
VS
S
I
E
VI
5
CV
S
I
E
6
CV
B
B
ma
mp
S
I
E

PALEONTOLOGY AND STRATIGRAPHY OF THE KARABURUN (İSTANBUL) MARINE OLIGOCENE

Mehmet SAKINÇ*

ABSTRACT.- The Karaburun formation, unconformably overlying the reefal limestone of Soğucak formation of Middle-Upper Eocene age, starts transgressively by the clastic shore-line deposits. In the coarse dastic horizons of the beach sediments, a benthic foraminiferal fauna is present besides *Nummulites vascus* Joly ve Leymerie (A ve B forms) characterizing the Lower Oligocene period. Towards the end of the early Oligocene, the Globigerinidae and Coccolithophora were ennched within the planktic fauna developed by the deeping of the marine environment. By the regression occured towards the end of the Middle Oligocene, the deep marine depositional environment was transformed into deltaic conditions. Spores and pollens derived from the various deltaic facies indicated that in the region, these deltaic environments were lasted until the Middle Miocene period

HOLOCENE OSTRACODS OF İSKENDERUN BAY

Atike NAZİK**

ABSTRACT.- In this study, ostracode faunae of 8 sediment samples taken from İskenderun Bay have been investigated. 26 genera and 29 species of ostracods were described from these samples. In addition, geographical disrtibution and depths that they live of these ostracods have been compared with the other studies and indicated that this fossil assemblage belongs to warm dimate belt

Mineral Res. Expl. Bull. 116, 39-46, 1994

PETROLOGICAL FEATURES OF THE METAMORPHICS OF THE YUKARIÇULHALI-BAŞÇATAK SEGMENT OF THE AKDAĞMADENİ MASSIF

M. Bahadır ŞAHİN* and Yavuz ERKAN**

ABSTRACT.- The investigated area is within Akdağmadeni massif and is composed generally of metapelites, semimetapelites, metapsammites and metacarbonates as a metasedimentary sequence. These rock units, especially metapelites have mineral paragenesis suitable for petrological evaluation. Petrographic investigation of different schists and gneisses indicate that there are two different metamorphic zones The first one is typically characterized by the biotite+garnet (almandine) paragenesis and is called the I. zone metamorphism and the second is characterized by the sillimanite+kyanite paragenesis called the II. zone metamorphism. Petrogenetic evaluation was carried out by using the assemblages indicating a single-phase progressive dynamothermal-regional metamorphism.

INTRODUCTION

Akdağmadeni massif metamorphics including the investigation area is extended to Yozgat, Akdağmadeni, Sivas at the north, Çayıralan at the south and Hasbek at the west (Fig. 1). The investigation area which has a distance about 30 km. to Akdağmadeni is located at the center of the massif (Fig. 2).

Akdağmadeni metamorphics as a metasedimentary sequence lies in the northeastern part of the Middle Anatolian crystalline basement and is affected by a regional-dynamothermal metamorphism.

Dominant lithologies of this metasedimentary sequence consist essentially of metapelites, amphibolites, metapsammites, metacarbonates, all being intruded by granitoids.

Evaluation of petrologic results of the investigated area shows that there is an intense deformation divided into two zones of metamorphism, the division being based on paragenesis.

First investigation of the metamorphics was done by Pollak (1958), separating this sequence into three units. At the base, the "Basement Series" is composed of quartzite, marble, mica-gneiss; the medial part uncomformably overlying this unit was called the "Marble Series" and the upper" part consisting of mica-schists and mica-quartzite was named as the "Top Series". Vache (1962) continued the investigation of Pollak and according to him, the "Basement Series" was metamorphosed in meso-catazonal conditions and "the Middle and the Top Series" uncomformably overlying the Basement Series suffered an epizonal regional metamorphism.

Ketin (1959; after Ketin, 1983) prepared a 1:100 000 scale geological map of the area differentiating the metamorphics into two units which are composed of mica-schist, marble and calcschist.

Erkan (1975), based on the mineral associations of sillimanite+orthoclase and kyanite+staurolite, suggested that the prevailing pressure conditions in this area were higher than that of the Kırşehir region. Erkan (1980) also suggested that metamorphic rocks of the region can not be divisible into a top and a bottom series defending that it would not be plausible to have a lower grade metamorphism without having an imprint on the earlier high grade rocks. He determined that this region was affected by a high grade regional metamorphism.

The study of Dökmeci (1980) around Akdağmadeni includes description of metamorphic rock groups and a generalized columnar section. He defined all metamorphics as the Akdağ metamorphic group and distinguished two formations. The older

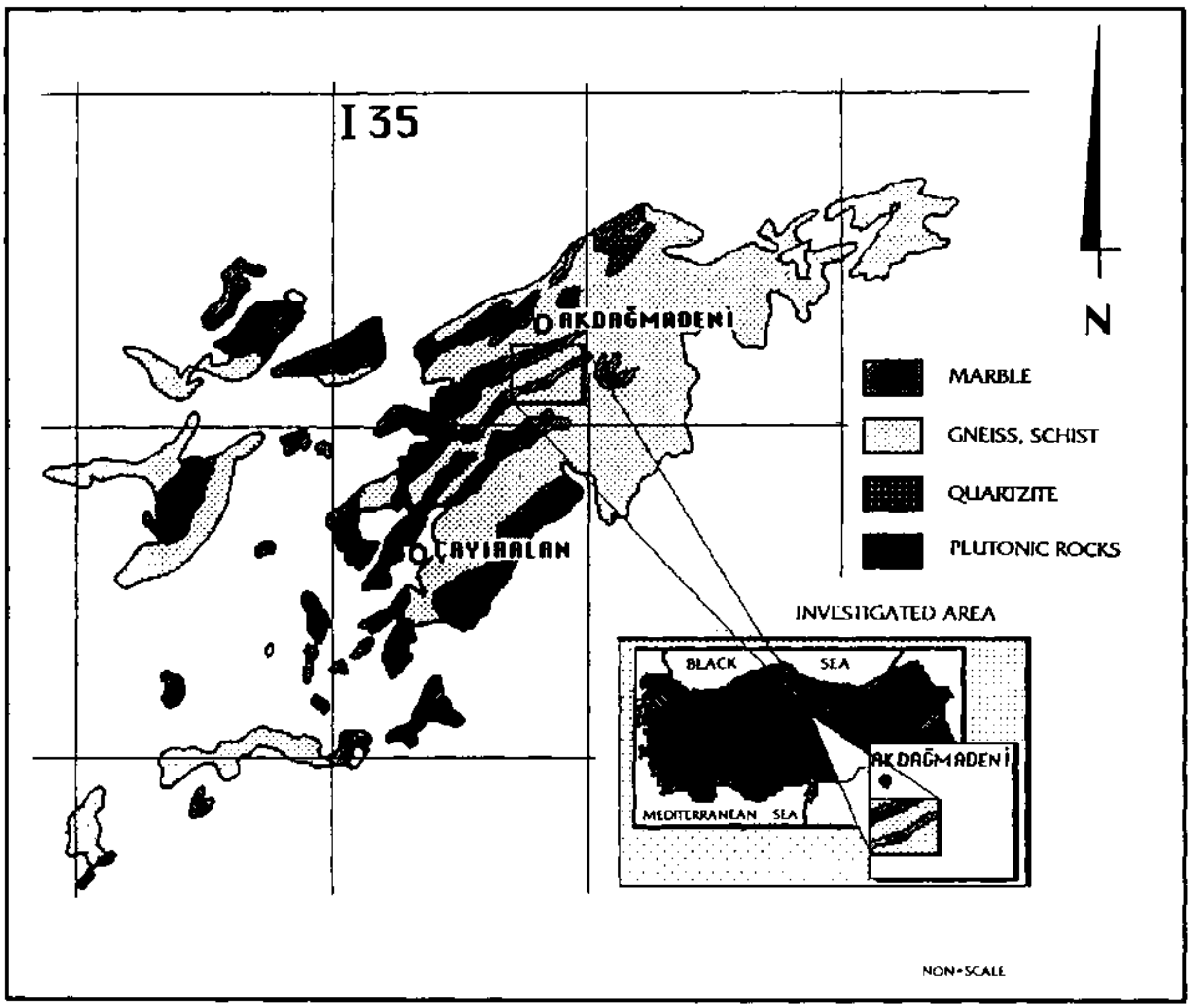


Fig. 1- Location of Akdağmadeni massif and the study area.

one, Köklüdere formation, is composed of gneisses and schists while the younger, Özerözü formation, comprise essentially of marbles. The authors observed that the metamorphic rocks were cut by granite, aplite-pegmatite and riolitic dykes.

Özcan et al. (1980) proposed a high temperature-medium pressure metamorphism which was described as an almandine-amphibolite facies metamorphism on the basis of the staurolite+kyanite+garnet and staurolite+sillimanite parageneses.

Tiilumen (1980) expressed that the metamorphic rocks were metamorphozed at temperatures of 500-600°C and a maximum pressure of 5 kb. He differantiated the regional metamorphic rocks into petrographic facies compatible with facies of metamorphism. Şahin (1991) described the metamorphic rocks as a metasedimentary sequence composed of mica-gneiss, calcsilicatic gneiss and muscovite-schists (metapelites) and marbles (metacarbonates) determining two metamorphic zones. The first zone is characterized by biotite+garnet paragenesis while the second by staurolite+kyanite and sillimanite+kyanite paragenesis. Tectonic elements (fault and folds) developed within the metamorphic units were investigated on a statistical basis, which yielded four sets of elements of folding.

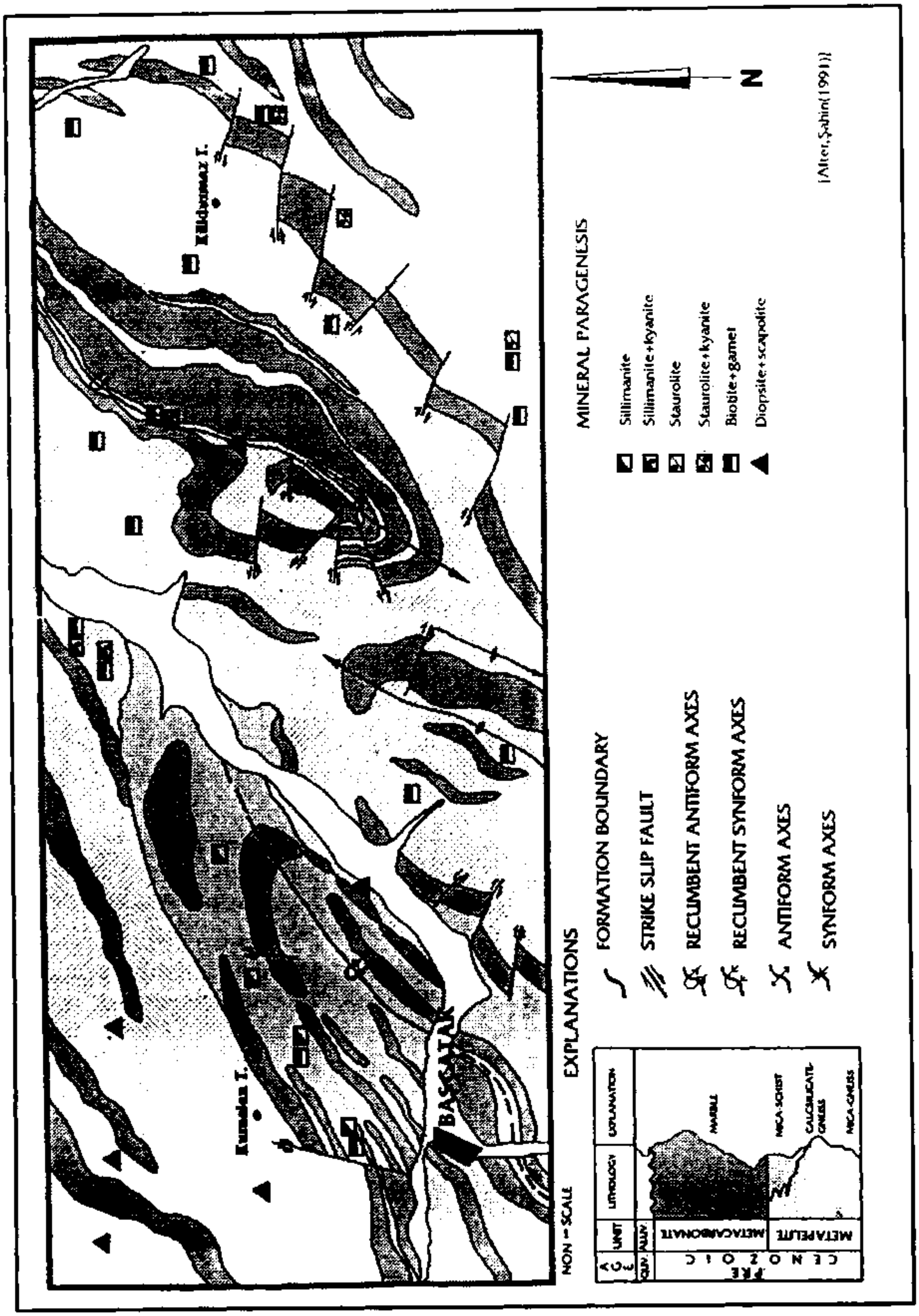


Fig. 2- Geological map of the study area [After, Şahin (1991)].

MINERAL ASSOCIATIONS AND ZONES OF METAMORPHISM

Typical mineral associations of the pelitic rocks of the area and physical conditions of metamorphism through a consideration are divided into two main groups.

Metapelites:

biotite+almandine

biotite+almandine+staurolite+kyanite

biotite+almandine+kyanite+sillimanite

Semi Metapelites:

diopside+scapolite+calcite+plagioclase+titanite

Biotite+garnet (almandine) association. - It seems that the "biotite+garnet" association represents the lowest grade of metamorphism of the area on consideration of physical conditions of metamorphism of the metapelites. It is noteworthy (Fig. 3) that biotite mineral appears first at temperatures above 400°C. Biotite existing in a very wide range of P/T condition does not yield information restricting the physical condition of metamorphism.

The zone where garnet appears was defined as the "garnet zone" by Winkler (1979). However, it is known that the first appearance of almandine in pelitic rocks is not indicative of P/T conditions. Almandine for which-stability fields have been determined by Hsu (1968), appears over 500°C as shown in Figure 4.

On evaluation of the above mentioned parameters together, we can suggest that biotite+garnet

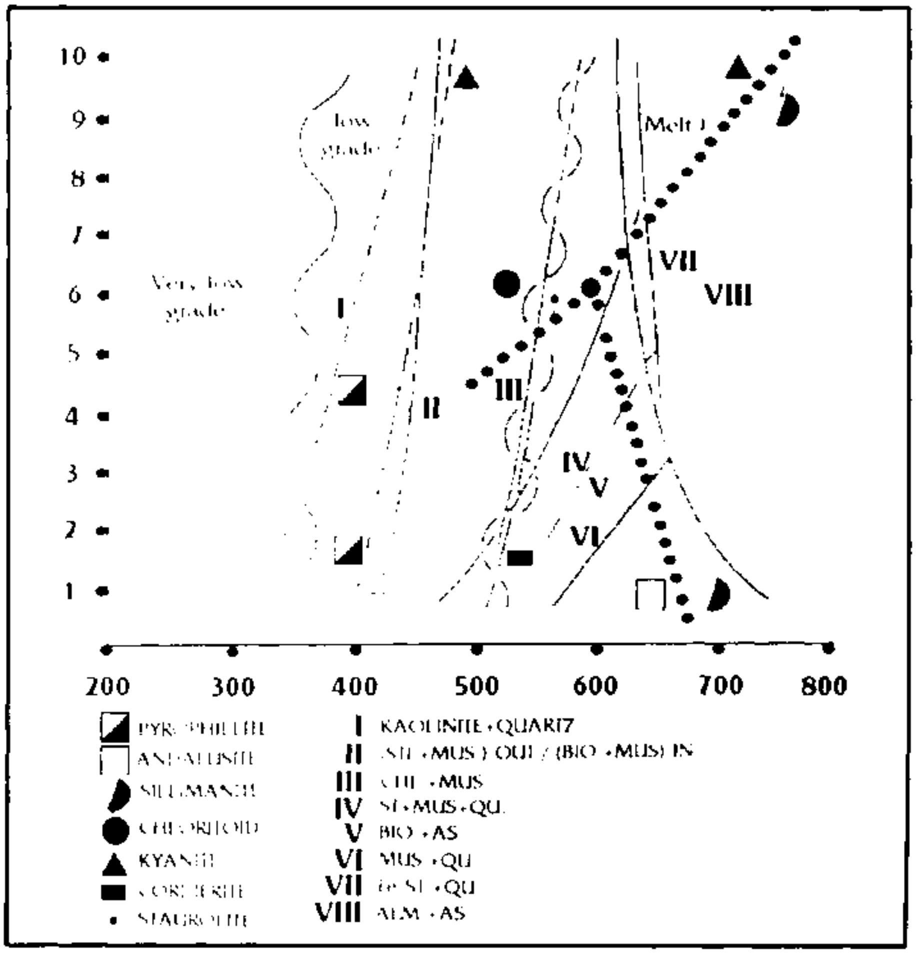


Fig. 3- Metamorphic reactions of pelitic rocks (Winkler, 1979).

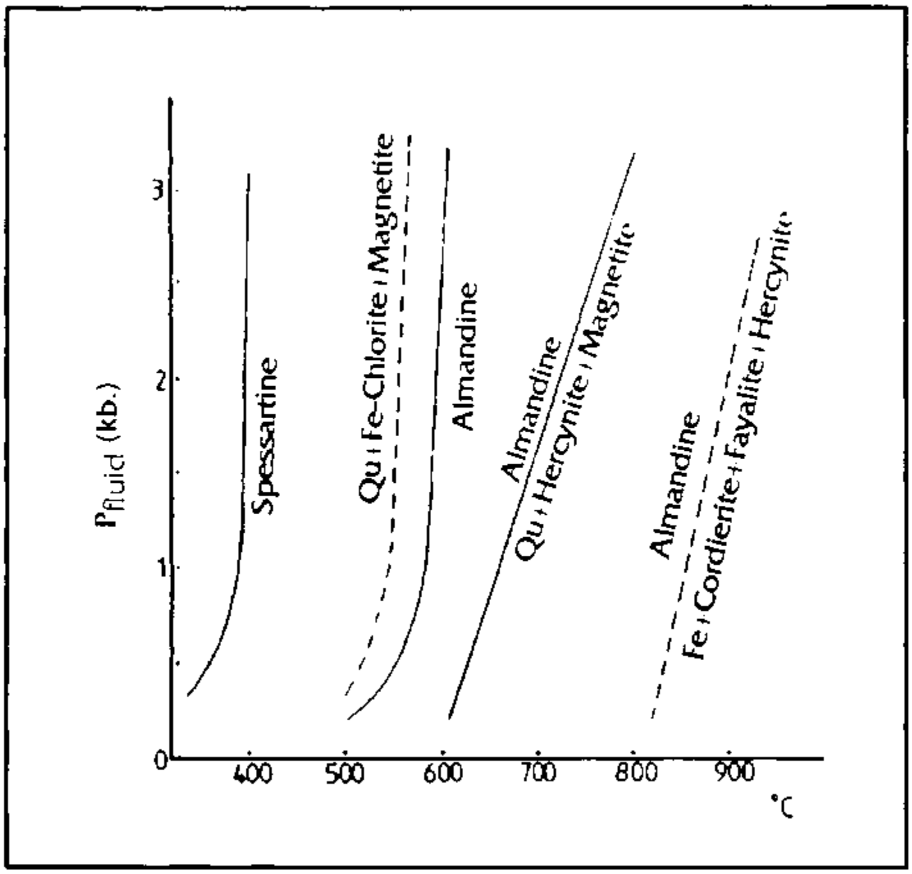


Fig. 4- Stability areas of almandine (Hsu, 1968).

association should correspond to the high-temperature range of the low-grade metamorphism. This association which was observed at the south-western part of the area is called as the I. zone of metamorphism. Mineral associations representing the lower limits of P/T conditions could not be determined. On the other hand the upper boundary is defined by the appearance of staurolite, kyanite and sillimanite which occur through progressive augmentation of P/T conditions. These minerals characterize the high grade zone of metamorphism.

Biotite+gamet (almandine) + staurolite + kyanite association. - The staurolite mineral observed in the eastern part of the area indicates the transition from low grade metamorphism to the medium. The medium grade zone was defined as the II. zone of metamorphism and was characterized by the biotite + almandine + staurolite + kyanite association in the metapelites of area.

According to Winkler (1979), the transition from the low grade to the medium grade is determined by appearance of staurolite and cordierite. The reactions of occurrence of these minerals have been evaluated as isoreaction-grads. It is noteworthy that instead of cordierite, staurolite appears within the metapelites of the area, with the implication that the physical conditions of the first appearance of staurolite need to be reconsidered.

It is shown in Figure 3 that the appearance of these minerals takes place at temperature greater than 500°C and at the same temperature range. But staurolite occurs at higher pressure ranges than cordierite, although one of the most important factors is the bulk chemical composition besides P/T conditions of occurrence of staurolite and cordierite. According to experimental studies, staurolite occurs with this reaction,

chloritoid+O_2 = staurolite+magnetite+quartz+H_2O

and P/T conditions are between 575°C temperature-10 kb. pressure and 545°C temperature-5 kb. pressure (Ganguly and Newton, 1969). In addition to experimental studies, staurolite can occur with chlorite+muscovite reaction if chloritoid absent is (Hoschek, 1969):

chlorite+muscovite = staurolite+biotite+quartz+H_2O

chlorite + muscovite + almandine = staurolite + biotite + quartz + H_2O

These reactions show that, staurolite occurs in metapelites of restricted chemical composition. Also Mg/(Mg+Fe) ratio is important. Winkler (1979) suggested that if this ratio is higher than 0.25, cordierite occurs instead of staurolite through the following reaction:

chlorite + muscovite + quartz = cordierite + biotite + Al_2SiO_5+H_2O

On consideration of the petrogenetic conditions of the occurrence of the biotite+garnet+staurolite+kyanite association and staurolite, in the II. zone of metamorphism in the investigated area, the medium-grade metamorphism was realized at temperatures greater than 550°C at 5.5-6 kbs. and the chemical composition had suitable [Mg/(Mg+Fe)] ratio for occurrence of staurolite.

Co-existence of cordierite+garnet paragenesis has been reported by Erkan and Tolluoğlu (1990) in the III. metamorphic zone in the northern part of Kırşehir. In the I. metamorphic zone of this region, chlorite+chloritoid paragenesis and high Mg content of chlorite have been determined. In the medium grade metamorphic zone of Kırşehir massif the existence of cordierite instead of staurolite indicates that the pressure in this region has been lower than that of the Akdağmadeni metamorphics and the Mg/(Mg+Fe) ratio is not suitable for the occurrence of staurolite.

Diopsite + scapolite + plagioclase + calcite + titanite association. _ The semi-metacarbonate lithologies or calcsilicate gneisses have the diopsite+scapolite+plagioclase+calcite+titanite paragenesis in the northwestern part of the study area. The same association was determined; by Erkan (1975) and Tolluoğlu (1986) in the calcsilicate rocks of the II. metamorphism zone in Kırşehir area. Existence of scapolite in this association is expected to occur in the high temperature part of the amphibolite fades of the regional metamorphism, suggesting higher temperature in the II. metamorphic zone of the area.

Kyanite-sillimanite mineral association. - Andalusite, kyanite and sillimanite minerals (Al_2SiO_5 polymorphs) yield important information for petrogenetic conditions. Experimental studies by Althaus (1967) to determine the stability fields of these minerals show that the P/T conditions of the triple point of the intersecting phase boundaries are P= 6.5 ± 0.5 kb., T= 595 ± 10°C. According to this study, with increase of temperature and pressure

andalusite - sillimanite

kyanite - sillimanite

transformation will be observed. The experimental works of various researchers indicated that kyanite = sillimanite transformation took place at 750°C temperature and 8.1 ±0.4 kb. pressure. Experimental studies of Richardson et al. (1968) showed that transformation was realized between 700-1500°C. Anderson and Kleppa (1969) investigated thermochemistry of kyanite = sillimanite equlibrium and pointed out kyanite = sillimanite transformation occured at 701°C at pressures lower than 12 kb. Evaluation of Figure 3 shows that kyanite = sillimanite transformation takes place at the P/T range of anatexis.

Sillimanite+kyanite association observed in the study area has not any features which are acceptable indicators of this transformation. Petrographic investigations showed that these minerals had not any indications of transformations. In addition to this, there are not any data for anatectic occurrence or indicator of anatexis in this area, implying that the temperature was lower than 700°C in the investigated rocks of the area. Nevertheless, for a general evaluation, conditions of occurrence of sillimanite and kyanite and of other minerals such as muscovite, biotite, quartz, almandine and plagioclase present with sillimanite and kyanite in the same rock must also be considered. Kyanite, the high pressure modification of Al_2SiO_5, appears at the high pressure range of low grade metamorphism by the following reaction:

pyrophillite = kyanite+3 quartz+1 H_2O

$Al_2Si_4O_{10}(OH)_2$ = Al_2SiO_5+3 SiO_2+H_2O

Pyrophillite loses its stability and enables occurrence of kyanite by this reaction. On the other hand, the other reaction by which kyanite occurs, is

staurolite+quartz = Al_2SiO_5+almandine+H_2O

This reaction occurs at about 700°C and in anatexis conditions (Fig. 3). As expressed before, non appearence of anatexis in the study area, presence of kyanite+staurolite association in the II. metamorphic zone and absence of staurolite = kyanite transformation in the investigated samples are datas implicit evidence showing that kyanite did not form through the staurolite+quartz reaction. In these samples, these minerals coexist.

First appearance of kyanite is with staurolite in the investigated area. The appearence of kyanite is thus, independent of transformations and the kyanite+staurolite association suggests that kyanite and staurolite crystallized from an appropriate bulk composition in the appropriate P/T range.

Two reactions had been investigated for occurrence of sillimanite, the high pressure modification of Al_2SiO_5.These are:

muscovite + quartz = sillimanite+orthoclase

staurolite + muscovite + quartz = biotite + Al_2SiO_5 + H_2O

Experimental studies showed that the high grade metamorphism was realized by muscovite and quartz reacting together to yield the sillimanite+othoclase association.

muscovite+quartz = K-feldspar+Al_2SiO_5+H_2O

For this reaction the equilibrium conditions are

PH_2O = 620°C for 2 kb.

PH_2O = 650°C for 3 kb.

PH_2O = 680°C for 4 kb. (Winkler, 1967).

On the basis of experimental work, it was stated that water pressure was effective on equilibrium temperature in the muscovite+quartz reaction and the temperature would augment by 30°C per 1 kb increase of pressure, so that the temperature would reach to 725°C at pressures of 5 kb. It was expressed that this temperature was the maximum stability temperature of muscovite+quartz assemblage, corresponding to begining of anatexis in gneisses. On the basis of these experimental data, and assuming a 30°C increase of temperature per 1 kb increase of pressure, a temperature of 740°C will be reached at a pressure of 6 kb. These physical conditions correspond to advanced stages of anatexis, which was not encountered in this study. The rocks in which kyanite+sillimanite co-exist, contain ample amounts of quartz in contact with muscovite, in addition to plagioclase having not been replaced by orthoclase, is suggestive that the temperatures are not high enough for the reaction:

muscovite+quartz = sillimanite+orthoclase

It is known that sillimanite can also form by the staurolite+muscovite+quartz reaction with increasing temperature (Hoschek, 1969):

staurolite + muscovite + quartz = Al_2SiO_5 + biotite + H_2O

Occurrence of biotite by this reaction associates it with biotites of earlier generations while formation of sillimanite is coeval with the second generation of biotite appearing through this reaction. The disappearance of staurolite implies that sillimanite forms through the staurolite+muscovite+quartz reaction. This impression is supported by occurence of biotite and fibrous sillimanite as clusters.

The kyanite+sillimanite association characterises high pressure/high temperatures in the II. metamorphic zone of the study area.

RESULTS

The petrographic and petrologic evaluation of collected samples shows that these rocks are of sedimentary origin. The following mineral paragenesis, found through this work, are indicative of facies changes ranging from the high temperature part of low grade to high grade temperature part of the medium grade:

biotite+garnet (almandine),

biotite+garnet(almandine)+staurolite+kyanite,

biotite+garnet(almandine)+kyanite+sillimanite,

diopsite+scapolite+plagioclase+titanite.

ACKNOWLEDGEMENTS

This paper presents partial results of the project (H.U. Pr. no: 89-02-010-04) supported by the Hacettepe University Research Fund.

Manuscript received July 6,1993

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MINERALOGICAL-PETROGRAPHICAL STUDIES AND GENESIS OF THE KARALAR (GAZİPAŞA, ANTALYA) GALENITE-BARITE MINERALIZATION

Ibrahim ÇOPUROĞLU***

ABSTRACT.- The study area is situated within the Alanya massif in the central Tauride belt. Low metamorphic folded phyllites in upper Carboniferous age cover large areas in this region. They are overlain partly by lower Permian - Triassic aged, interbedded with ore levels, and partly dolomitized thickly bedded, light coloured limestones and quartzites. In the study area a limited amount of pyrite, chalcopyrite, sphalerite and fahlerz minerals accompany economically viable galenite-barite mineralizations. Along with these minerals cerussite, anglesite, covellite, azurite, malachite, goethite, lepidocrocite are found as alteration products. Galenite and barite rich levels alternate with each other as well as with quartzites and dolomitic limestones. These rhythmically alternating mineralized zones appear in the same stratigraphic level throughout the area. Barites are fine grained and have a very definite contact relation with the enclosing rocks. All this data indicates that the galenite-barite mineralizations in the area have a synsedimentary origin, and metal and barium ions probably originated from the submanne volcanism.

NEOTECTONIC CHARACTERISTICS OF BEŞPINAR-HAVZA SEGMENT OF NORTH ANATOLIAN TRANSFORM FAULT ZONE

Kadir DİRİK****

ABSTRACT.- The Beşpınar-Havza segment of North Anatolian Transform Fault Zone (NATFZ) is dominated by a well developed right lateral strike-slip fault system. This system consists of well developed single fault and/or fault sets. These fault sets are: (1) Köprübaşı fault set, (2) Dereköy fault set, (3) Çeltek fault set and (4) Beyviran fault set. According to the interpretation of these faults, direction of the compressional strees is 150°. Morpho-tectonic features with dextrally offset stream channels (7 km) and ground ruptures of the 1943 Ladik-Ilgaz earthquake of M 7.2 strongly suggest that the first fault system is an active right lateral strike-slip fault zone

THE Pb-Zn DEPOSITS IN THE SOUTHWEST OF TUTAK DAĞI (ŞEBİNKARAHİSAR-GİRESUN)

Ahmet ŞAŞMAZ* and Ahmet SAĞIROĞLU*

ABSTRACT - The Pb-Zn cxe deposits of the area southwest of Tutak Mountain are situated in Eastern Black Sea Region, in the southern parts of the Pontids Tectonic Unit and in roughly 20 km s northwest of Şebinkarahisar township The ore deposits are studied in five sectors; this mineralizations are vein type The area is a part of Eastern Black Sea metallogenic province The area is made up of volcanic, plutonic and sedimentary rocks of upper Cretaceous to Plio Quaternary These lithologies are as follows; upper Cretaceous volcanics (dacites, andesites, pyrodastics) and carbonaceous sandstones, upper Cretaceous-Paleogene granitoids, Eocene volcanics (andesites, basalts, trachiandesites and tuffites), Oligo-Miocene gypsiferous senes (gypsium and mudstone), and Plio-Quaternary volcanies (andesite). The studied area has been subjected to intense tectonic movements dunng upper Cretaceous and later Two main fault systems strike NE-SW and NW-SE The NE-SW striking fault zone geherally mineralized and pre-Eocene aged and the NW-SE striking ones are post Eocene aged and not mineralized. The mineralizations occur within a broad fault zone which strikes NE-SW This 250-300 m.s wide and 1.5-2 km s long zone is faulted intensely, mineralized and altered The intensity of alteration changes vertically and honzontally The main alterations in the studied area are siliafication, carbonatization, chlontization, argillization, epidotization and sencization These alterations indicate a low to medium temperature of formation The ore minerals of the studied area are; sphalente, galena, pyrite, chalcopynte, fahlore group minerals, calcocite-covellite and hematite Gangue minerals are quartz, calate, day minerals, chtonte, hematite and bante

Mineral Res. Expl. Bull., 116, 9-22, 1994

EPITHERMAL MINERALIZATION POTENTIAL OF THE VOLCANICS IN SOUTH EAST HAVRAN (BALIKESiR)

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ABSTRACT.- The Hallaçlar formation of Upper Oligocene-Lower Miocene age is the oldest unit of the area. The volcanics of this formation are affected by widespread hydrothermal alteration. The Dedetepe formation, of Lower Miocene age, unconformably overlies the Hallaçlar formation and is characterized by andesitic lavas, tuffs and aglomerates which are not affected by the hydrothermal alterations. Soma formation (Middle Miocene-Lower Pliocene in age) consists of claystones, marls, dolomites and limestones unconformably overlying the volcanics. This sequence is overlain by the Quaternary alluvium. The volcanics of Hallaçlar formation, displaying various colors as a result of the hydrothermal alteration, are divided into the units of unaltered and altered volcanics. Altered volcanics are further divided, according to the degree of alteration, into the four subunits of slightly altered volcanics, argillic, silicified and sulfidic zones. As the result of chemical analyses, it is concluded that epithermal trace element enrichments are localizied only in the Hallaçlar formation. Au, Ag, Cu, Pb, Mo, As, and Hg anomalies are determined in extensively silicified zones. It has been concluded that the silicified zones of the Hallaçlar formation seem to have a potential for precious metal mineralization.

INTRODUCTION

This investigation establishes the features of hydrothermal alterations and precious metal concentrations in an area of 60 sq km. in the SE of Havran (Bahkesir). The results and recommendations of previous studies have encouraged this study.

The previous works in the .vicinity of the study area by Tchihatcheff, 1967; Phjllipson, 1958; Kaaden, 1957, 1959 and Kovenko, 1940, produced the geologic maps of the region. More detailed geological work was carried out by Akyürek and Soysal (1978, 1982). There are a number of studies on the petrology and modes of occurence of plutonic and volcanic rocks by Aslaner, 1965; Bürküt, 1966, 1975; Izdar, 1968; Ataman, 1975; Krushensky, 1976, Krushensky et al. 1980 and Bingöl et al. 1982.

Schuiling's (1958) work on the prospection of radioactive minerals, with a negative result, indicated that there could be metallic mineralizations with the element enrichments such as Fe, Pb, Zn, W, Cu, Mn and Mo around granodiorite plutons. In geochemical prospection studies, Gonca et al. (1984) has identified Cu, Zn, Pb, Sb. Mo and As anomalies.

The earliest prospection works on mining geology in the area, are of Krushensky (1968, 1971, 1976). This author gives brief information on various ore occurences (hematite, magnetite, galena, sphalerite, calcopyrite, molibdenite, stibnite) in an area of 600 sq km. It was revealed that randomly collected andesite pebbles contained 5 gr/ton Au and 4 gr/ton Ag. The importance of hydrothermal alterations for gold and other element concentrations has been stated. Based on the results of this investigation, detailed prospection and mapping studies were recommended.

The rocks around Havran are represented by Tertiary volcanics. In the west of the study area there are three silicified (gold bearing) calcite veins which are 1 to 30 m. thick and 200 m long. These are owned by private sector. Because of the existence of Au and Ag deposits formed relation to the volcanism in Arapdağı, İzmir and Madendağ Çanakkale, (Erler and Larson, 1992), the study area was found worth for investigation. The study area was initially mapped at the scale of 1:10 000 to determine the mineral paragenesis formed by volcanic activities and their relationships to adjacent rocks and hydrothermal alterations. This map also contains hydrothermal alteration zones. The samples were collected from each volcanic unit and alteration zone for the investigation of geochemistry.

By the studies on samples collected, hydrothermal alterations have been described and alterations in the district have been correlated. The element distributions in the host rocks and alteration zones have been determined, and the behavior of elements, which could be a clue for ore minerals, has been interpreted.

THE GEOLOGY OF THE STUDY AREA

The oldest unit in the investigated area is the Hallaçlar formation. It was formed during upper Oligocene and Lower Miocene. The Hallaçlar formation contains unaltered and altered andesitic, dacitic rocks, silicified rocks and alteration clays. Dedetepe formation of Lower Miocene age. Unconformably overlies Hallaçlar formation. Dedetepe formation is unconformably overlain by Soma formation of Middle Miocene and Lower Pliocene age, all being covered by alluvium of Quaternary age. (Fig. 1).

Hallaçlar formation

Hallaçlar formation is unconformable on Bağburun formation and Kocaçal Hill limestone which are not observed in the study area. This formation is formed by andesitic, dacitic rocks, lava flows, silicified rocks, and their alteration products. The thickness of the formation is about 400 m. It outcrops typically in the vicinity of Hallaçlar village. The age of Hallaçlar formation is Upper Oligocene-Lower Miocene. (Krushensky, 1976). Hallaçlar formation is composed of lava flows of 90 % andesitic and 10 % dacitic composition. The andesites and dacites of the formation are considerably affected by hydrothermal alteration. Clay alteration and silicification occurred as a result of this process. The Hallaçlar formation is subdivided into the groups of unaltered and altered volcanics after macroscopic and microscopic studies. Altered volcanics are further subgrouped into slightly altered volcanics, sulfide zone, argillaceous zone and silicified zone.

Dedetepe formation

The volcanics, consisting of andesitic aggiomerates, lava, tuff and crystallized tuff which uncorfornrably rest on Hallaçlar formation are named as Dedetepe formation and the age of this formation is Lower Miocene (Krushensky, 1987). This formation's type section is around Dedetepe Hill. Dedetepe formation begins from soijth-west of the study field and extends towards the north-east. In the vicinity of Dedetepe Hill, from bottom to top, there are light green and gray lavas and tuffs and at the top, agglomerates similar to those of the bottom are found. These units are well stratified. The andesite blocks in the agglomerates are variable in size, differing from a few cm to 30-40 cm.

Soma formation

The units consisting of claystone, marl, dolomite and limestone in the surveyed field appearing north of the Aşağıdamlar and Köylüce villages are named Soma formation by Akyürek and Soysal (1982). The age of Soma formation is determined as Middle Miocene-Lower Pliocene by Ercan et al. (1984). The units of the Soma formation unconformably overlying Hallaçlar formation in the vicinity of Köylüce village are dirty yellow, beige and the various tones of gray. North of the Köylüce village in the massive and stratified sedimentary units, there are laminated claystones in between bedded limestone and marl. The beds are gently dipping and strike N 80 E with a thickness of 5.50 cm.

Alluvium

The Quaternary alluvium is composed of small and large pebbles and sands are found at the north west of the study field especially around Havran stream.

The tectonic units of the study area

As there is a vegetation cover in the study area and the hydrothermal solutions are substantially effective, difficulties arise in observing the tectonic structures. In the studied field, there are vertical faults positioned towards N and NE directions. There are two vertical faults located northeast to the Solar Quarter each 400 m. long and one to the west of the Çakal Hill positioned N-S direction in between altered volcanics with 300 m. long. South of the surveyed field there is one vertical fault striking NE-SW between Hallaçlar and Dedetepe forma-

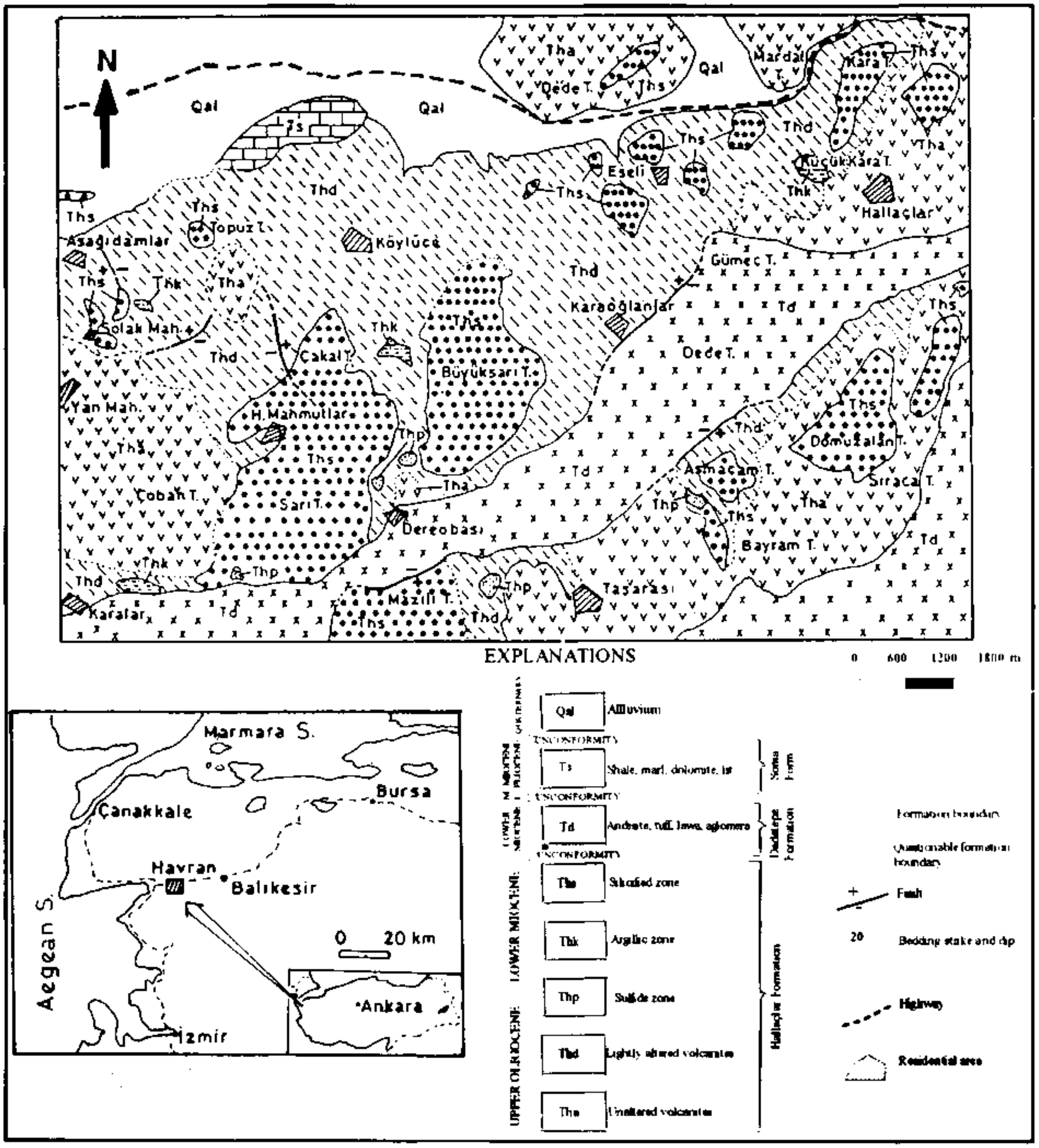

Fig. 1- Geological map and columnar section of the study area.

tion and another vertical fault north of the Karaoğlanlar formation and Asmaçam Hill. The..volcanics are jointed at various directions. This jointed structure in the rocks of the Hallaçlar formation allows easy access of hydrothermal solutions.

HYDROTHERMAL ALTERATIONS

In the research area, the hydrothermal alterations that developed due to tectonic activity, can be differentiated by contrasting colors. The hydrothermal solutions which is particularly effective in the Hallaçlar formation consisting of andesites and dacites have led to extensive silicification and clay formation in various places. For example, silicified rocks are colored in tilered and gray and beige, gray and dirty yellow colored clay formations are observed in the Küçüik- Karatepe Hill and east of the Karalar village. The field surveys are evaluated by thin section observations and consequently the Hallaçlar formation is further subdivided into the following units:

a) Unaltered volcanics

b) Altered volcanics (Slightly altered volcanics, sulfide zone, argillic zone, silicified zone.)

a) Unaltered volcanics zone:

During the field surveys, the unaltered volcanics zone, which seems to be unaffected or only insignificantly affected from hydrothermal alterations, consists of andesites and dacites which are dark gray, dirty yellow and beige. The boundaries of the unaltered volcanics which appear extensively around Çoban Hill and Hallaçlar village with other units are not very visible and in most places this boundary is gradational. During thin section studies of the unaltered volcanic rocks, the following common properties are observed. These rock specimens with a generally hyalopilitic texture; Diorite porphyr shows holocrystalline porphyritic texture. In plagioclases, albite, pericline and carlsbad twinning can be observed. In porphyry rocks plagioclases are found as phenocrysts. Among mafic minerals, there are pyroxenes, amphiboles, Biotites occasionally altering to opaque minerals. Also, though less significantly, chloritization and alteration to epidote, hematite and zeolite are also seen. In the dacitic rocks there are euhedral quartz phenocrysts.

b) Altered volcanics:

Slightly altered volcanics— These rocks which have been affected by hydrothermal solutions, widespread are in pale yellow, light green and gray and they are around Köylüce village and Eseli Quarter. These units are relatively less altered when compared to the argillic, sulphidic and silicified zones. Hydrothermal solutions seem to be effective, and completely altered the rocks in fault scarps and the effects of alteration decrease towards the gerypheric areas. The altered volcanic units and unaltered volcanics are gradational. In thin sections of slightly altered volcanic rocks, the original structures of the minerals seem to have been deformed. The origin of rocks can only be estimated from mineral remains. In these rocks which are originally andesite and dacite, alteration to hematite, limonite, silicification and chloritization is observed. The plagioclase are silicified and saussuritized and altered to clay minerals and occasionally replaced by sericite and carbonates. The mafic minerals are altered to chlorite, uralite and opaque minerals. The XRD analyses showed that these rocks contain albite, sanidine, quartz, kaolinite and illite, and hematite minerals in lower rates. (Fig. 2a).

Argillic zone.- The rocks which are substantially influenced by hydrothermal solutions are in dirty yellow, beige and grey colors. These units that can be observed most typically west of the Hallaçlar village and east of the Karalar village are completely altered to clay minerals. The argillic zones also have gradational contact with altered volcanics and silicified rocks. XRD analysis showed that in these argillic aeous rocks, montmorillonite, kaolinite, quartz, dickite, illite, albite, sanidine are major constituents and in minor amounts jarosite, feldspars and crystobalite are found. (Fig. 2b).

Sulfide zone.- These units found to the west on Mazılıtepeler, North of Dereoba, Southwest of Asmaçam Hill are grey, dirty yellow in color. In these silicified and clay alteration rocks, macroscopic disseminated pyrite crystals are observed. XRD analysis showed, in these samples which are taken from silicified rocks, quartz, crystabolite, pyrite, albite, orthoclose and illite (Fig. 2c).

Silicic zone.- Peaks of the studied area are occupied by, (Sarı Hill, Büyüksarı Hill, Domuzalanı Hill) silicified rocks. They are grey, yellowisch brown and tile-red. Brown color results from hematitization of these rocks. Completely silicified rocks (Sarı Hill, Domuzalanı Hill) are very hard, but partly silicified (Kara Hill, north of Hacımahmutlar) dacites and andesites are moderately hard. At some localities (Solak Quarter), silicification and alteration into clay minerals are found together. In the silicifed rocks, from the thin section observations, it is seen

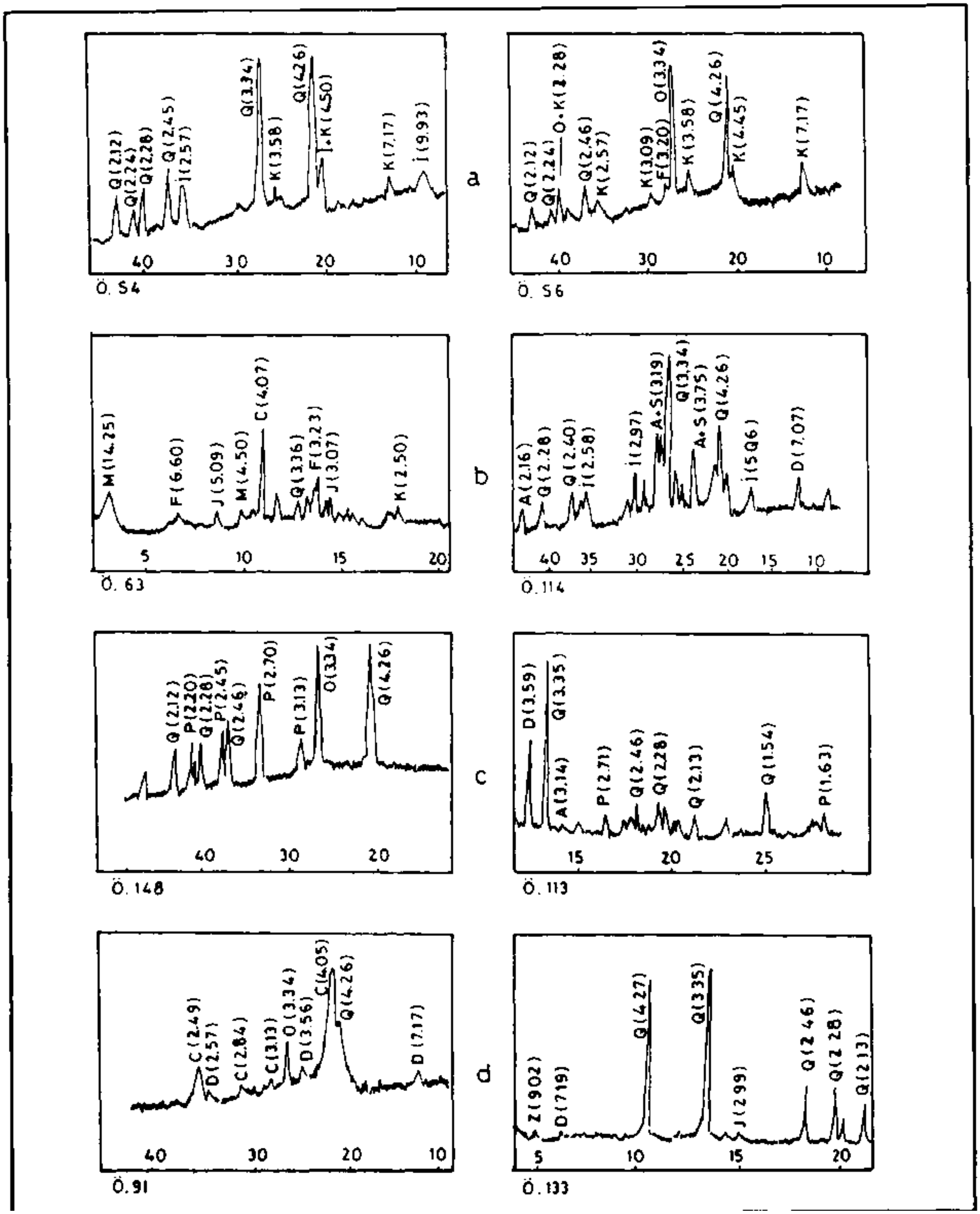

Fig. 2- XRD scans from Hallaçlar formation (6- sample no.; Q- Quartz; K- Kaolinite; I- İllite; F- Feldspar; M- Montmorillonite; J- Jarosite; A- Albite; S- Sanidine; D- Dickite; P- Pyrite; C- Cristobalite; Z- Zeolite).

a- Slightly altered volcanics; b- Argillaceous zone of altered volcanics; c- Sulphidic zone of altered volcanics; d- Silicified zone of altered volcanics.

that in the ground mass made of cryptocrystalline quartz, some quartz phenocrysts are found. In thin sections of silicified rocks, quartz phenocrysts are occassionally observed in a matrix composed of cryptocrystallame quartz. Combe, spherolitic and corona textures are found in silicified rocks.

These rocks are mostly primary but occasionally some secondary silicification is observed. In the silicified rocks, ferroxides, zeolite, clay minerals and carbonates plus opaque minerals are observed. From the XRD analysis of these silicified rocks, the main mineral is thought to be quartz and additionaly occurrences of chalcedony, dickite, zeolite, jarosite and crystobalite are found as secondary minerals.

MICROSCOPIC STUDY UNDER REFLECTED LIGHT

Polished sections of the samples, taken from various formations of the study area, are examined under reflected light. Pyrite, limonite, hematite, magnetite, rutile, anatase, chalcopynte and gold were observed. Accessory minerals are not described in detail.

Pyrite: It is found in many samples especially in the sulfide zone. Pyrite is found as euhedral or subhedral crystals and has resicular structure with concentrated shell of kidney shape. Pyrite crystals are replaced by limonite along the joint margins.

Limonite: Limonite is found along the joints or faurts in the rocks and mostly color the rock. Occasionally, they appear as the alteration product of pyrite and hematite.

Gold: They are found in silicified rocks as 5-10 micron crystals.

GEOCHEMICAL AND GEOSTATISTICAL ANALYSIS

Geochemical properties

The hydrothermal alterations seen in volcanic can lead to the occurrences of Au and Ag metals. The quality of hydrothermal alteration and the possibility of occurrences of ore minerals are determined by the composition of the volcanic rocks and the hydrothermal alteration. It is known that the solution takes Au and Ag with other elements into its constitution during circulation and at the proper environments it precipitates and deposits these elements. For this reason, especially at the localities where alteration is seen widely it is necessary to investigate the geochemical properties of the volcanic rocks whether they are plutonic or not. The tables of occurrences of Au, Ag, and their trace elements As, Hg, Sb in the unaltered volcanic rocks are given in Table 1a (Boyle, 1979) and their major oxide compositions are given in Table 1b (Jakes and White, 1972). The chemical analysis data of units obtained from the field is given in Table 2., and the

Table 1-a. Trace element content of volcanic rocks (Boyle, 1979); b. Major element content of volcanic rocks (Jakes and White, 1972).

Elements	[illegible]	Ag	Cu	Pb	Zn	As	Sb	Mn	Hg
ppm	[illegible]	[illegible]	80	[illegible]	[illegible]	7	[illegible]	[illegible]	[illegible]

Ag % Rocks	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	TiO_2
Low Si Andesite	55.54	[illegible]	[illegible]	5.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Low K Andesite	[illegible]	[illegible]	[illegible]	[illegible]	0.15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Andesite	[illegible]	[illegible]	2.54	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
High K Andesite	58.52	16.20	[illegible]	[illegible]	[illegible]	4.14	[illegible]	[illegible]	[illegible]	0.40	[illegible]
Dacite	66.80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.40	[illegible]

Table 2- Chemical analysis of the units in the study area.

Formation	Unit	Zone	S.No	SiO2	Al2O3	Fe2O3	SO3	CaO	MgO	Na2O	K2O	A.Za	Top	Sb	Au	Ag	Zn	Pb	Mo	Cu	As	Hg
				MAJOR ELEMENTS (%)										TRACE ELEMENTS ppm (Au: ppb)								
HALLAÇLAR FORMATION	Unaltered Volcanics		130	60.70	15.68	5.76	1.20	5.63	2.35	3.20	3.15	1.34	99.01	<4	4	<1	36	10	1	48	<5	<1
			151	64.35	14.88	4.18	1.19	5.61	0.89	3.32	3.57	1.05	99.04	<4	<2	<1	24	12	1	25	<5	<1
			S.2	60.34	14.60	5.83	0.79	6.51	2.20	2.87	3.27	2.60	99.01	4	<28	<1	50	18	2	65	5	<1
			K.5	61.42	14.99	5.63	0.34	6.34	2.40	3.00	2.50	2.41	99.05	<4	<2	<1	20	<10	4	53	<5	<1
			3	65.81	15.25	3.89	1.48	2.86	0.37	2.87	3.47	3.00	99.00	<4	7	<1	14	44	1	21	<5	<1
	Altered Volcanics	Slightly Altered Volcanics	K.2	73.91	9.03	7.52	1.78	0.35	0.18	0.00	0.00	6.25	99.02	6	2	<1	15	<10	1	32	12	2
			K.1	70.65	13.79	6.71	0.38	0.48	1.00	0.07	0.02	6.23	99.33	6	<2	<1	<10	<10	1	10	15	<1
			S.9	63.07	13.23	11.6	0.67	0.69	0.49	0.07	0.09	9.08	99.05	<4	9	<1	19	44	10	22	12	<1
			S.3	78.96	9.57	2.89	1.48	0.91	0.24	0.02	0.40	5.36	99.83	14	3	<1	8	64	8	31	130	<1
			S.6	73.42	14.78	1.28	0.17	1.35	0.49	0.10	2.83	4.63	99.05	<4	<2	<1	<10	108	1	23	10	<1
			K.3	81.20	4.84	6.41	1.21	1.03	0.24	0.04	0.12	4.07	99.26	4	2	<1	16	10	1	62	60	2
			K.4	71.75	14.14	1.46	1.21	1.10	0.79	0.10	2.87	5.61	99.03	<4	4	<1	10	32	<1	14	<5	<1
			S.11	51.83	13.48	15.4	1.05	1.38	1.19	0.04	1.15	8.89	99.41	<4	<2	1	109	16	1	69	<5	<1
		Sulf. z	65	57.84	16.63	6.79	0.11	4.03	1.36	0.48	2.44	10.8	100.5	<4	<10	<4	30	21	<1	60	55	1
			148	70.50	6.18	9.27	21.6	0.33	0.17	0.02	0.12	10.6	118.8	<4	<2	<1	83	230	3	81	120	<1
		Argillic ?	150	64.17	16.50	3.20	1.75	1.25	0.36	0.63	1.83	9.46	99.15	<4	2	<1	10	25	<1	15	60	<1
			114	64.96	16.02	2.93	1.96	1.08	0.58	0.90	3.57	7.69	99.69	<4	<2	<1	<10	44	2	9	10	<1
			S.4	66.73	18.03	1.90	1.00	2.05	0.18	0.02	1.80	8.13	99.84	<4	<2	<1	11	40	1	13	20	<1
			S.5	74.69	13.97	1.06	1.07	1.93	0.20	0.10	3.20	3.94	100.2	<4	<2	<1	<10	385	1	7	10	1
			S.10	68.00	15.74	4.00	0.41	1.25	0.54	0.04	2.95	6.13	99.07	<4	<2	<1	10	36	4	13	45	<1
		Silicified zone	S.7	91.57	0.70	3.94	0.24	0.65	0.22	0.00	0.07	1.93	99.32	44	3310	<1	23	310	8	89	25	5
			S.8	91.52	0.89	3.55	0.43	0.45	0.16	0.00	0.05	2.18	99.24	44	1850	<1	33	222	32	130	20	2
			43	85.95	4.62	0.55	1.91	0.74	0.03	0.48	0.19	5.07	100.5	<4	<10	<4	19	14	1	17	20	<1
			72	95.91	0.50	1.04	0.23	1.01	0.14	0.00	0.00	0.46	99.29	<4	<10	<4	32	7	1	12	5	<1
			25	92.74	1.31	2.72	0.11	1.01	0.01	0.02	0.03	1.94	99.89	407	24	5.3	75	22	1	2120	165	3
			125	85.53	3.09	2.33	0.51	3.12	0.78	0.04	0.17	3.95	99.52	<4	<10	<4	9	16	5	8	55	1
			131	93.55	1.63	1.02	0.74	0.96	0.14	0.07	0.17	2.15	100.4	<4	<10	<4	15	13	4	13	25	<1
			134	91.30	1.20	4.85	0.80	0.60	0.07	eser	0.07	0.35	99.34	11	<5	6.1	15	40	3	7	100	6.80
			135	94.10	1.50	2.05	0.75	0.05	0.15	eser	eser	0.30	99.00	8.00	800	3.2	13	<10	1	7	20	3.2
			40	88.17	5.06	2.17	0.28	1.18	0.02	0.00	0.07	3.02	99.95	<4	20	<4	33	43	36	20	15	1
			79	81.10	4.40	9.45	0.75	0.05	0.10	eser	0.40	2.60	99.05	<4	<5	4.6	18	50	12	7	110	2.6
			91	75.85	12.15	2.85	0.60	0.10	eser	0.10	0.40	6.55	99.70	<4	10	6.2	12	40	1	3	100	2.7
			99	74.45	12.25	6.05	0.50	0.30	0.10	0.10	0.30	5.45	99.55	<4	5	8	20	65	1	4	100	4.2
			K.6	61.53	6.36	4.36	0.91	1.58	0.38	0.04	0.14	3.70	99.30	<4	3	<1	10	32	2	21	60	<1
			128	72.41	4.64	13.5	2.06	0.88	0.21	0.13	0.17	6.31	100.4	<5	<10	<4	21	45	28	53	9	3
Dedetepe Formation			15	60.86	16.95	4.95	0.60	4.50	2.75	3.10	3.55	2.50	99.76	<4	<5	8	35	30	1	4	5	2.65
			47	61.50	16.90	4.95	0.53	4.40	2.35	3.45	3.55	1.65	99.28	<4	<5	<1	35	25	12	1.5	110	2.60
			107	63.48	13.38	4.19	0.74	8.45	1.93	2.39	3.27	3.02	100.8	<4	<10	<4	28	22.00	<1	26	<5	<1
			123	68.24	12.44	3.42	0.12	7.15	1.01	2.25	4.32	1.66	100.6	<4	<10	<4	29	16	<1	13	<5	<1
Soma Formation			1	4.1	16.50	3.20	eser	25.6	20.0	0.10	0.20	44.5	117.2	5	<5	2.5	15	<10	1	0.7	20	2.60
			132	4.70	1.20	1.00	0.15	28.5	19.6	0.10	0.30	44.1	99.6	6	<5	5.3	20	<10	1	0.7	5	1.80

results of minimum, maximum, standard deviation and mean values of these analysis are given in Table 3. In the volcanic rocks of Hallaçlar formation and altered zones oxide compositions have shown that some elements have some distinct anomalies. For example SiO_2 content in unaltered volcanics are 60%. This shows that volcanics are rich in silica. When compared to the Table 1a, Al_2O_3 content is low in the zones except the argilic. CaO and Na_2O content in altered units and MgO amount are low in all units. K_2O is of low amount in slightly altered volcanics and at faces where sulfide occurrences are found, and silicified parts of the rocks, but it is a high amount of argillic zone and unaltered volcanics (Table 2). The total iron amount has monotonous distribution among units as seen in the diagram in Figure 3. If the average iron content of volcanic rocks (7.7%) is taken into consideration, then the result of chemical analysis of the samples are below this value. The table showing the average values of samples shows us that the iron amount is high (8%) only at the sulfide zone (Table 3).

The amount of S in volcanic rocks is 0.40% (Table 16). The S contents of the units belonging to Hallaçlar formation is very high compared to the normal values. These data (Table 3) and diagram (Figure 3) show that S content increases with alteration and it is also high enough at the silicified rocks although it is comperatively lower than the other rocks. The S amount in Dedetepe formation is lower than that in the Hallaçlar formation. In Dedetepe formation, SiO_2, Al_2O_3, CaO and Na_2O values are near normal values, but K_2O is found to be relatively higher. Figure 3, shows the distribution of the major, elements in volcanics and alteration units also shows the relations between the elements. The SiO_2 curve shows that in all units silica content is over 60%, and at units where alteration is changeable, it increases especially in silicified zones where it reaches the maximum value (95.9%). In Dedetepe formation, silica content do not vary from sample to sample and it has a constant value (63%) Same thing can also be seen in the curve which is smooth and straight.

Table 3- Minimum, maximum, standard deviation and mean values of chemical analysis.

			MAJOR ELEMENTS (%)							
			SiO_2	Al_2O_3	Fe_2O_3	[illegible]	CaO	Mg	[illegible]	[illegible]
HALLAÇLAR FORMATION	Unaltered Volcanics	min	51.83	14.60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		max	[illegible]	15.48	15.44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		ss	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		avg	62.52	15.08	5.48	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Altered Volcanics [illegible]	min	51.83	4.84	1.28	0.17	0.35	[illegible]	[illegible]	[illegible]
		max	81.30	18.48	15.40	1.78	[illegible]	[illegible]	0.10	2.42
		ss	9.26	4.22	4.76	0.33	0.19	[illegible]	[illegible]	[illegible]
		avg	70.61	12.23	6.66	[illegible]	0.32	0.38	[illegible]	[illegible]
	Sulf.	min	57.84	6.18	6.79	0.13	0.33	0.17	[illegible]	[illegible]
		max	70.62	16.63	9.27	21.50	4.03	[illegible]	0.48	2.44
		ss	9.02	7.30	1.75	15.20	2.61	0.84	0.22	[illegible]
		avg	64.22	11.40	8.03	10.80	2.18	0.76	0.25	1.28
	Argillic	min	64.17	13.97	[illegible]	0.41	[illegible]	0.18	[illegible]	[illegible]
		max	74.69	18.03	4.00	1.76	2.05	0.58	[illegible]	[illegible]
		ss	4.18	1.46	[illegible]	0.62	0.44	0.18	0.40	0.91
		avg	67.71	16.05	2.61	1.23	1.51	0.37	0.33	2.67
	Silic.	min	72.41	0.50	0.55	0.13	0.05	0.01	0.00	0.00
		max	95.91	12.25	13.56	2.06	3.12	0.28	0.48	0.43
		ss	7.61	3.79	3.46	0.57	0.76	0.20	0.12	0.19
		avg	86.45	4.03	4.10	0.72	0.85	0.17	0.06	0.19
Dedetepe Formation		min	60.86	12.44	3.42	0.12	4.40	[illegible]	2.25	[illegible]
		max	68.24	16.95	4.95	0.74	8.45	2.75	3.45	[illegible]
		ss	3.34	2.35	0.73	0.29	2.06	0.75	0.57	0.45
		avg	63.52	14.91	4.37	0.49	6.12	[illegible]	2.79	[illegible]
Soma Formation		min	4.1	1.20	1.00	eser	28.45	19.6	0.10	0.20
		max	4.7	16.50	3.20	0.15	28.60	20.0	0.1	0.30
		ss	0.42	10.82	1.55	0.11	0.11	0.28	0.00	0.07
		avg	4.4	8.85	2.10		28.52	19.8	0.10	0.25

			TRACE ELEMENTS ppm (Au ppb)								
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HALLAÇLAR FORMATION	Unaltered Volcanics	min	[illegible]	1	5	[illegible]		[illegible]	[illegible]		[illegible]
		max	[illegible]		[illegible]	[illegible]	4	[illegible]		[illegible]	[illegible]
		ss			4		[illegible]	[illegible]			
		avg			[illegible]		[illegible]	[illegible]			
	Altered Volcanics [illegible]	min	[illegible]	1	8			[illegible]	[illegible]	[illegible]	[illegible]
		max	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	4
		ss			[illegible]	[illegible]	[illegible]	[illegible]			
		avg			[illegible]	[illegible]	4	[illegible]			
	Sulf.	min	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		max	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
		ss			[illegible]	[illegible]		[illegible]	[illegible]		
		avg			[illegible]	[illegible]		[illegible]	[illegible]		
	Argillic	min	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		4
		max	[illegible]		[illegible]	[illegible]	4	[illegible]	[illegible]		[illegible]
		ss				[illegible]	[illegible]	[illegible]	[illegible]		
		avg				[illegible]	[illegible]	14	[illegible]		
	Silic.	min	5	[illegible]	[illegible]	7	[illegible]	[illegible]	5	1	4
		max	[illegible]	8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		ss			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
		avg			24	[illegible]	[illegible]	[illegible]	[illegible]		
Dedetepe Formation		min	5	[illegible]	28	[illegible]	[illegible]	[illegible]	[illegible]	1	4
		max	5	8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4
		ss			3.77	5.85		[illegible]			
		avg			[illegible]	[illegible]		[illegible]			
Soma Formation		min	5	2.5	15	[illegible]	1	[illegible]	5	5	5
		max	5	[illegible]	20	[illegible]	1	[illegible]	[illegible]	[illegible]	6
		ss		1.98	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		avg	5	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

When the Al_2O_3 and SiO_2 *curves* are compared it is seen that Al and Si elements has a reverse relation. K element in Hallaçlar formation has a higher value than average which is (2%) in volcanics. Ca and Na elements have lower values in Hallaçlar formation in the altered units. Mg is lower than the normal values in all units. The three elements are decreasing although the alteration is increasing. From the curves it is seen that Ca, Mg and Na elements are increasing from unaltered volcanics towards silicified zones. In Dedetepe formation, Ca has normal values (6.12%) where Na and mostly Mg show a decreasing trend.

Disseminated pyrite occurrences seen in Hallaçlar formation (west of Asmaçam Hill, north of Dereoba Village), can be the result of high amounts of iron and sulphur in this zone. The lowest and nearly stationary amount of iron (2.61 in average) is found in the argillic zone.

Chemical analysis data of Au, Ag, As, Hg, Ma, Pb, Zn, Cu elements of units taken from volcanics and altered zones are given in Table 2 and their diagrams are shown in Figure 3. It is seen from the diagram that the values of Cu, Zn, and Pb have ircieasing values at the zones where alteration is seen.

In slightly altered volcanics, Mo and As show a small increasing amount where it reaches the maximum (36-165 ppm) at silicified zone.

On the contrary, Au, Ag and Hg values are only seen in silicified zones (Fig. 3).

The dispersing values of gold in the various rocks are close to the amount of it to be found in volcanic rocks. (Fig. 4). Silver is commonly below the detection limit (1 ppm). As seen from the diagrams, Au (max. 3300 ppb) and Ag (max. 8 ppm) has high values at the silicified zone of Hallaçlar formation.

According to the values of unaltered volcanics, Zn (93 ppm) has a low value in the study area. Cu has high values at the silicified zones. For example, Cu normally has a value of 80 ppm in volcanic rocks but in silicified zones, it has a value of 157.1 ppm on the average. Mo is higher than the normal (1.8 ppm) in altered zones and it has a maximum value (9 ppm in average) in silicified zones. It is known that in porphyry rocks, hydrothermal solutions can lead to porphyry copper and molybdenite anomalies. These anomalies are the result of washing volcanic rocks with solutions which are enriched in Cu and Mo which are deposited in the silicified zone. Pb has an increasing trend in slightly altered volcanics. (45.3 ppm), in the argillicious zone (107 ppm in average) and in sulphide zone (125.5 ppm). Usually Sb and Hg are generally below the detection limit (Sb: 4, Hg: 1 ppm), only Hg has a high value in the silicified zone. Mo has higher values than the normal (1.8 ppm) in all samples except in those taken from the silicified zone.

Gaostatlstical evaluation

The geostatistical relation of elements can be explained by the correlation coefficient method. The accuracy of this method depends on the number of analysis. The number of analyses are limited in this research thus we can use the correlation coefficient method which will have a meaning when evaluated with the other data (Table 4). In order to clarify the effects of hydrothermal alteration on elements it will be helpful to outline the data. In the volcanics of Hallaçlar formation, as seen from Table 4 and Figure 3, there is a negative relation between Si-Al, Si-Fe, Si-Cu, Si-Ca, S-Mo, K-Mo and a positive relation between Fe-Cu, Fe-Mg, S-K, Ca-Mg, Mg-Cu elements. In the slightly altered volcanics, Si-Al, Si-Zn elements have negative Al-Mg, and Mg-Zn elements have positive relations. In the argillic zone there is a negative correlation between Fe-Ca, Ca-Mg and a positive one between Si-Pb, S-Na, Cu-As, Fe-Mo, Mo-As and Fe-Mg. In the silicified rocks, Al-Si have negative and Ca-Mg, Cu-Zn and Au-Pb elements have positive correlation. In Dedetepe volcanics Si-(Al, Na, Mg, Fe, Bp), Al-Ca, S-K, Ca-Na, Ca-Zn, Na-Cu and Zn-Cu, Mg-Pb, Na-Zn have positive correlation.

RESULTS AND DISCUSSION

Most of the elements, contained in solutions which result in the deposition of epithermal gold and other metals, are gained from plutonic rocks. (Hedenquist and Henley, 1985). The analyses obtained from the nearest rocks to the gold deposits show that the solutions carrying ore minerals have changed the chemistry of these rocks through

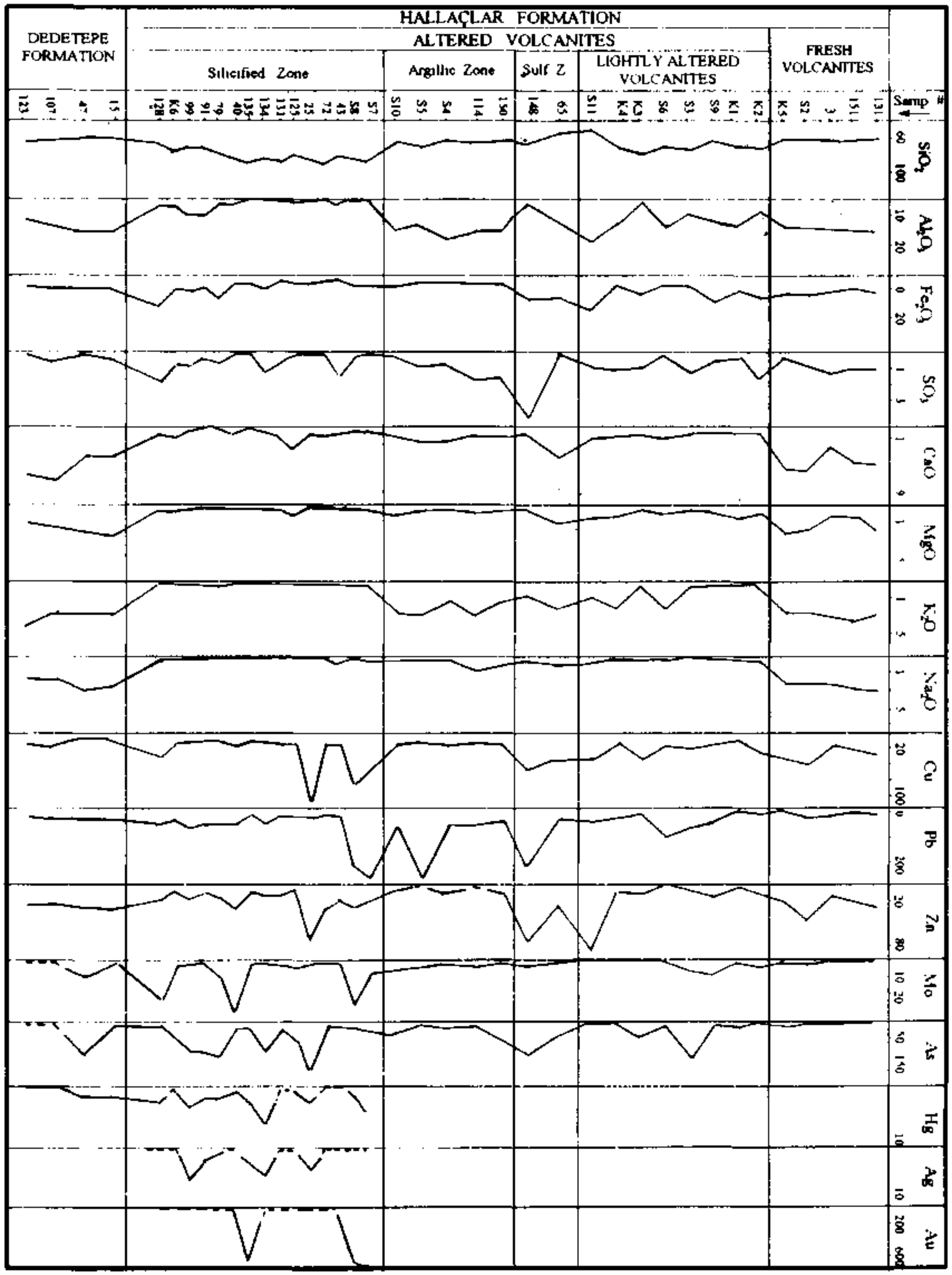

Fig. 3- Seperation diagram of the major and trace elements of Haliaçlar and Dedetepe formations.

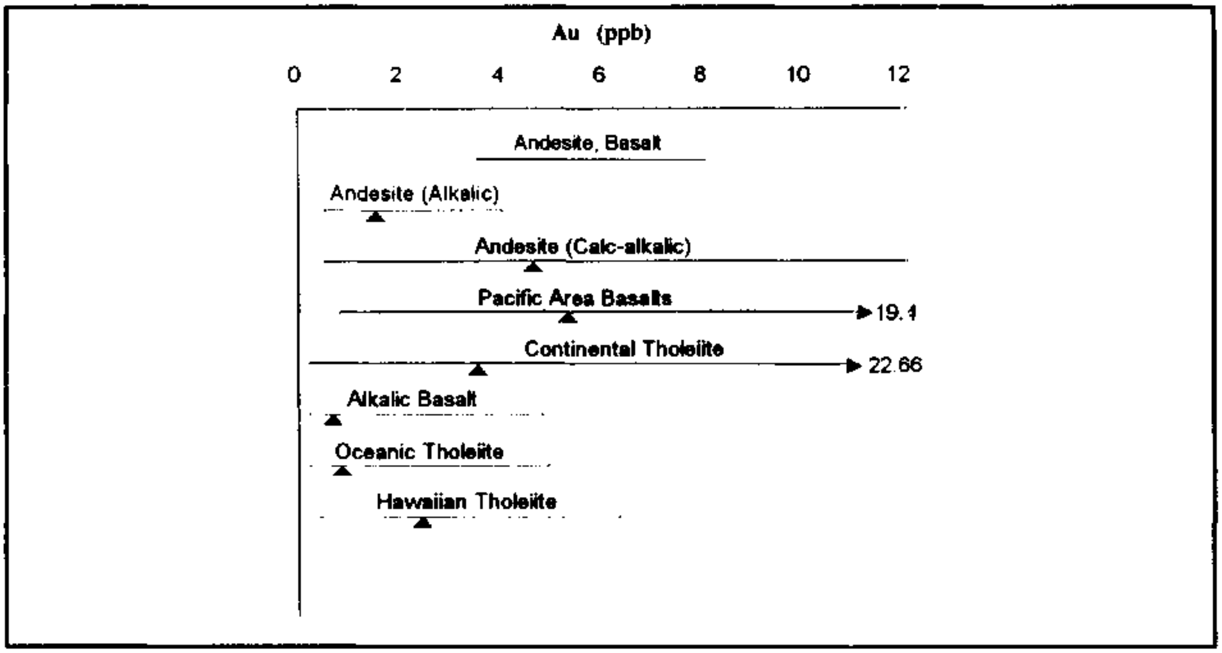

Fig. 4- Gold content of volcanic rocks (Hedenquist and Reid, 1986).

which they pass. (Krauskopf, 1967). Field surveys, microscopic and geochemical investigations showed that only the Hallaçlar formation has some alterations due to hydrothermal solutions among the other formations in the study area. Hallaçlar formation is divided into subunits, unaltered volcanics, slightly altered volcanics, argillic zone, silicified zone and sulfide zone according to the hydrothermal alteration processes that occurred in the rock. Similar subdivision is also explained by Erdoğan (1993). It is seen during the microscopic and XRD investigations that the volcanics considered unaltered, are slightly affected by hydrothermal solutions and they are enriched in silica. In these rocks, K is higher than the normal. Apart from these, Al content is lower than the volcanic rocks in all the units except the argillic zone and Mg content is low in all units. The values of Na and Ca decreases with alteration. It is expected that the elements (Ca, Mg, Na) decreases with the alteration degree (slightly altered volcanics, argillic zone, silicified zone) of the volcanic rocks affected by hydrothermal solutions (Table 2, Figure 3). On the other hand, K is high in unaltered volcanics, and normal in the argillic zone and decreases in the silierified zone. The relation of potassic montmorillonite and illite determined by X ray diffractions can explain the excess K in the argillic zone. Although Fe and Mg ions can overtake with the Al and Si elements found in clay minarals, the decrease of Fe, Mg, Ca, and Na elements in the argillic zone points out that these solutions are not rich in the considered elements. Hydrothermal alterations occurred in volcanic rocks and occurrences of ore minerals due to the same genetic period especially related with metal content of the plutonic rocks. (Hedenquist and Henley, 1985). The contents of Au, Ag metals with the trace elements Pb, Zn, Cu, As, Sb, Hg, Bi, Te in source rocks and their dispersion points out clues for ore deposition. The vertical and horizontal zoning known in epithermal systems (Hollister, 1985; Berger and Eiman, 1982) shows the importance of these mentioned elements. Hydrothermal alterations and trace element anomalies are only seen in Hallaçlar formation among the investigated volcanic rocks. Hydrothermal solutions are not effective in Dedetepe and other young formations. Observation continued in a wide area and geochemical analysis showed that hydrothermal activity has stopped before the formation of Dedetepe formation (Lower Miocene), unless alteration products should be observed in the other formations. Excluding the silicified zone of Hallaçlar formation, in the other units, Au, Ag, Cu, Mo, and Hg are lower than the normal values. On the other hand, As and Pb show anomalies in all units of this formation. In the silicified

Table 4- Correlation coefficients of element contents in the Hallaçlar and Dedetepe formations.

Hallaçlar Formation
Unaltered Volcanites

	Si	Al	Fe	S	Ca	Mg	Na	K	Zn	Mo	Cu
Si											
Al	0.91	1									
Fe	0.98	0.01	1								
S	0.54	0.45	-0.68	1							
Ca	0.83	0.40	0.77	0.76	1						
Mg	-0 [illegible]	0.01	0.98	0.73	0.32	1					
Na	0.03	0.29	0.25	0.23	0.28	0.01	1				
K	0.56	-0.04	-0.65	0.85	0.48	0.75	0.19	1			
Zn	-0.77	0.31	0.70	0.20	0.63	0.60	0.08	0.06	1		
Mo	0.29	0.35	0.51	0.94	0.52	0.57	0.32	0.91	0.37	1	
Cu	0.95	0.27	0.95	0.72	0.78	0.91	0.30	0.58	0.76	0.55	1

Hallaçlar Formation
Slightly Altered Volcanites

	Si	Al	Fe	S	Ca	Mg	Na	K	Zn	Pb	Mo	Cu
Si	1											
Al	0.82	1										
Fe	-0.78	0.31	1									
S	0.23	-0.49	0.05	1								
Ca	0.25	0.39	0.06	0.25	1							
Mg	-0.74	0.82	0.39	0.43	0.30	1						
Na	0.13	0.48	-0.35	0.76	0.42	0.78	1					
K	0.08	0.15	-0.49	0.31	0.70	0.27	0.75	1				
Zn	0.82	0.70	0.79	0.28	0.61	0.81	0.06	0.11	1			
Pb	0.25	0.18	-0.56	-0.63	0.15	0.31	0.41	0.45	0.48	1		
Mo	-0.03	0.05	0.06	0.07	0.16	0.28	0.01	0.28	0.41	0.1	1	
Cu	0.24	0.14	0.55	0.34	0.44	0.02	0.47	0.21	0.70	0.59	0.17	1

Hallaçlar Formation
Argillic Zone

	Si	Al	Fe	S	Ca	Mg	Na	K	Pb	Mo	Cu	As
Si	1											
Al	0.74	1										
Fe	0.66	0.24	1									
S	0.47	0.09	0.06	1								
Ca	0.60	0.18	0.83	0.39	1							
Mg	0.48	0.07	0.81	0.17	0.92	1						
Na	-0.60	0.03	0.23	0.91	0.72	0.55	1					
K	0.38	0.70	0.01	0.05	-0.34	0.53	0.25	1				
Pb	0.94	0.79	-0.77	-0.15	0.53	-0.51	-0.33	0.38	1			
Mo	-0.30	0.07	0.93	0.46	-0.72	0.77	-0.02	0.27	0.48	1		
Cu	0.59	0.70	0.61	0.10	0.22	0.07	0.04	0.79	0.77	0.47		
As	0.47	0.24	0.68	0.10	-0.42	0.20	0.02	-0.56	0.50	0.85	0.85	1

Hallaçlar Formation
Silicified Zone

	Si	Al	Fe	S	Ca	Mg	Na	K	Zn	Pb	Mo	Cu	As	Hg	Au
Si	1														
Al	-0.82	1													
Fe	-0.70	0.26	1												
S	0.45	0.15	0.44	1											
Ca	0.07	-0.19	0.22	0.06	1										
Mg	0.06	-0.14	0.00	-0.01	0.82	1									
Na	0.14	0.28	0.10	0.72	0.03	-0.16	1								
K	-0.76	0.75	0.37	0.24	0.22	-0.06	0.06	1							
Zn	0.33	-0.30	-0.12	0.38	0.05	0.38	0.15	0.40	1						
Pb	0.17	0.25	0.07	0.27	-0.27	0.01	-0.26	-0.20	0.04	1					
Mo	0.12	0.12	0.36	0.08	0.00	0.06	0.19	0.13	0.14	0.32	1				
Cu	0.24	-0.22	0.10	-0.30	0.05	0.22	0.11	0.27	0.89	0.09	0.14	1			
As	-0.22	0.33	0.15	0.29	0.13	0.18	0.16	0.38	0.35	0.40	0.40	0.60	1		
Hg	0.12	0.11	0.15	0.10	0.42	0.32	0.05	0.11	0.11	0.23	0.46	0.03	0.25	1	
Au	0.50	-0.50	0.01	0.29	0.20	0.33	0.51	0.38	0.08	0.97	0.20	0.19	0.51	0.47	1

Dedetepe Formation

	Si	Al	Fe	S	Ca	Mg	Na	K	Zn	Pb	Cu
Si	1										
Al	-0.89	1									
Fe	-0.98	0.96	1								
S	-0.51	0.11	0.34	1							
Ca	0.62	-0.90	-0.75	0.26	1						
Mg	-0.98	0.91	0.97	0.53	0.67	1					
Na	0.82	0.96	0.91	0.07	0.90	0	1				
K	0.80	0.45	0.69	0.80	0.05	0.74	0.39	1			
Zn	-0.74	0.96	0.85	0.12	0.99	0.76	0.66	0.79	1		
Pb	-0.95	0.90	0.94	0.51	0.69	0.99	0.76	0.66	0.79	1	
Cu	0.42	0.78	0.58	0.48	0.97	0.47	0.81	0.18	0.91	0.50	1

zones of the rocks, Au, Ag, Cu, Pb, Mo, As and Hg have high values with anomalies. The behavior and dispersion of the elements in volcanics and alteration zones shows that the silicified zone of the Halaçlar formation has importance in the enrichment of valuable metals. It is known that during transportation of gold in epithermal systems, the liquids with H_2S and chlorite, having virtually neutral PH and a considerable amount of gasses in solution plays an important role (Hedenquist ,1983). The boiling, cooling and mixing of these solutions, depending on the place and time factors are the mechanisms which affects the economic importance of ore metals. The condensation near the surface or at the deeper parts of the mixture of vapor and gas produced by the boiling and evaporation of the meteoric water, reaching the source of heat can lead to different mineralization. The condensation near the surface leads to kaolinite, alunite, crystobalite, amorphous silicates, and sulphur deposition. If this mixture condenses in the deeper parts, then, montmorillonite, illite and kaolinite will appear (Hedenquist and Reid, 1986). The samples from the study area, examined by X-Ray diffraction, showed that mostly montmorillonite, illite and kaolinite occurred as clay minerals. From this data, we can conclude that the mixture of vapour and gas is condensed in fairly deep conditions. For this reason, the condensation in the deeper parts is a handicap for occurrence of ore deposit (Hedenquist and Reid, 1986), explains the precious metal deposits, or enrichments occur in small amounts.

Some metals can be deposited because of vapor condensation with ore carrying chlorite solutions rarefication. As a result, although it was not found any valuable metal enrichment in the study area, mineralogical and geochemical characteristics of hydrothermal alterations encourage further investigations. The silicified zones which reflect the remarkable increase in elements important for epithermal mineralizations implies the important circulation of the hydrothefmal solutions in this area. Although they do not directly lead to the ore mineralization. The reduction of primary porosity by widespread silicification can result in the formation of the liquid reservoir in certain parts which leads to jointing and brecciation in the later stages. In addition to the silicified zone, extremley argillicious zone are important from the point of ore mineralization in the study area. The silicified calcite veins with gold in the study area implies a detailed tectonic survey of the area should be done. Following this study, at the sites which seem to be important for precious metals (silicified and argillic zones), investigations related to determine the vertical characteristics of mineralization are to be planned in the future.

ACKNOWLEDGEMENTS

This investigation is a part of a project performed under Contract No. 92050101 of the Research Branch of Ankara University Under the supervision of Dr. Şükrü Koç. The project also contains Msc research by Selahattin Erdoğan. The authors are grateful to Ankara University Research Branch for its financial support, to MTA (The Mineral Research and Exploration Institute) for the asistance in the field work, and to Assist Prof. Dr. I. Sönmez Sayılı for his scientific contribution.

Manuscript received June 9,1994

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PETROGRAPHY OF LACUSTRINE DOLOMITES IN SİVRİHİSAR NEOGENE BASIN AND INTERPRETATION OF THEIR DEPOSITIONAL ENVIRONMENT USING STABLE ISOTOPES ($d^{18}0;d^{13}C$)

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ABSTRACT.- The most common lithologies comprising the lacustrine deposits in the Sivrihisar Neogene (Upper Miocene-Pliocene) basin are dolomite, dolomite-bearing claystones, and gypsum. The scanning electron microscope (SEM) study of has revealed, microcrystalline dolomite (dolomicrite) different petrographical types such as euhedral, spheroidal, and sub-spheroidal. Stable $d^{18}O$ and $d^{13}C$ isotopes of above-mentioned dolomite types classify into 3 groups. 1) $8^{18}O$ between -1 and +4 %o; $d^{13}C$ between -4 and +0.5 %o; 2) $d^{18}O$ between 6 and -1 %o; $d^{13}C$ between -3 and -1 %o; 3) $d^{18}O$ between -5 and +2 %o;$d^{13}C$ between -1.5 and 0.0 %o. Petrographically different dolomite types and difference in their stable isotopes values may reflect the effect of climatological and hydrodynamic conditions in the Neogene lake-basin which controls the variation in temperature, salinity, and biological activity. Dolomites were formed in a lake environment where the water balance and salinity changes continuously Alkaline dolomite lake was transformed into ephemeral lake which has resulted in the deposition of magnesite and strontianite at the upper limit of evaporation. Salinity was extremely decreased when fresh water inflowed into the lake area or rise in groundwater level, that is supported by lighter $d^{18}O$ values. The local swamps, which has developed at these stages, provided the suitable conditions for the formation of sepiolites and dolomite-bearing sepiolites. The different petrographic types of dolomite crystals and their stable isotope values reflect the continuously changes temperature, salinity, and depth of the lake area The environmental conditions ranging from hipersaline to hyposaline indicate that Sivrihisar Neogene dolomites had been formed in a schizohaline environment as recorded in the geological literature.

INTRODUCTION

Dolomites and dolomitization are the result of a series of complex events during the early-and late-stages of diagenesis. Many different theories and models have been proposed for the origin of dolomites and dolomitization (Hardie, 1987). Among various dolomite types, particularly those of marine origin have been studied in more detail owing to their complex structure, variability, and economical potential. On the other hand, lacustrine dolomites has been drawn less interest than marine counterparts as they show very simple internal structure and homogeneous appearance in the field. It has been shown that majority of lacustrine dolomites were formed either in shallow lakes .under conditions of increasing evaporation, salinity, and Mg/Ca ratio or during early stages of diagenesis (Miiller. 1968; Muller and Irion, 1969; Irion, 1970). Recently, the formation of thick and uniform lacustrine dolomites have been observed in the modern lakes in which dolomite deposition occurs (Von Der Borch and Lock, 1979). The use of field and petrographical data are not adequate to examine the lacustrine dolomites which are very sensitive to all sorts of atmospheric conditions and seasonal changes. $d^{18}O$ and $d^{13}C$ stable isotopes particularly provide useful criteria to about the determine: The different climatological and hydrodynamic conditions affecting the fossil lakes; the salinity and biological changes in lake environments; and different steps, such as drying off , shrinkage and widening, in the general tectonic evolution of lakes (Talbot, 1990; Talbot and Kelts, 1990). Such lakes are recognized and known to be favorable places as economical mineral occurrences such as sepiolite, magnesite, bentonite, and strontianite (Bellance et at., 1992).

The wide-spread dolomite occurrence in Sivrihisar area provides suitable clues to understand the different factors upon the Neogene lake sedimentation (Fig. 1). In this study, all of data were used in determination of different climatological, hydrodynamic, and biological conditions controlling

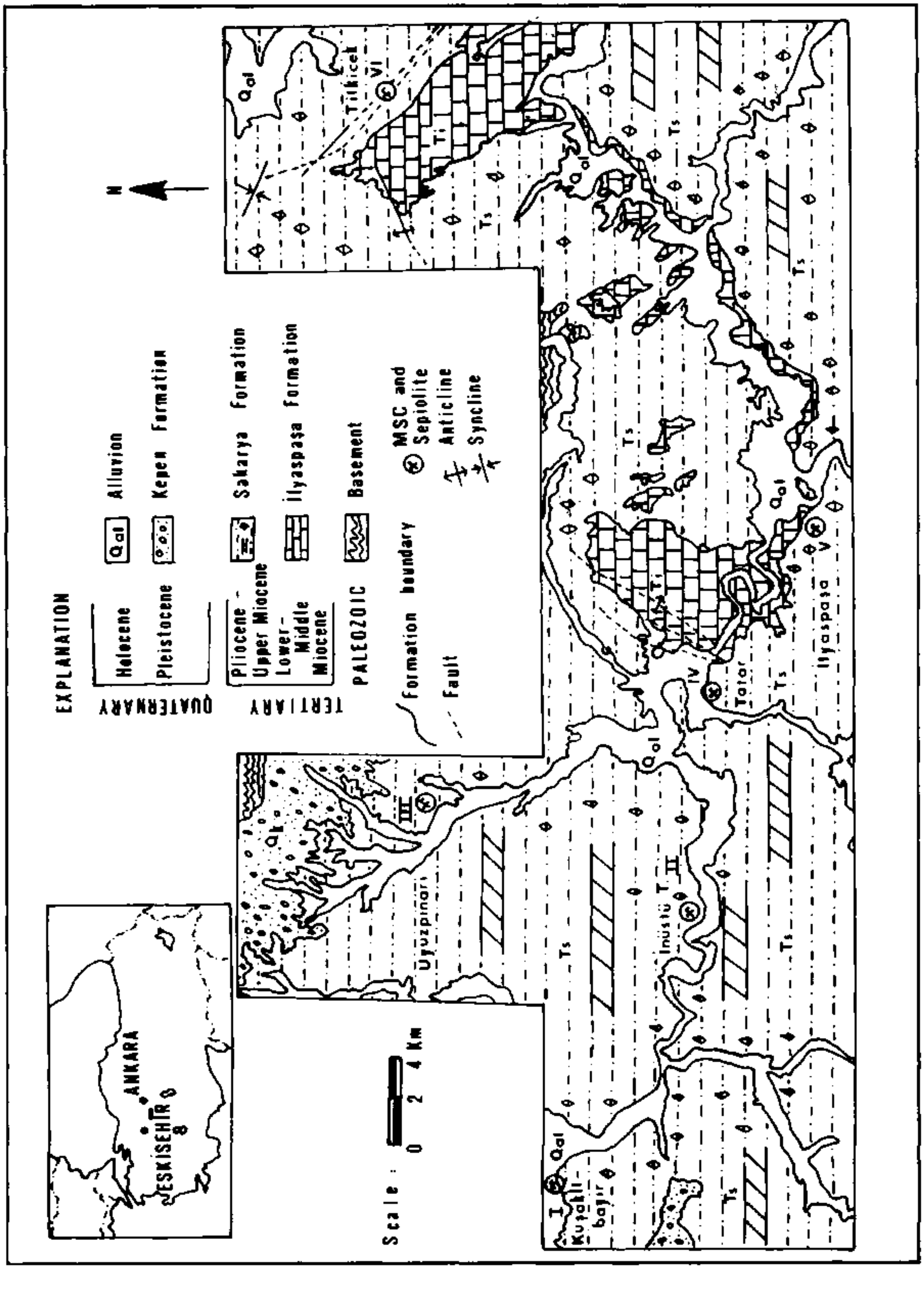

Fig. 1- Location and geological map of the study area.

the formation of these lacustrine dolomites and examination of the effect of these conditions over the environmental changes.

MATERIAL AND METHOD

Dolomites (40 samples) were collected for analysis through 6 different sections measured at Kuşaklıbayır, Inüstü, Uyuzpınarı, Tatar, İlyaspaşa and Tilkicek Yayla, the area covering about 1000 km^2 and lies 13 Km southeast of Sivrihisar (Fig. 1, 2).

In the field study, the lake dolomites were defined by microcrystalline texture, fracture pattern, white colour. Whole rock chemistry and mineralogical analysis provided by X-Ray (XRD). Dolomites were recognized, using their XRD graphy through their peaks at 2.89 A', 2.19 A', and 1.79 A'. This study was carried out using Philips PW 1140 model X-Ray difractometer. Electron microscope observations and micro -texture analyses were performed by means of Scanning Electron Microscope. Semi-quantitative spot analyses were performed using X-Ray spectrometer linked to the Trakor TN 5502 energy dispersive system fitted to a Jeol JSM 840 A type Scanning Electron Microscope. The measurement of stable isotopes ($d^{18}O$, $d^{13}C$) in the 20 selected samples were performed using special solutions through Varion Mat 250 type of mass-spectrometer. For this, the method proposed by Epstein et al., (1964) and Becker and Clayton (1972) were used.

STRATIGRAPHY

Dolomites are commonly present in Sakarya formation in association with gypsum, claystone, marl and limestones (Karakaş and Varol, 1993). The ostracod fossils of *Cyprinotus salinus* (Brady), *Candona neglecta* Sars, *Candona* cf. *compressa* (Koch), *Candona* cf. *angulata* Mueller, //yocypns cf. *gibba* (Ramdohr), *Cyprideis* cf. *torosa* (Jones), *Cyprideis* cf. *heterostigma* (Reuss), *Pseudocandona* sp., *Candonopsis* sp. were found in the marl levels in this formation. In addition, the pollens of *Compositae type pollen, Pityosporites* spp., *Tricolporopollenites* spp., *Monoporopollenites* sp., *Ovoidites* spp., *Monocolpopollenites trachycarpoides, Periporopollenites multiporatus* are generally predominant marly dolomite layers. In limestone samples gastropod fossils of *Coretus sulekianus* Brusina, *Gyraulus radmanesti* Fuchs, *Bulimus* sp., *Pisidium* sp., *Hydrobia sp., Valvata* sp. were recognized. This fossil associations of the formation indicate Upper Miocene-Pliocene time. The well-preserved gastropod fauna in the limestones, which conformably overlie dolomites in Tilkicek Yayla area, points to the age of Dacian (Lower Pliocene). Sakarya formation unconformably overlies the underlying Lower-Middle Miocene İlyaspaşa formation which is composed of limestone with chert, marl, claystone, and thin levels of peat and is unconformably overlain by the alluvial deposits of the Kepen formation (Karakaş and Varol, 1993) (Fig. 3).

Different lithologies in dolomite-dominated Sakarya formation display both lateral and vertical facies changes (Fig. 2). In particular, massive and bedded gypsum in Kuşaklıbayır area exhibits an interfingering with the gypsiferous dolomites in Inustu Tepe area. Similar relationship is also encountered between gypsiferous and clayey dolomites.

FACIES PROPERTIES OF DOLOMITIC UNITS

The diagnostic features of the dolomites are their with colour, thin-to medium-thick- bedding, calcarecous appearance, conchoidal fractures, and their highly cracked structures. The other rocks associated with dolomites help to identify the different facies among the uniform dolomite. Such as gypsiferous, clayey and calcarecous dolomites.

1- Gypsiferous dolomites: A great portion of dolomites falling into this group are characterized by their discoidal gypsum crystals, gypsum rosette and swallow-tail twin, and brown-green colours (Fig. 4a). These structures were developed in the form of displacive grown scattered crystals or fracture-fillings in dolomites. The fracture-fillings are more common in dolomitic levels containing less amount of clay (10-15 %). Typical examples of these structures are observed at the bottom levels of Uyuzpınarı, Inüstü, and İlyaspaşa sections (Fig. 2).

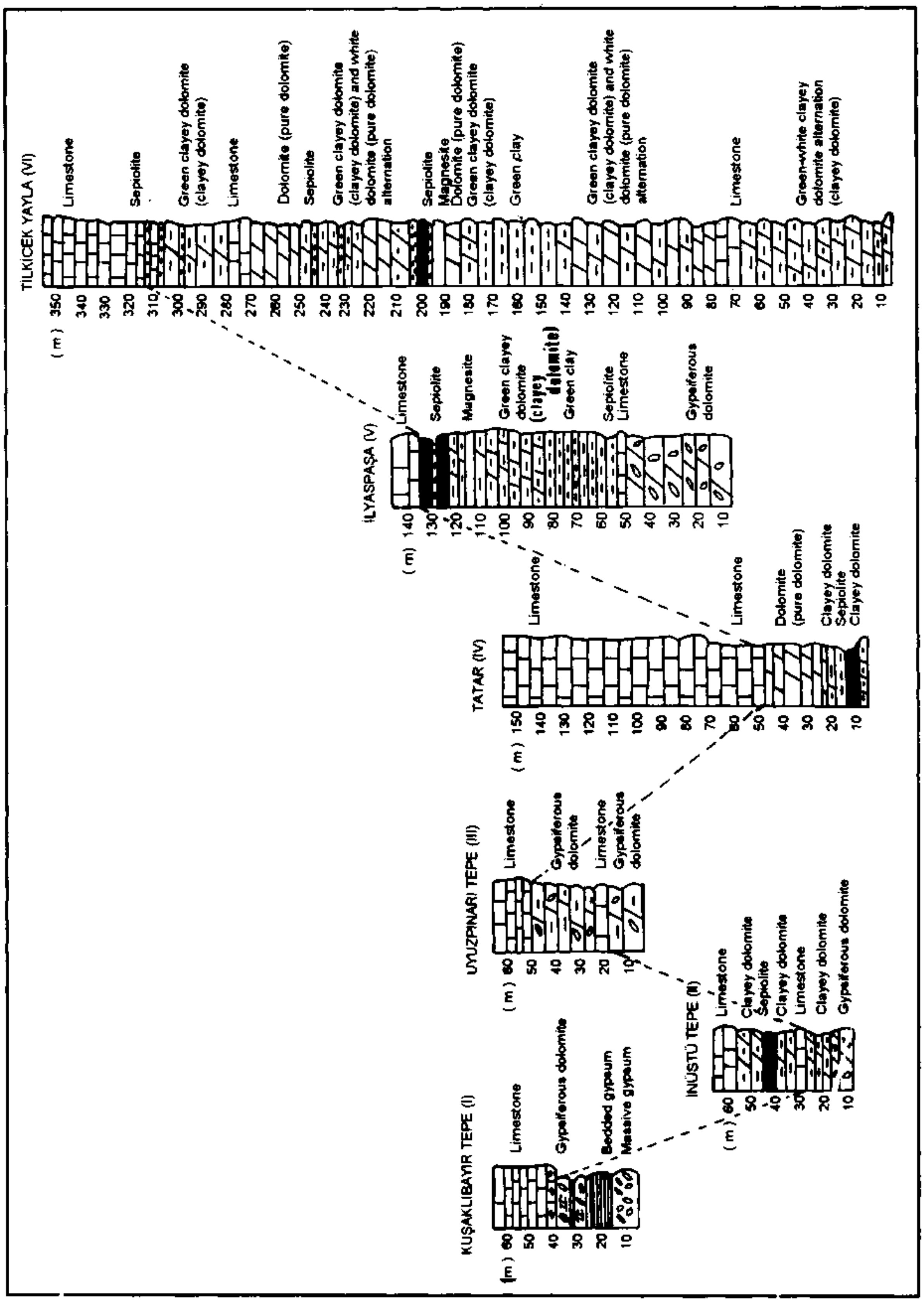

Fig. 2- Measured stratigraphical sections representing the different parts of the study area.

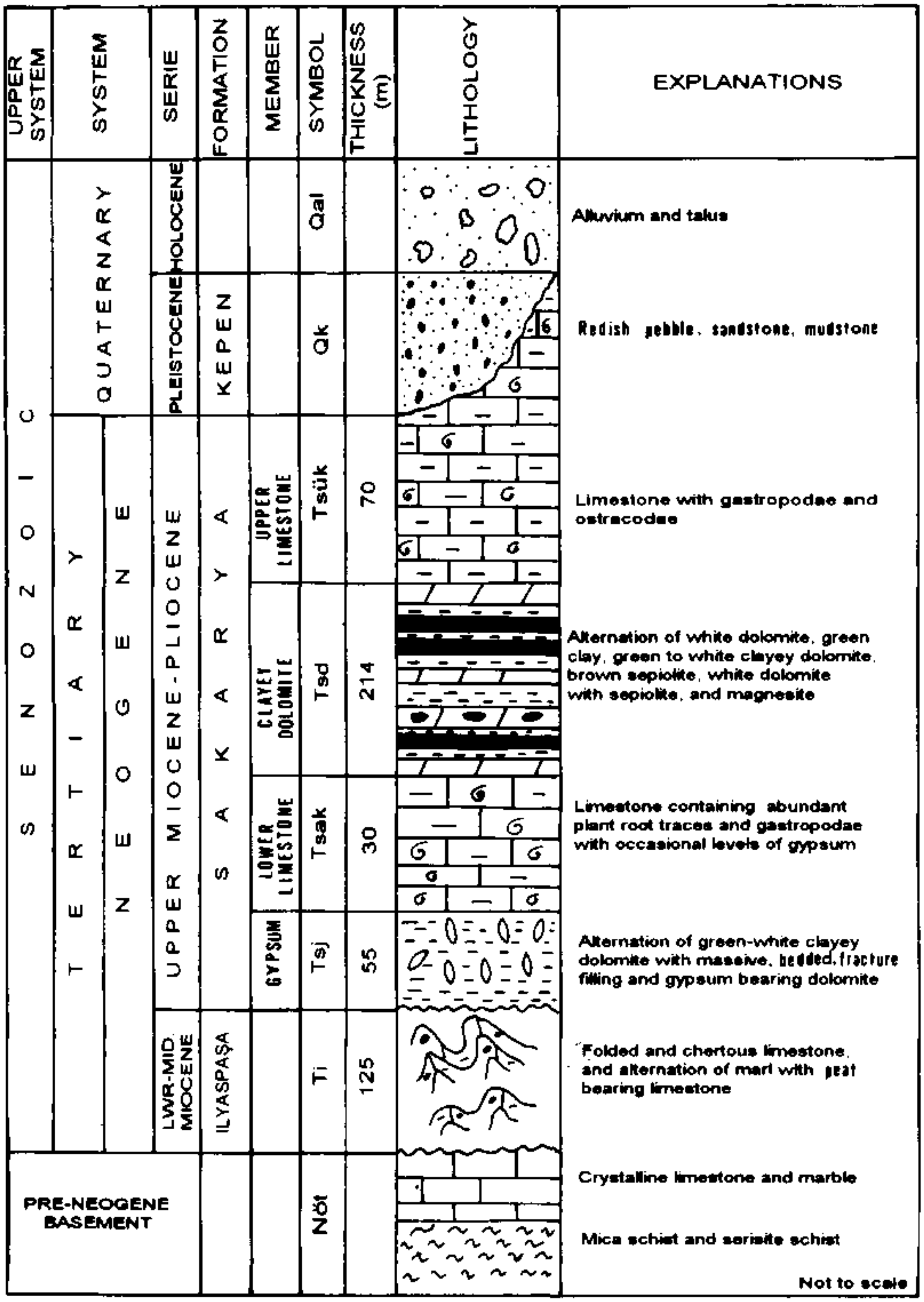

Fig. 3- Generalized columnar section of the Neogene units in the study area.

This facies also alternated with the bedded and massive gypsum levels which composed of white prismatic gypsum crystals. Reverse gradations, microparallel-and cross-laminations, and very weak ripple structures appear to be synsedimentary structures in this alternating section. The lower

Fig. 4a- Brown gypsum roses developed in dolomites in fracture-filling forms (Kuşaklıbayır Tepe).

most part of Kuşaklıbayır section is the only location exposed gypsiferous dolomites (Fig. 2). Towards eastward, the gypsiferous dolomites become thin and make up lateral facies change with the another gypsiferous dolomite beds composed of displacive gypsum crystals. In addition, fracture-filling gypsum with dolomite is observed at the Kuşaklıbayır section and grades into the gypsiferous limestones at the upper levels of this section (Fig. 2).

2- Clayey dolomites: Clay-bearing dolomites give a loose and soil-like appearance and have a minimum of 20 % clay in their composition. They are classified into two groups with respect to colour of the rock: such as green clays and white and brown clays. The green clays are characterized by the smectite-illite-chlorite group clay minerals and observed to be bentonites in İlyaspaşa and Tilkicek Yayla sections (Fig. 2). They also alternate with pure dolomite units. Individual limestone layers interbedded with green clays are also observed in the dolomite-bearing sections. Limestone beds of varying thicknesses are repeatedly encountered in Tilkicek Yayla section. The second group of clays in the same facies are the white coloured sepiolitic clays. These are observed either as pure clay levels or in mixed forms with dolomites which are highly fractured, occasionally brecciated nature, and filled by clays (sepiolite) in the root moulds. Brown clay is pure sepiolite in which organic matter is high but dolomite is very low (at about %5). As the dolomite content increases, the colour changes from black to white. The typical colour change in this facies depends on clay+dolomite+organic matter content, Inustu, Tatar, İlyaspaşa and Tilkicek Yayla locations exhibits these colour changes varying from brown clay (pure sepiolite) to white clay (dolomite-bearing sepiolite). In the last two locations, a few meter-thick lenticular magnesite formation is observed in association with the clayey dolomite facies (Fig. 4b).

3- Pure dolomites: These are uniform dolomites and lack of gypsum, clay, and any other matter. Plant moulds are commonly found in this dolomites. This facies display lateral facies change with the gypsiferous and clayey dolomite facies. In some areas, it is interfingering with limestones. Locally it

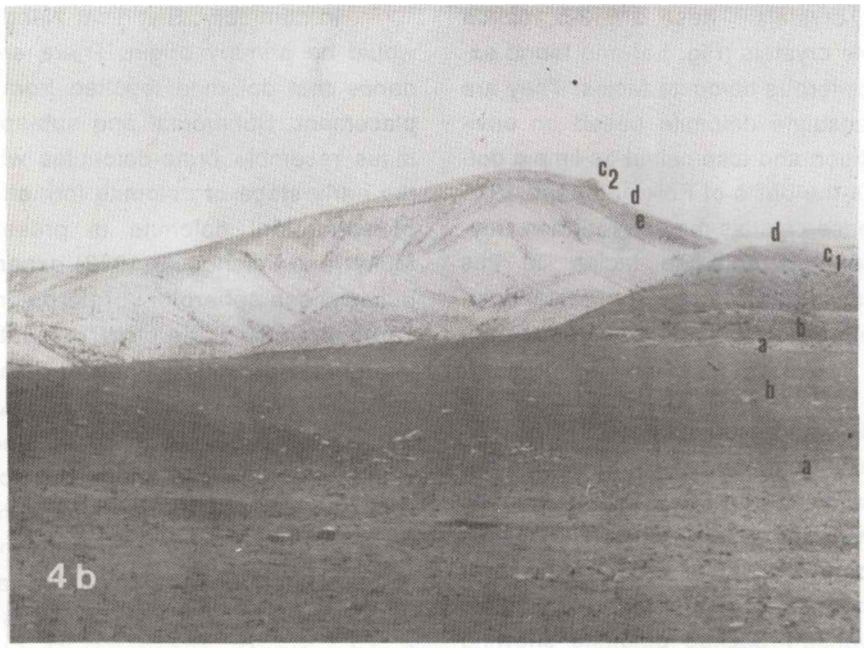

Fig. 4b- Alternation of clayey and pure dolomite (Tilkicek yayla). a) White clayey dolomite (clayey dolomite). b) Green clayey dolomite (clayey dolomite) c_1) Lower limestone. c_2) Upper limestone. d) Dolomite (pure dolomite). e) Sepiolite.

alternates with gypsifefous dolomite fades and some levels having conchoidal fractures show weak clay mineralization represented by sepiolite. Kuşaklıbayır section is typical area with the alternations of above facies types as shown in the Figure 2.

PETROGRAPHICAL TYPES

The samples collected from the above described facies present a dolorhicritic feature under polarizan microscope. In gypsiferous dolomite samples, individual gypsum crystals in dolomicritic matrix show displacive form. These crystals do not present any inclusions and irregular crystal boundary resulting from dolomite replacement. Dolomites usually encompass gypsum crystals. In these sorts of formations gypsum crystals develop in the displacive form in the soft dolomite mud formed related to the saline pore water (Masson, 1955; Arakel, 1980; Cody and Cody, 1988; Rosen and Warren, 1990; Magee, 1991). Various types of gypsum crystals Which are brown in colour, lack of bedding and fracture fillings are important features and indicate the rise of groundwater level enriched by earth elements due to the dehydration cracks in the slowly drying off dolomite lake (Cody and Cody, 1988). Anhydrite is rarely found in gypsiferous dolomites. It occurs in few mm thick crust forms in the alternating layers of thin dolomites and massive gypsum. Individual gypsum implacements in dolomites are often observed and indicates the fresh water leaching. Brecciations are found in clayey dolomites along the desiccation cracks and root tubes. Sepiolite infillings in these root tubes and brecciate are commonly. Present pure dolomites give generally homogeneous appearance. They are characterized by micro-concretion, soil formation, oxidation and rare algal traces.

Dolomites, which is petrographically describe as dolomicrite, described are classified into euhedral, sub-spheroidal and spheroidal crystals with respect to SEM examinations (Bellanca, et al., 1993).

Euhedral crystals: These are 2-5 micron rhombic dolomite crystals (Fig. 5a) and found extensively in gypsiferous dolomite facies. They are similar to schizosaline dolomite based on environmental condition and also called as limpid dolomite crystals in the basis of Folk and Land 1975 terminology. These crystals may be found in clayey (sepiolite-bearing) dolomite facies. In this case, they are mixed-up with the spheroidal dolomite crystals with the association of fibreous bundle of sepiolite.

Spheroidal and sub-spheroidal crystals: The nomenclature on these type of dolomites are based on the study of Von Der Borch and Jones (1976) and Amiri-Garroussi (1988). The typical rhombic and perfect crystals are gradually replaced with spheroidal or nearly-rounded crystals (Fig. 5b, 6). Densely packed dolomite showing plate type growing habit are also observed within the petrographic type. The spheroidal and subspheroidal dolomites are generally intercalated with euhedral dolomites. External dissolutions of the dolomite plate and vugs are associated with spheroidal and sub-spheroidal dolomite crystals. Inter-crystal pores are quite common and reflect ' dissolution activity (Fig. 5b, 6). Diatome shells- and remnants are often observed in the levels of spheroidal dolomites. Many researchers have reported that these spheroidal dolomites precipitated in the micropores of diatome shells or silicium gel (opal silicium) from dissolutions of diatomes involved in the spheroidal habit of dolomite crystal (Cook, 1973; Weaver and Beck, 1977). There are no clear evidence that diatomes invoked for the formation of spheroidal dolomite crystals. Nevertheless, the existence of this kind of crystals in the dolomitized diatome mud supports the above explained opinion. Sub-spheroidal and plate dolomite crystals are either products of marginal dissolution of rhombic crystals or they were formed through several-stages of dolomite crystalization that had been interrupted by non-dolomitization periods. They also covered sepiolite fibers in the micron-size length or precipitated within the open spaces of sepiolitic mass as shown in the Figure 5c.

In summary, Sivrihisar Neogene dolomites would be primary origin. There are no any evidence that dolomite resulted from aragonite replacement. Spheroidal and sub-spheroidal dolomites resemble proto-dolomites which represent the early stage of dolomite formation. The origin of spheroidal dolomite is presently debated. Muller and Fischbeck (1973) experimentally produced these spheroidal proto-dolomites from the carbonate-gel. Spheroidal dolomites were also interpreted as initial phase of dolomite or proto-dolomite (Von Der Borch and Jones, 1976). Spheroidal vugs could be related to diatome shells, which existed before the dolomitization in lake bottom. The porous shell structures would served as microenvironments in which spheroidal dolomite had been precipitated as pointed by Weaver and Beck, 1977. The transition from proto-dolomites to perfect euhedral-limpid crystals are very typical. It is very likely that this transition of the different dolomite crystals was controlled by the increase of magnesium content in the lake environment. In Figure 6, it is shown that decrease in magnesium content results in dissolution leading to pore development, and increase in magnesium content produces the perfect rhombic crystals shapes.

STABLE ISOTOPES

Stable isotope values obtained from the different petrographical types of dolomites have plotted in three different areas as shown in the Figure 7, 8. In these areas, a stable isotope values show a change from relatively small values (negative) to higher (positive). Among of them, the first group is $d^{18}O$: -1 to +4 %o and $d^{13}C$: -4 to +0.5 %o; the second group is $d^{18}O$: -6 and to -1 %o and $d^{13}C$: -3 to -1 %o; the third group is $d^{18}O$: -5 to +2 %o and $d^{13}C$: -1.5 to 0.0 %o (Fig. 7, 8). The variations observed in stable isotopes of dolomites are directly related to the changes of salinity and temperature of dolomitizing fluids through dolomitization periods (Folk and Land, 1975). In the Neogene lake area, rapld changes in the water chemistry of lake environments are quickly affected by atmospheric conditions and this involved in abrupt changes in the

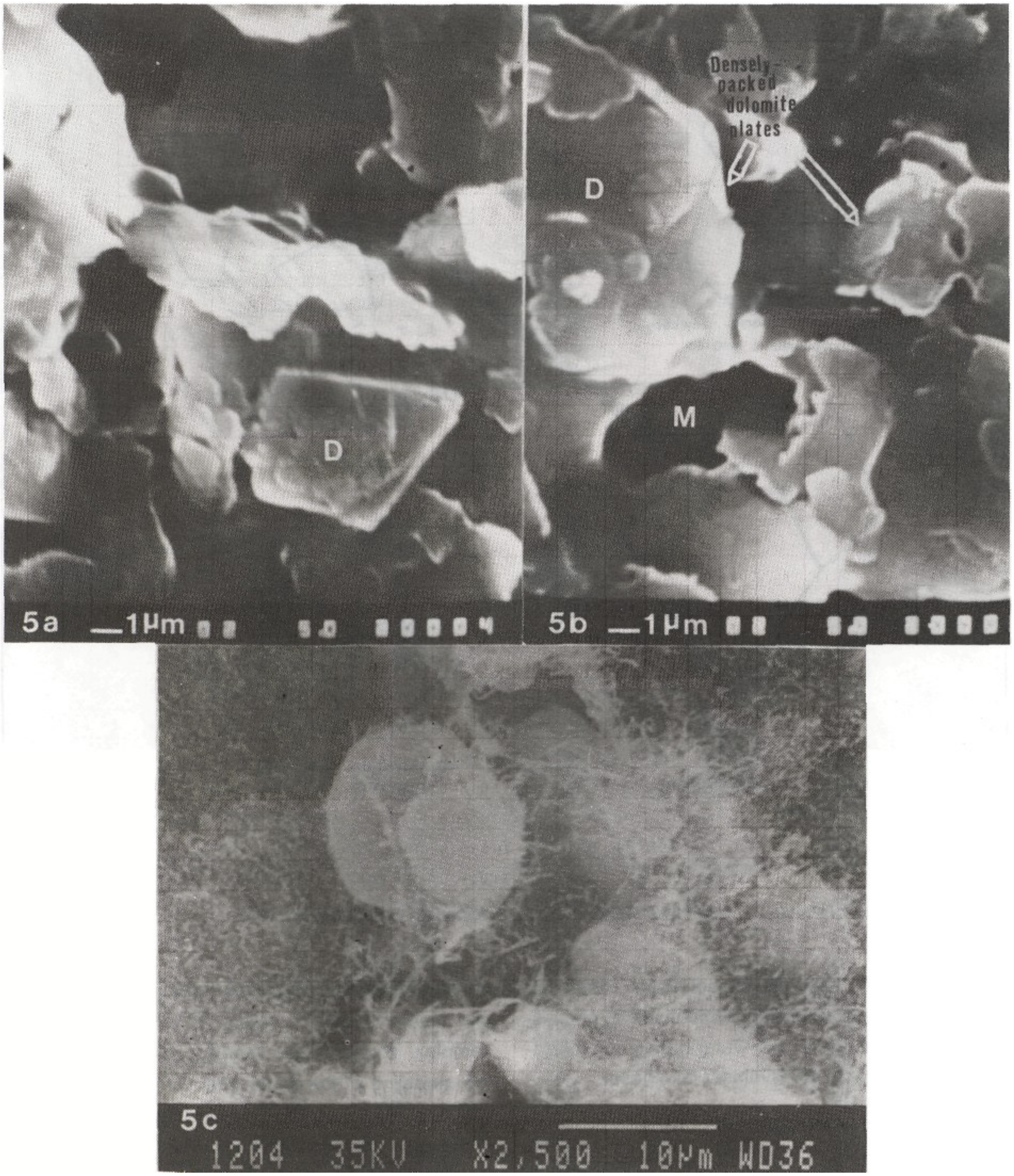

Fig. 5a- Euhedral dolomite (D) crystals developed in the gypsiferous dolomite fades.

Fig. 5b- Micropores (M) formed by external dissolution in the spheroidal dolomite crystals and densely packed dolomite plates (D).

Fig. 5c- Spheroidal and sub-spheroidal dolomite crystals in fibreous sepiolite bundles.

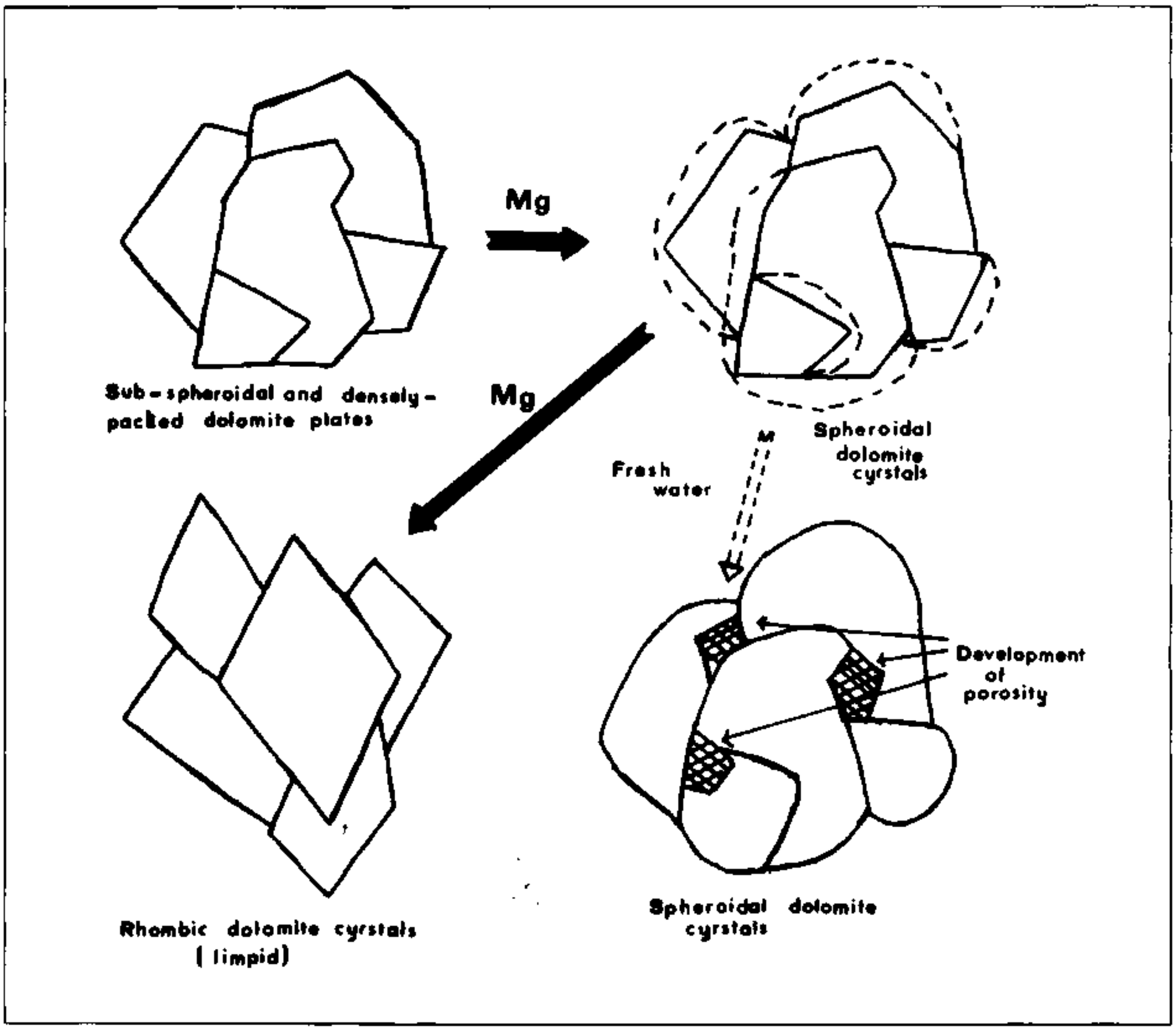

Fig. 6- Scheme showing the transition of different types of dolomites from one to another.

stable isotopes of dolomitizing solutions. These isotopic features are reflecting fluctuations of chemistry and temperature of lake water during dolomitization are very typical for Sivrihisar lake basin.

CONCLUSIONS AND DISCUSSION

Sivrihisar Neogene lacustrine dolomites present a fine-grained (dolomicrite) feature in the field and are similar to a number of lacustrine dolomites described in the literature (Muller, 1970; Von Der Borch and Jones, 1976). Lacustrine dolomites generally have simple appearance, but their internal structures, microscopic features, trace elements and stable isotope contents ($d^{18}O$; $d^{13}C$) are very complex. This provides important information about the modeling of the water chemistry and hydrology which of the lakes are heavily affected by the climatological changes. In particular, the variations in the oxygen isotope values ($d^{18}O$) provide important information about the isotopic composition and temperature of the lake water in which primary and early diagenetic lacustrine carbonate deposition takes place. The formation mechanism of $d^{18}O$ stable isotope values in lacustrine carbonates usually indi-

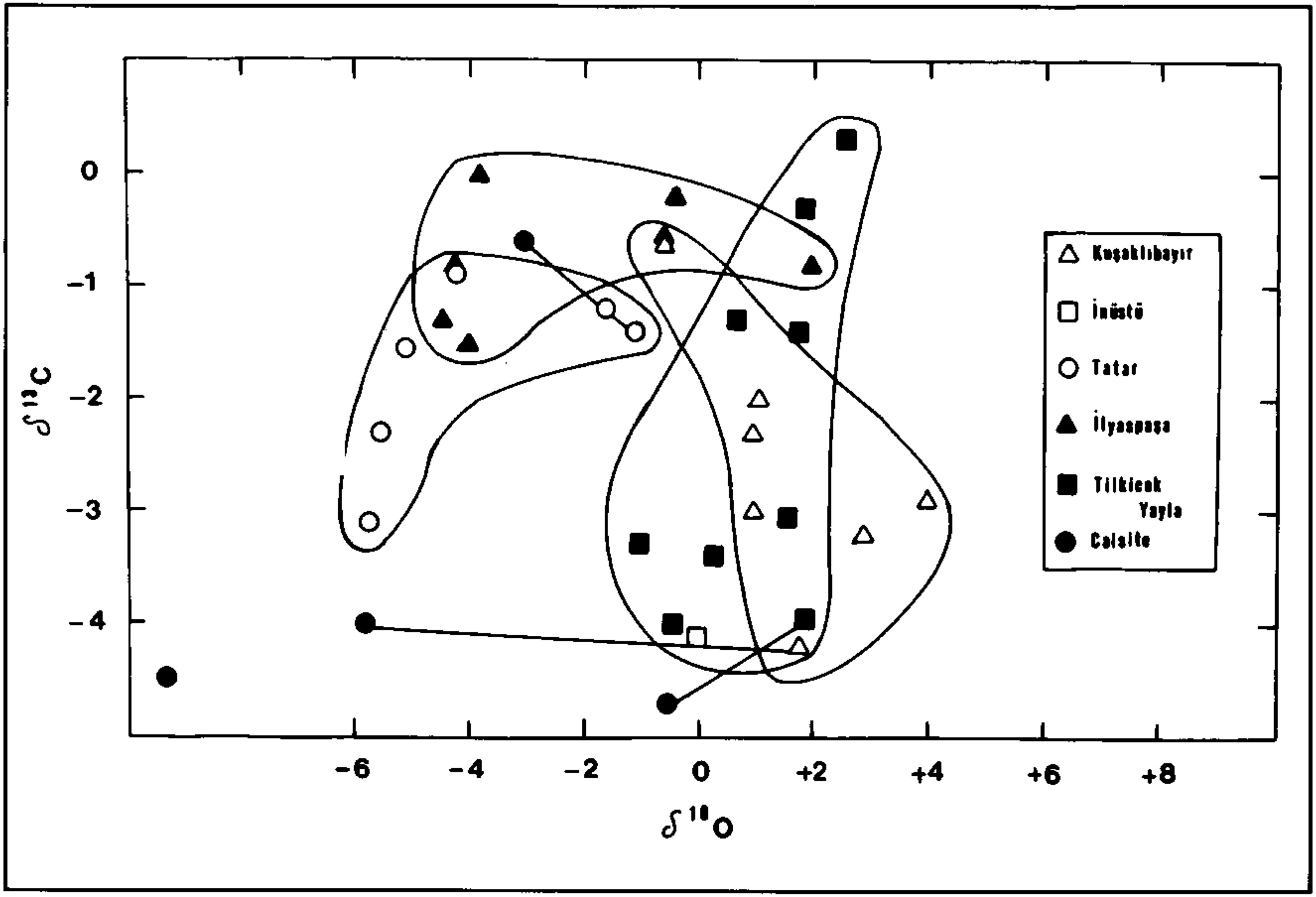

Fig. 7- Distribution table $\delta^{18}O$ and $\delta^{13}C$ stable isotopes of Sivrihisar Neogene dolomites according to the columnar sections (‰, PDB-1).

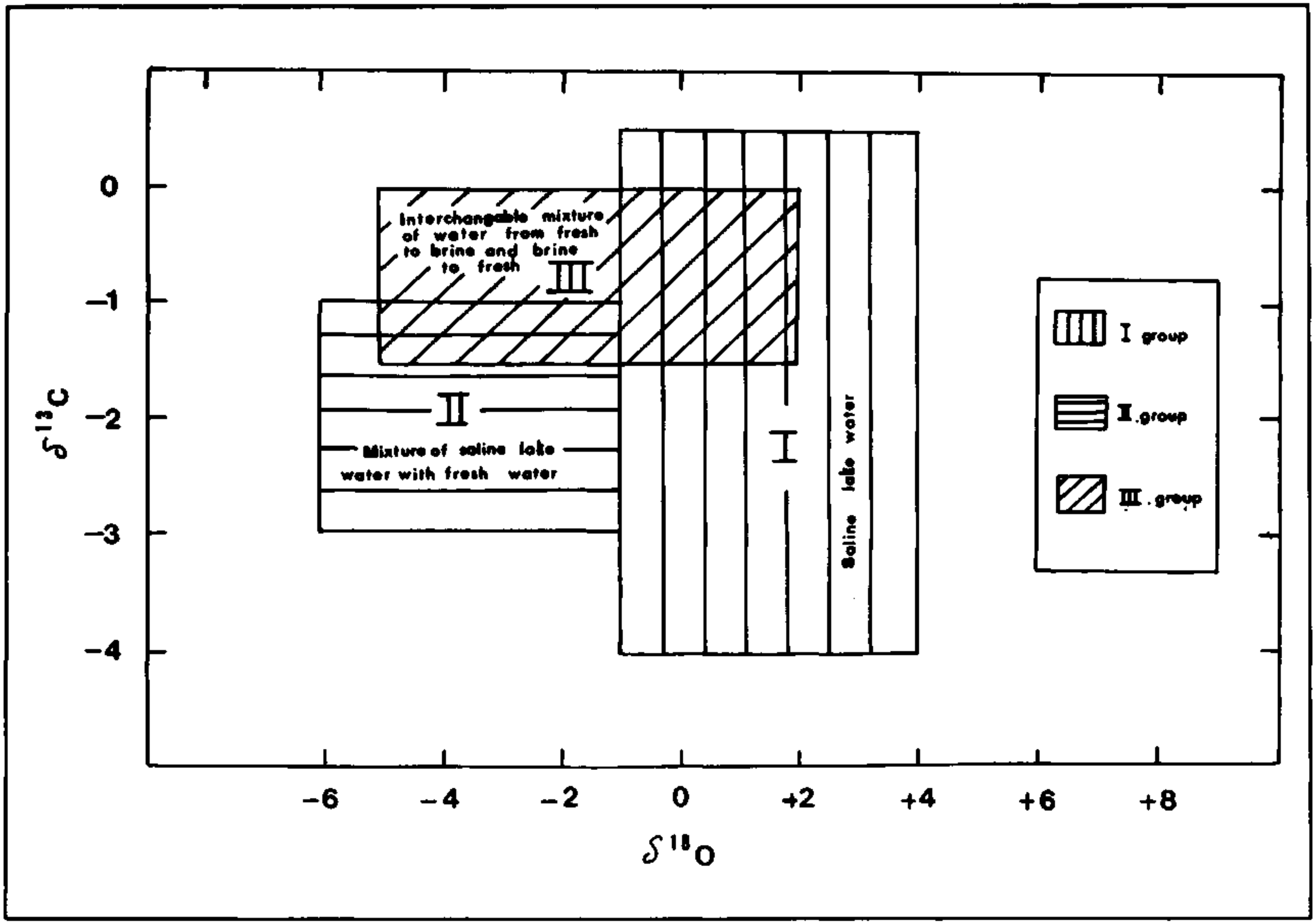

Fig. 8- Geochemical character of lake water according to $\delta^{18}O$ and $\delta^{13}C$ stable isotope groups of Sivrihisar Neogene dolomites.

cates that they are heavily affected by the evaporation during dry climate conditions (Gonfiantini, 1986; Gasse et al., 1987). Carbon isotope ($d^{13}C$) composition is controlled by many factors in lakes. The most important one is the derivation of CO_2, through photosynthesis from soil profile into the lake and causes great decrease in $5^{13}C$ values in lake areas (-10 to -28 %o) (Salomons and Mook, 1986). Decrease in $d^{13}C$ is rebalanced by the atmospheric sources (Gonfiantini, 1986; Hoefs, 1987). Another factor which cause decrease in $d^{13}C$ isotope is the microbiological destruction of the organic matter in the diagenesis environment.

Stable isotope of dolomites in the study area represent a variable character. Different isotope values which reflect variation in depth, salinity, and biogenic activity in the paleo-lake environment. The stable isotope data reveal different depositional and hydrologic periods of Neogene lake as follows:

Gypsiferous dolomites of the first facies and their typical crystals are limpid dolomites. These are placed in the first category and have values of $d^{18}O$: -1 to +4 %o and $d^{13}C$: -4 to +0.5 (Fig. 8) Positive values with the oxygen isotopes depends on increasing salinity due to excess evaporation. Under these environmental conditions, the enrichment of $d^{18}O$ isotope is the result of quick consumption of $d^{16}O$ which is lighter due to increasing ionization speed (kinetic isotope effect; Anderson and Arthur, 1983). The highest values of $d^{18}O$ in our samples indicate the decrease in water or negative water balance and even the complete dry-off of the lake. Low values of $d^{13}C$ in these samples indicate the effectiveness of the limited air circulation conditions (stagnant) in the lake. Thus, production of CO_2 is connected to the local biological sources (Talbot, 1990). $d^{18}O$ values in magnesite and strontianite occurrences are found considerably high. The deposition of strontianite is an indication of the limited biological activity in and around the lake environment. As the use of strontianite by fauna flora in areas of biological activity prevents the deposition of strontianite (Magee, 1991).

The second group consists of dolomites composed of spheroidal, dolomite crystals. Clayey dolomites are partially found in the second group. $d^{18}O$ values of this group are relatively low and between -6 to -1 %o (Fig. 8). Nevertheless, $d^{13}C$ isotope values are high and between -3 to -1 %o, which suggests that the fresh water partly mixed with saline lake water during dolomite deposition and the vicinity of the lake had a weak plant cover under the semi-arid climate conditions (Talbot, 1990).

The third group is composed of clayey dolomite and partially pure dolomite facies. It is a mixture of dolomite crystals of euhedral, and sub-spheroidal shapes. The samples in this group had isotope values of $d^{18}O$: -5 to +2; $d^{13}C$: -1.5 to 0.0 %o covering the two groups described above (Fig. 8). This indicates the rapid changes in short periods from fresh to saline and from saline to fresh water conditions. Overall, it reflects the climatological variations in short periods as humid-semiand-arid conditions.

Stable isotope values of $d^{18}O$ and $d^{13}C$ as explained above reflect changes from positive to negative in a certain interval (Fig. 7). According to the stable $d^{18}O$ isotope values, dolomites can be grouped into three accepting that the SMOW value for normal saline sea water environment is zero (Land, 1980) (Fig. 8). These different groups indicate the variations in the temperature and salinity of the lake water during the deposition of various types of dolomites deposited in the Sivrihisar lake basin of Neogene age. These variations might be due to climatological factors, geomorphological position of the lake as well as the tectonic activities. The type of dolomite was affected by the shrinkage, extension, and dry off of the fossil lake. The separation of the stable isotope fields shown in Figure 8 suggest that different hydrodynamic, tectonic, and seasonal changes existed in the Neogene lake basin. Stable isotope values of $d^{18}O$,and $d^{13}C$ are also affected by the short and long-term variations in salinity, temperature as well as biological activity. Neogene dolomite series make up a typical example of the dolomite depositions dependent upon the depositional environments of changing salinity conditions (schizohaline dolomite; Folk and Land, 1975). At the stages-of excess fresh water inout into the lake area, dolomite deposition ceases and transforms into dolomite dissolution. This is the event controlling the external dissolutions and pore development (Fig. 6). Similarly, interruption of the source of magnesium as a result of short-period variations in salinity caused densely-packed plates type of several-stage, sub-spheroidal shaped crystal growth. Peryt and Magaritz (1990) describe these dolomites as formed in sabkha environments open to the entries of fresh water. From the standpoint of depositional environment conditions, dolomites of the study area show a great similarity to ephemeral lake varying from hipersaline to hyposaline.

The resulting stable isotope values show that even under the most saline conditions leading to the dolomite deposition in the Sivrihisar lake basin, the depositional environment never had the character of a playa lake. This is because $d^{18}O$ values measured in gypsiferous dolomite facies in which the evaporation may have been the greatest are lower 4-6 %o than Coorong dolomites (Warren, 1990), typical for the highly saline lacustrine lagoons. The results also indicate that evaporitic dolomite deposition environments representing Sivrihisar Neogene basin were open to fresh water flush.

The stable isotope values of Sivrihisar Neogene basin show that the fossil lake had no stability with respect to either its salinity or areal extension. Short and long period seasonal changes controlling this character of the lakes provided new sources for the ionic enrichment of the lake water. For instance, in addition to the renewed magnesium sources due to fresh water inflows, magnesium and silicium enrichments dissolved through the lake sediments (dolomite-diatome) lead to the mineralizations increasing the economic value of the lake. The best example of these occurrence for the region is the formations of sepiolite and sepiolite bearing dolomite.

ACKNOWLEDGEMENTS

This study is funded by TÜBİTAK (Project No: YBAG-0006; TBAK-896) and a part of a larger PhD study of the first author. The authors are grateful to Professor Adriana Bellanca from Universita Degli Studi Di Palermo Institute Di Mineralogia Petrografia E Geochimica (Italy) for the stable isotope and geochemical analysis; to Professor Güler Taner from A.Ü.F.F. for the paleontological descriptions, to Zuhtu Batı from T.P.A.O. for the description of pollens; to Aynur Hakyemez from MTA for the description of ostracodas; and to Mustafa Karabıyıkoğlu from MTA for providing support for field investigations.

Manuscript received July 13, 1994

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RESEARCH METHOD ON BEACH PLASER DEPOSITS CASE STUDY FROM THE THRACIAN COASTAL ZONE OF THE BLACK SEA, TURKEY

H.Yavuz HAKYEMEZ** and Tevfik ERKAL**

ABSTRACT.- In order to carry out the plaser investigation on a coastal zone, it is necessary 1° to define the sedimentary sub-basins and source area of these basins, 2° to differentiate the geomorphtc units and sedimentary facies, and 3° to collect the representative samples from these facies By this way it is possible to find where the tenof increases; in which coastal sub-zone and sedimentary sub-basin fed by which source area This method has been carried out in the Thracian coastal zone of the Black Sea So it has been understood that the plaser rutile is concentrated in winter-beach and that the higher percentage of rutile defined in the coastal zone near the Ormanlı village fed by a source area mainly composed of the upper Miocene aged Ergene formation

A NEW EVIDENCE OF AGE DETERMINATION FROM THE AKGÖL FORMATION AROUND DESTEK, (MIDDLE PONTIDES) NORTHERN, TURKEY

Ergün AKAY**. Erdal HERECE** and Şerafettin ATEŞ**

ABSTRACT - Areally widespread Akgöl formation within the Middle Pontides is also observed around Destek, a small town near Amasya in northern Anatolia Here this formation is assigned to Lower-Middle Jurassic in terms of the bentonic foraminiferas

Mineral Res. Expl Bull 116, 47-48, 1994

ORDUINA ERKI SIREL 1969 RENAMED AS ***LAFFITTEINA ERKI*** (SIREL) FROM THE THANETIAN OF ORDU AND BURDUR (TURKEY)

Ercüment SİREL*

ABSTRACT - In 1969, *Orduina erki* Sirel and its subspecies *Orduina erki conica* Sirel were first described and figured by the present author from the Paleocene of Gölköy (south of Ordu) *Orduina erki* is reviewed on well preserved and isolated speomens collected from the Paleocene (Thaneban) of Ordu and Burdur regions Orduina was accepted as a synonym of Laffitteina Mane by the presence of ramifying interseptal canals that open as two alternating rows of pores along the sutures on the spiral side and coarsely perforate, calcareous, hyaline wall

INTRODUCTION

A new rotalid foraminiferal genus Orduina Sirel (1969) and its two trochospiral represantatives *Orduina erki* and *Orduina erki* var. *conica* were previously described (Sirel, 1969, p. 145) from the Paleocene of Gölköy town. Sirel (1969) mentioned a close relationship between *Orduina* and *Laffitteina,* both having coarsely perforate, calcareus, hyaline walls. Despite of the presence of the sutural openings along the septa on the dorsal side and coarsely perforate, calcareous, hyaline wall, *Orduina* was shown as a synonym of *Kathina* Smout (1954) by Loeblich and Tappan (1988, p. 661, Plate 760, fig. 6-'10). *Orduina erki* is reexamined on well preserved and isolated specimens from the Paleocene (Thanetian) of Ordu and Burdur regions (fig. 1). As a result of this investigation, the genus *Orduina* is synonymized under *Laffitteina* Marie (1946) by the presence of bifurcate interseptal canals that open as two alternating rows of openings along the septal sutures on the dorsal side (Plate II, fig. 1, 4, 8-10). Therefore, *Orduina* erki has been proposed the one species of *Laffitteina* as *Laffitteina erki* (Sirel).

Isolated specimens and all thin sections containing this foraminiferal species figured in this paper are deposited in the collection of General Directorate of Mineral Research and Exploration (MTA), under the number shown in Plate I, II.

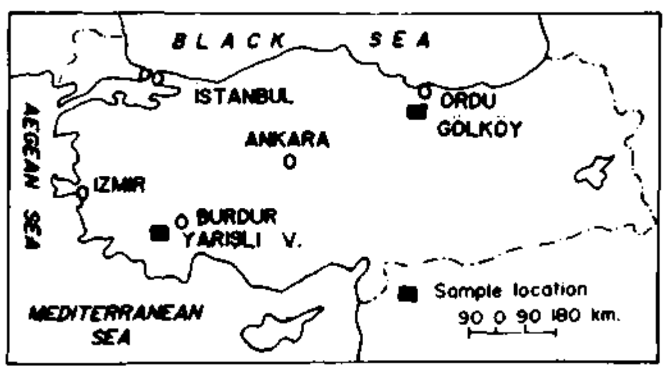

Fig. 1- Location Map.

SYSTEMATIC DESCRIPTION

Order : Foraminiferida Eichwald, 1830

Suborder : Rotaliina Delage and Herouard, 1896

Family : Rotaliidae Ehrenberg, 1839

Genus : Laffitteina Marie, 1946

Type species : *Nummulites mengaudi* Astre, 1923

Laffitteina erki (Sirel) 1969

(Plate I, fig. 1-10; Plate II, fig. 1-11)

1969 *Orduina erki* Sirel, p. 145, Plate I, fig. 1A-D; Plate II, fig. 1-5; Plate III, fig. 3.

1988 *Kathina erki* (Sirel), Loeblich and Tappan, p. 661, Plate 760, fig. 6-10.

DESCRIPTION

Test relatively high trochopiral, with large size up to 4,3 mm in diameter, spiral side strongly convex and evolute (Plate I, fig. 1, 4, 6, 7; Plate II, fig. 2, 3, 5-7, 11); opposite side slightly convex or concave involute (Plate I, fig. 2-5, 10; Plate II, fig. 2, 3, 5-7, 11); 35 chambers in the penultimate whorl of a test measuring 2, 25 mm in diameter; umbilical cavity large and filled by numerous pillars; thin vertical canals between the umbilical pillars; septa double, with ramifying interseptal canals that open as two alternating rows of pores along the sutures on the dorsal side; wall ocarsely perforate, calcareous, hyaline wall; aperture an interiomarginal slit.

REMARKS

Because of the presence of the bifurcate interseptal canals that open as two alternating rows of openings along the septal sutures on the dorsal side (Plate II, fig. 1, 4, 8-10) and the presence of the coarsely perforate, calcareous, hyaline wall, the genus *Orduina* was shown as a synonym of *Laffitteina.*

Laffitteina erki differs from all other species of *Laffitteina (Laffitteina conica* Drooger, *Laffitteina mengaudi* (Astre) and *Laffitteina koyulhisarensis* n. sp., Sirel in press) by its large size and conical shape with strongly developed trochoid spire.

This species is the youngest represantative of *Laffitteina.* It is associated with *Idalina sinjarica* Grimsdale, *Miscellanea primitiva* Rahaghi, *Orduella sphaerica* n. gen. n. sp. (Sirel, in press), *Haymanella paleocenica* n. gen. n. sp. (Sirel, in press), *Cuvillierina* sp. Miliolidae and algae at the type locality, Gölköy town, south of Ordu, north Turkey. This foraminiferal assemblage indicates a Early Thanetian age.

Laffitteina erki was found in the Thanetian alga! limestones and marls of Yarışlı village (west of Burdur, south Turkey) and is associated at this locality with *Bolkarina akserayi* Sirel, *Idalina sinjarica, Miscellanea primitiva, Miscellanea globularis* Rahaghi, *Sistanites iranica* Rahaghi, *Globoflarina sphaeroidea* (Fleury), *Hottingerina anatolica* n. sp. (Sirel, in press), *Periloculinasp., Delhedia?sp.* and Miliolidae.

Manuscript received September 30, 1994

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PLATES

PLATE-I

Lattitteina erki (Sirel)

(Early Thanetian, all figs. X 35)

Fig. 1- Axial section, Yarışlı village, southwest of Burdur, B. III/2/3/1.

Fig. 2- Axial section, Yarışlı village, southwest of Burdur, B. 111/2/2/1.

Fig. 3- Axial section, Yarışlı village, southwest of Burdur, B. 111/6/1/2.

Fig. 4- Axial section, Gölköy town, south of Ordu, G. 10/A/4/3.

Fig. 5- Subaxial section, Yarışlı village, southwest of Burdur. B. 111/1/1/3.

Fig. 6- Axial section, Gölköy town, south of Ordu, G. 10/A/2/3.

Fig. 7- Axial section, Gölköy town, south of Ordu, G. 10/5/1.

Fig. 8- Oblique equatorial section, Yarışlı village, southwest of Burdur, B. 111/2/2/1.

Fig. 9- Equatorial section of young specimen, Yarışlı village, southwest of Burdur, B.III/2/3/2.

Fig. 10- Axial section of young specimen, Gölköy town, south of Ordu, G. 10/A/3/3.

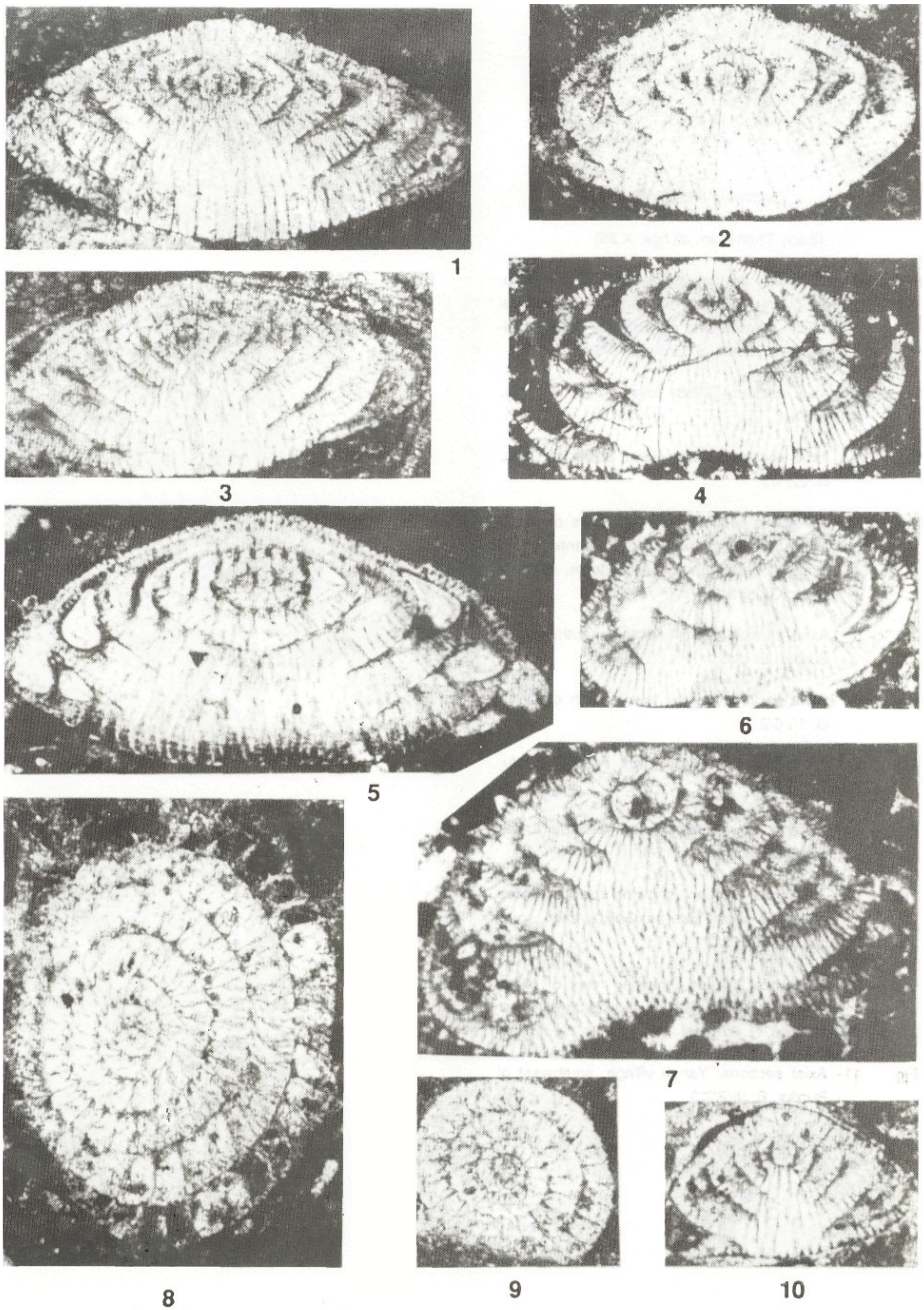
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PLATE -II

Laffirteina erki (Sirel)

(Early Thanetian, all figs. X 35)

Fig. 1- Horizontal section, almost parallel to equatorial plane, showing ramifying interseptal canals in ultimate and penultimate whorls, Gölköy town, south of Ordu, G. 9/8/1.

Fig. 2- Axial section, Gölköy town, south of Ordu, G.7b/1.

Fig. 3- Axial section, Gölköy town, south of Ordu, G. 22/1/2.

Fig. 4- Horizontal section, note two rows of pores along the septal sutures in the center of the shell (at upper part), Gölköy town, south of Ordu, G. 23/2/1.

Fig. 5- Axial section, Yarışlı village, southwest of Burdur. B. III/E/1/1.

Fig. 6- Axial section, Gölköy town, south of Ordu,. G. 10/6/2.

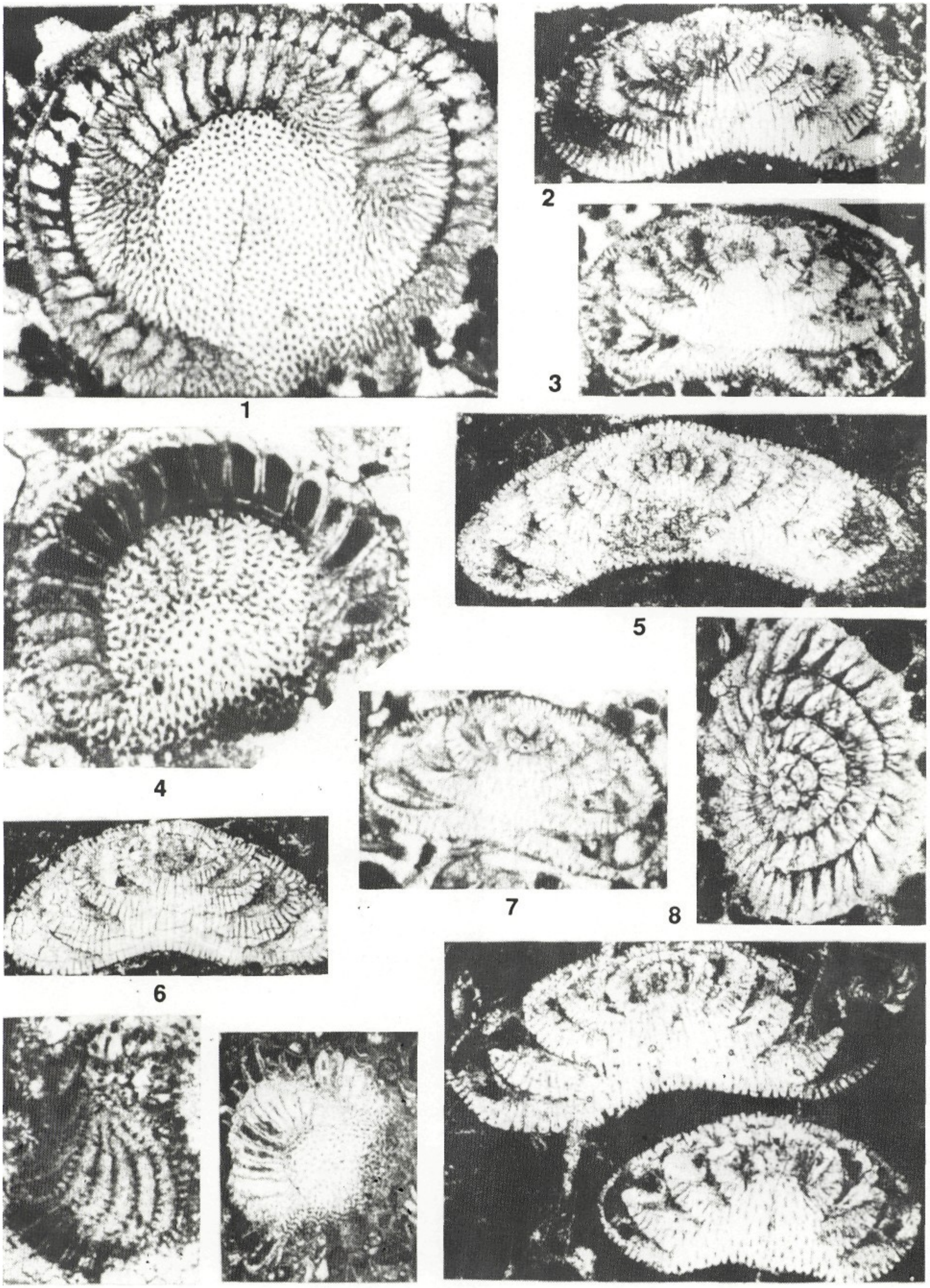
Fig. 7- Axial section, Gölköy town, south of Ordu, G. 10/C/1.

Fig. 8- Oblique equatorial section, Gölköy town, south of Ordu, G. 17/1-4.

Fig. 9- Tangential section, showing rows-of pores. . along the septal sutures, Gölköy town, south of Ordu, G. 23/3/1.

Fig. 10- Tangential section, showing rows of pores along the septal sutures, Gölköy town, south of Ordu.G. 37/b/1/1.

Fig. 11- Axial sections, Yarışlı village, southwest of Burdur, B. III/2/2/3.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