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GEOLOGIC AND STRATIGRAPHIG INVESTIGATION OF THE DARENDE-BALABAN BASIN (MALATYA, ESE TURKEY)*

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ABSTRACT. — The northern and southern parts of the area under investigation are surrounded by the uplifts which are formed of the Jurassic - Lower Cretaceous and Upper Cretaceous formations, and the younger sediments are deposited in the depression between these two uplifts. Due to the confinement of the area by uplifts in the northern and southern parts, as well as the presence of peripheric faults, the area shows the characteristics of a basin. Because Darende and Balaban towns arc situated within the basin in question, this basin is named as the «Darende - Balaban Basin» by the author.

The stratigraphic sequence consists of Mesozoic and Cenozoic strata. Igneous rocks include ophiolites and pre-Lutetian and post-Lower Miocene (Burdigalian) volcanics.

The Geniz Limestone, which is the oldest formation (Upper Jurassic - Lower Cretaceous) in the area under investigation, shows the characteristics of a comprehensive series. It is not possible to draw a boundary line between the Jurassic and Lower Cretaceous formations. It is, therefore, concluded that these limestones were deposited in a durable and shallow sea during Jurassic and Lower Cretaceous periods.

The Upper Cretaceous reefs (Maestrichtian), named the «Tohma Reefs», are transgrcssive-type reefs that have organic or biohermal characteristics. The variegated-colored sediments, that were described as Upper Cretaceous flysch, are now named the «Ulupınar Formation» by the author, and it is clearly understood that these sediments are not flysch, taking into consideration the typical conditions for flysch deposition. These appear to be coarse detritic elastics which are deposited in a shallow and active environment.

The Eocene is represented by marine facies of Lutetian age and by gypsiferous formations. The gypsiferous formations have been proved to be Upper Eocene (Bartonian). Only limestone and gypsum were found in the gypsiferous formation occurring in the basin, and the typical limestone-gypsum-salt sequence which is common in normal evaporite basins was not formed. In the sandstone and siltstone beds of the formation, some sedimentary structures, such as load casts and flute casts, are common and an average flow striking N 55°W and trending NW-SE was observed. These formations show that the Lutetian sea turned into an inland sea gradually, and that they belong to «molasse» facies which were deposited when the turbidity flows were effective.

The Lower Miocene formations (Burdigalian) consist of marine and Plio-Quaternary continental sediments. Stream terrace deposits, travertines and young alluvium are Quaternary in age.

The area under investigation belongs to the Taurid tectonic unit and is located at the northern border margin of the virgation which is striking in the northeast direction of this unit. The region is affected by the Vorgosau (Austric), Laramian, Pyrenean and Old Styrian phases of the Alpine movement.

As a result of plotting the measured dips and strikes of the formations on the Schmidt diagram, certain deviations between the strike of the fold axis of the Upper Jurassic - Lower Cretaceous, Upper Cretaceous and Eocene (Lutetian) formations are observed. Conformity between the Lutetian and Upper Eocene formations (Bartonian) is also observed.

Although no major dislocations are present in the area, typical examples of strike-slip faults were observed.

INTRODUCTION

This study covers areas contained in the Malatya K39-d_4 and L39-a_1 sheets on 1:25,000 scale. The investigation which deals with the geologic structure and stratigraphic sequence of the studied area, has been done as a doctorate thesis under the supervision of Prof. Dr. Fuat Baykal, at the Geology Department of Faculty of Science of the University of Istanbul. Lithostratigraphic units are studied in a parallel way with time units and the rock units are named for the first time according to the stratigraphic nomenclature.

I express my deepest gratitude and thanks to Prof. Dr. Fuat Baykal, who supervised me in this scientific work. I also thank Prof. Dr. Mehmet Akartuna for his kind interest in my work.

I am grateful to Assoc. Prof. Dr. Sadrettin Alpan, General Director of the M.T.A. Institute, for assisting and facilitating the present work. Thanks are due to Dr. Cahit Erentöz, and Dr. Fikret Kurtman for contributing many stimulating ideas and encouragement.

Thanks are also due to my colleagues in the M.T.A. Institute for making paleontological and petrographical determinations, and to Dr. L. Dubertret for the identification of Cardium fossils at the Centre National de Recherches Scientifiques, Institut de Paleontologie. Friends' suggested improvements and valuable comments on the work are gratefully acknowledged.

I am deeply indebted to my wife, Bihter Akkuş, for her assistance and support.

Note: The geologic map is prepared in grid squares which are numbered in order to facilitate finding the locality names given in the text. Example: Darende (4A).

I. GEOGRAPHY AND MORPHOLOGY

The area under investigation is located within the boundaries of Darende (4A) and Balaban (7C) towns, Malatya province, ESE Turkey (Fig. 1). Darende, which is located just west of the north half of the region, is the main center of settlement. It is located 110 km and 35 km from Malatya and Gürün (Sivas), respectively. Balaban, 15 km south of Darende, is the second largest center.

The area is limited by two uplifts which are formed of the Upper Jurassic - Lower Cretaceous and Upper Cretaceous formations on the north and south. A gentle relief, caused by the subsidence of the monoclinal structure toward the center from the uplifts at the north and south, is observed. The area appears to be a basin, due to this characteristic. It also has the geological features of a typical basin.

The following morphological features are observed in the area:

1. High mountains which are formed by the Upper Jurassic - Lower Cretaceous, Upper Cretaceous and Eocene formations as well as by basalts and ophiolitic rocks, on the north and south parts of the area.

2. Slightly disturbed hills and plains formed by the Plio-Quaternary conglomerates and Upper Eocene gypsiferous series, showing a gentle relief and a monoclinal structure formed as a result of the settling down from north and south toward the center.

3. Plains, along the Tohma and Ayvalı Tohması Çayı, consisting of recent alluvium at the center of the area.

As will be seen on the oro-hydrographic map (Fig. 2), the gypsiferous series are cut by numerous major and minor streams as a result of their low resistance to erosion.

Tohma Çayı and Ayvalı Tohması Çayı, at the northern half of the region, constitute the river system of the area under investigation. These rivers flow following a meander course, they join at Suçatı locality (5D), southeast of the northern hall, and continue flowing in the southeastern direction as Tohma River, one of the tributaries of Fırat River. All the valleys observed in the area are perpen-

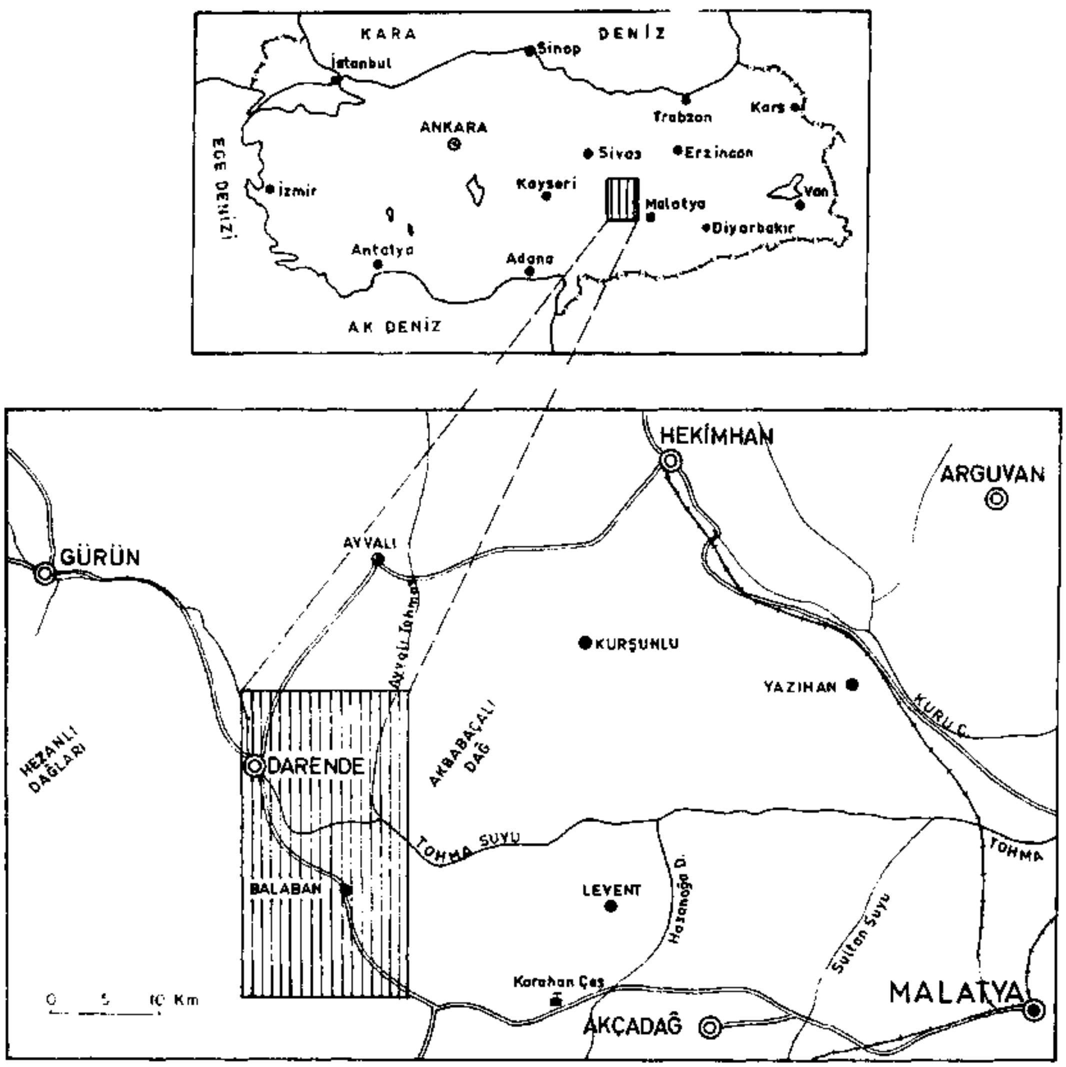

Fig. 1 - Geographic location map of the investigated area.

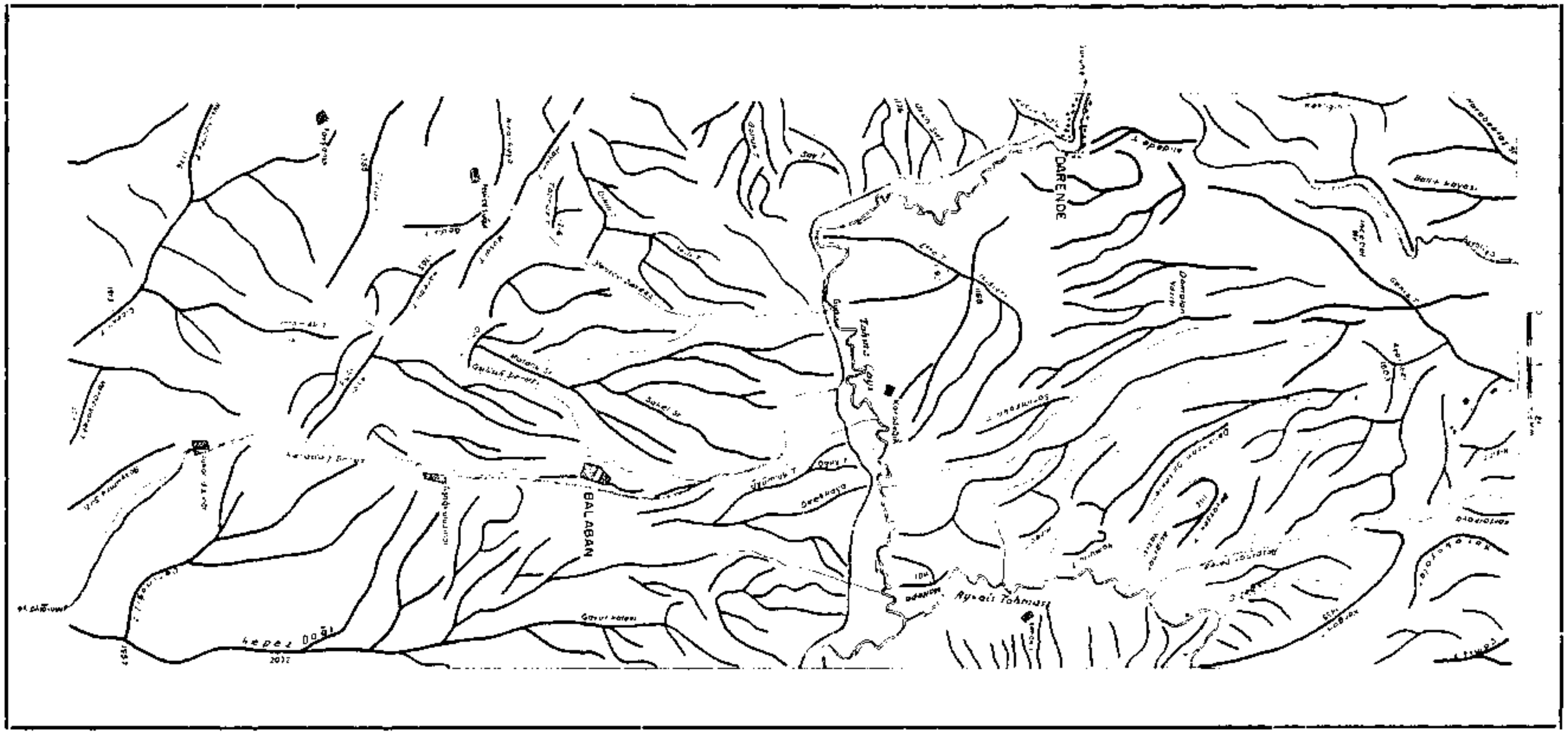

Fig. 2 - The oro-hydrographic map of the Darende - Balaban Basin.

dicular or oblique to the rivers in question. In general, «dendritic drainage» appears to be dominant in the area.

Due to the continental climate of the region, summers are warm and arid, and winters are cold and snowy. Only the springs and autumns are rainy.

No important seasonal changes in the yields of the Tohma and Ayvalı Tohması rivers are observed. These rivers are not fully exploited although their yields are high.

The Ankara - Malatya highway crosses the region. In addition to this highway, the Darende - Ayvalı road passing through the northwest corner of the area and some cart tracks make the transportation easy.

II. PREVIOUS INVESTIGATIONS

Preliminary studies for the geologic mapping of the area started with the 1 : 100,000-scale geologic mapping program carried out systematically by the M.T.A. Institute since 1936. Among these studies is the report «Geological Structure of the Taurids, between Malatya and Kayseri Provinces» (F. Baykal, 12; 13), covering the area in question.

In his work, Prof. Dr. Baykal pointed out the general geological structure of the region, including the area covered in the present paper.

Since no fossil specimens were found in the gypsiferous series located at the center of the area, the age of these series was supposed to be the same as the gypsiferous series occurring in Central Anatolia. The series, however, was shown to be of Upper Eocene (Bartonian) age due to the presence of micro and macrofauna found during our investigations.

F. Baykal (14), indicates in his work that the green rock observed in the south part composes the core of an anticline and that these rocks are of Turonian age. Limestones of Jurassic - Lower Cretaceous age are cut by the ophiolitic series. Maestrichtian sediments overlie the ophiolitic series transgressively, and the stratigraphical position of these series conforms with Baykal's statement.

Other studies including the investigated area have been made by V. Stchepinsky (45, 46), D. Wirtz (50) and T. E. Gattinger (28). There are, however, some differences in respect to the lithological features, age and distribution of the formations, between the descriptions and views indicated by the writers referred above and the author of the present study.

F. Kurtman (35), in his work on the south half of the area, has described the Jurassic, variegated Upper Cretaceous flysch, reef limestone lenses, yellow-colored bedded limestones, Eocene sediments, gypsiferous series, Miocene formations occurring to the southeast and late basalt flows. Apart from the points on which we agree with F. Kurtman, we have distinguished the Eocene sediments in two lithostratigraphic units. We also proved the Upper Eocene (Bartonian) age for the gypsiferous series based on the fossil content; these series were previously determined to be Oligocene.

Works on the petroleum geology of the adjacent areas by T. Ayan (9), E. Demirtaşlı (23), T. Norman (41),. S. Ürgün (47), and C. Bulut (8) are also available. These geologists also indicate the extension of the formations occurring in our area.

III. STRATIGRAPHY

The stratigraphic succession in the investigated area consists of the Mesozoic and Cenozoic formations (Fig. 3). The oldest formation in the region is the limestones of Upper Jurassic - Lower Cretaceous age. These limestones only outcrop in the northern and southern parts of the area and form two major uplifts. Middle Eocene (Lutetian), Upper Eocene (Bartonian), and Plio - Quaternary formations were deposited in the depression situated between these two uplifts (Fig. 4). The bordering of the region by peripheral faults and of the northern and southern parts of the studied area by uplifts indicate basinal characteristics. Therefore, this area has been named by the author the «Darende - Balaban Basin».

Lithostratigraphic units are studied in a parallel way to the time units, and the formation names for the region are proposed for the first time according to the stratigraphic nomenclature.

MESOZOIC

Mesozoic in the area is represented by: 1) Jurassic - Lower Cretaceous and 2) Upper Cretaceous Formations.

I. JURASSIC - LOWER CRETACEOUS

GENİZ LIMESTONE (J_G)

These limestones are the oldest formation in the area. They are exposed at northern and southern parts of the area and form the two major uplifts. Younger formations are deposited in the basin located between the uplifts.

This formation is composed of limestones. It outcrops around Geniz Tepe (1B) in the north, and Oturak Tepe (9A), Armutlu village (11A), and Gavur Kalesi (8D) in the southern part of the area. These limestones are called Geniz Limestone because of the geographical locality where the outcrops are best seen. In the previous studies the limestones at Geniz Tepe and in its vicinity were considered as Nummulitic limestones.

The Geniz Limestone is light gray or white in color. It usually has a cryptocrystalline or microcrystalline texture. The structure is fractured and these fractures are filled with calcite. The upper horizons have pseudoolitic characteristics. Although these limestones appear to be massive, bedding is also observed in places. Bedding is very scarce at Geniz Tepe and in its vicinity, but in the outcrops of the southern part of the area unimportant bedding can be observed in the lower horizons. It appears to have a massive limestone characteristics because the bedding cannot be seen in the upper levels, which are eroded. According to our observations, bedding is well-developed in the lower levels of the formation occurring in the adjacent areas (north of Hasanağa Dere, crossing the Malatya road on

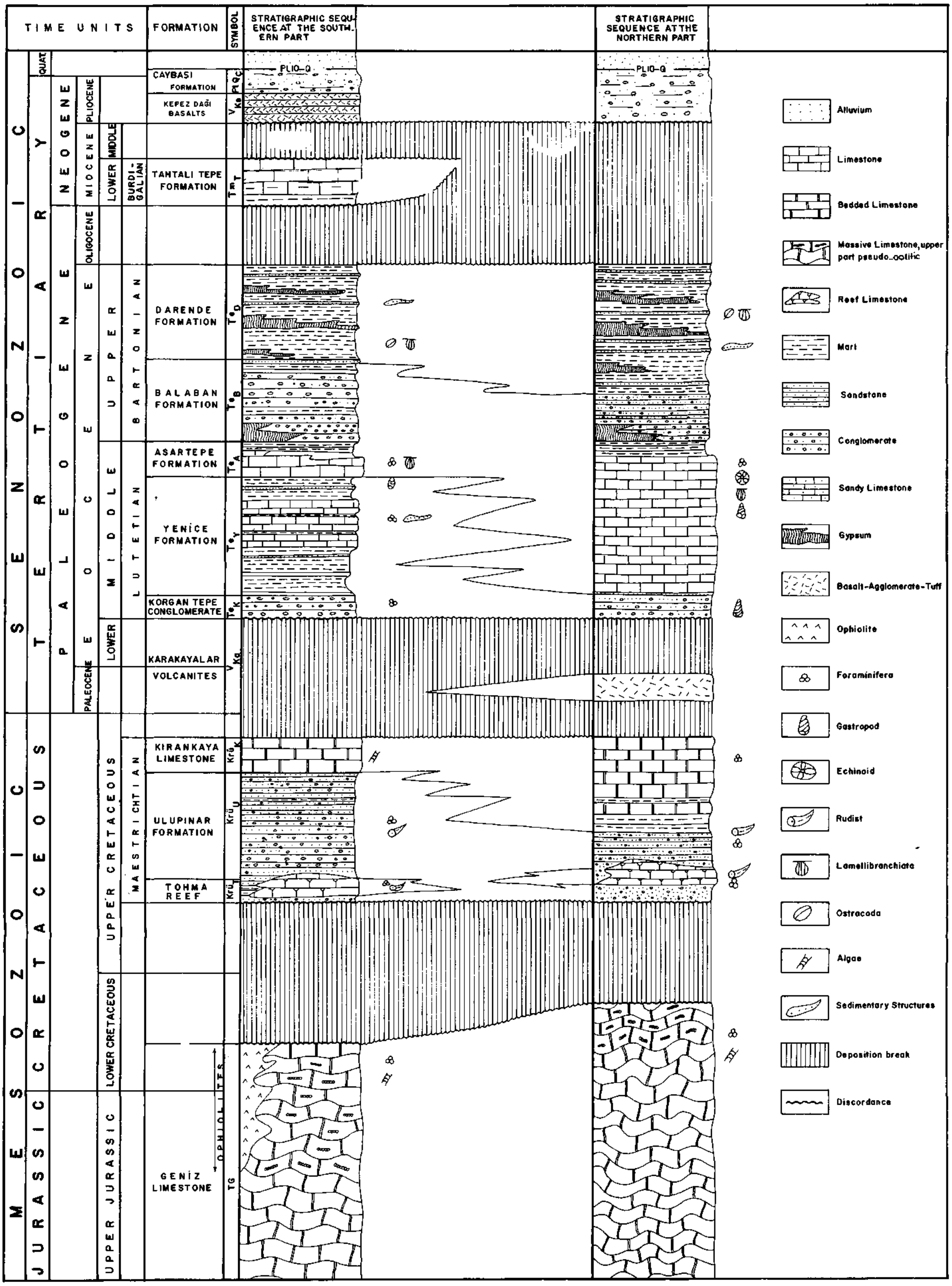

Fig. 3 - Stratigraphic sequences at the southern and northern parts of the investigated area and their correlation.

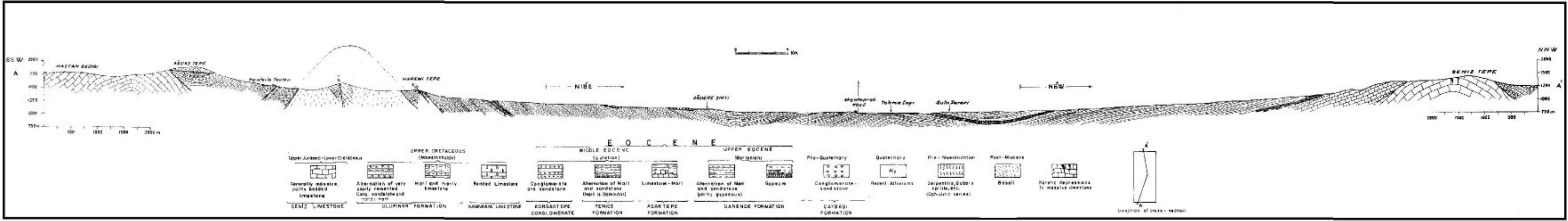

Fig. 4 - Geologic cross-section of the investigated area.

southeast; along Tohma Çayır; northwest of Yılanhüyük village north of Gürün; at Hezanlı Mountains south of Gürün; and south of Pınarbaşı). The layers are 25-50 cm thick. During the investigations carried out in 1962 for the M.T.A. Institute, we observed that limestone beds alternate with shale beds, 2-5 cm thick, north of Hasanağa Dere located just outside of the studied area. During the drilling carried out by the M.T A. Institute in the vicinity of the Darende-Gürün road, it was found that the same limestone beds alternate with thin shale bands and that chalk, chert and dolomitic layers, as well as an intraformational conglomeratic bed, are present.

The basal part of the formation cannot be seen in our area. Its minimum thickness is 500 m, as seen in an outcrop. The total thickness of the formation south of Pınarbaşı, where the formation overlies the Triassic (E. Demirtaşlı, 24), is 1175m. As to the drilling operations which were carried out by the Mineral Research and Exploration Institute in the west of the studied area, the drilling was advanced in the same limestone down to 1985 m, then stopped within it.

The Upper Cretaceous (Maestrichtian) coarse elastics overlie the Geniz Limestone in the area. It is not possible to see the base or the relation between the Geniz Limestone and the underlying formation.

The basal part of the Geniz Limestone, however, can be seen north of Yılanhüyük, situated north of Gürün; in the vicinity of Katarası village south of Pınarbaşı, and at Sürgü, on the Malatya-Maraş highway, which are outside of our area. The above observations were made during our previous studies of these regions.

On the northwest of Yılanhüyük, about 22 km north of Gürün, which is located 34 km west of the area, formations resembling the Geniz Limestone are underlain by Upper Permian limestones. During our investigations carried out in 1962, Upper Permian, dark gray to black to black-colored detritic limestones underlying the Upper Jurassic-Lower Cretaceous limestones, were observed (M. Akkuş, 5). The limestone formation in question contains the following fossil specimens which represent Upper Permian age: Paleotextulariidae, Cribrogenerina, Ozawainellidae, Reichelina, Staffella, Earlandiidae, Earlandia, Ammodiscidae, Hemigordiopsis. The relation between the Permian limestone and the Upper Jurassic-Lower Cretaceous limestones cannot be seen, due to the fact that the outcrops are relatively small, that the area is uplifted as a result of the faulting, and that the contact observed is not normal.

The basal part of the Upper Jurassic-Lower Cretaceous limestones can be easily followed down to the Silurian at Pınarbaşı-Sanz area. During the investigations carried out in this area, the Jurassic-Cretaceous limestones, as well as the succession of the underlying formations, are observed. Jurassic-Cretaceous limestones overlie the Triassic shales and marly limestones unconformably, as shown in Figure 5.

No macrpfauna is found in the Geniz Limestone. The following microfauna specimens, representing the Upper Jurassic - Lower Cretaceous age were encountered:[1] Tintinnina, *Pseudocyclammina* sp., *Trocholina* sp., *Valvulina* sp., Verneuilinidae, Lituolidae, Textularia, Radiolaria.

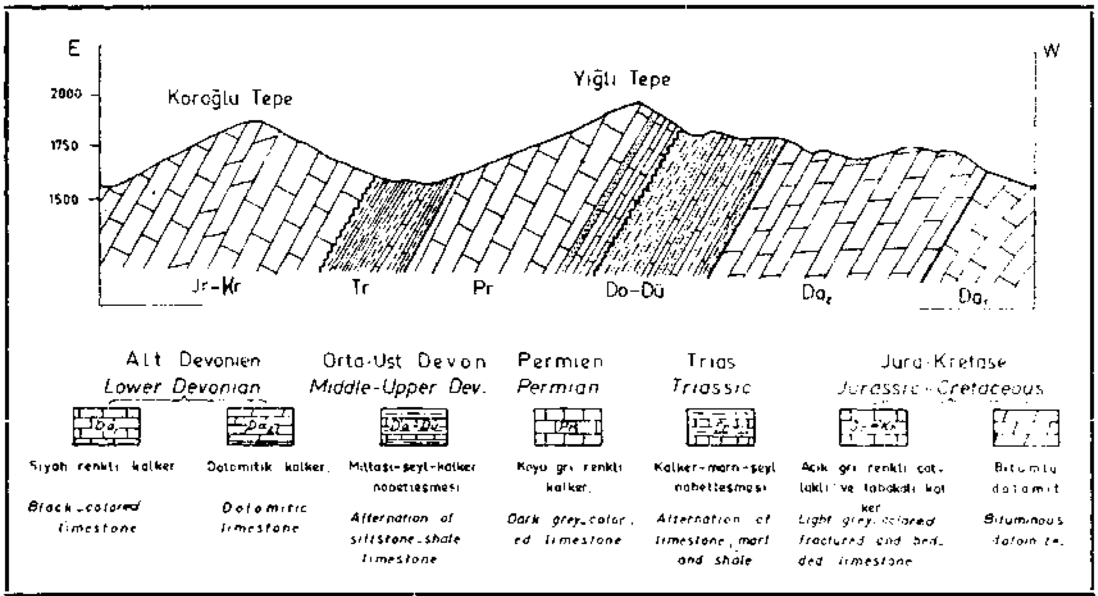

Fig. 5 - Cross-section between Katarası and Kan villages, approx. 70 km south of Pınarbaşı, showing Paleozoic formations and overlying Jurassic-Cretaceous limestones.

The transition zone between the Upper Jurassic and Lower Cretaceous cannot be distinguished. Based on the fossil content referred to above, the Upper Jurassic-Lower Cretaceous age is ascribed to the Geniz Limestone. Data is not available for the lower levels, since the basal part cannot be seen at the surface. However, from the drilling conducted by the M.T.A. Institute at Doğankayası, located on the Darende - Gürün road, close to the area of study, the following stratigraphic sequence was determined:

Time units	*Thickness (m)*	*Lithology*	*Fossils*
Maestrichtian	89	Reef limestone.	*Orbitoides media, O. apiculata, Siderolites calcitrapoides, Lepidorbitoides socialis.*
Cenomanian-Senonian	541	Brecciated limestone, marl interbedded with sandstone, partly chalky and cherty and dolomitized limestone.	*Globotruncana fornicata, Gl. stephani, Gl. lapparenti, Gl. apennінica, Cuneolina pavonia, Dicyclina* sp.
Aptian-Albian	230	Partly chalky and fractured limestone.	
Neocomian-Barremian	250	Partly dolomitized limestone.	*Hensonella cylindrica, Salpingoporella* sp. (Pl. XI, photo 22). *Actinoporella podolica.*
Dogger-Malm	550	Partly chalky and dolomitic limestone in the upper levels.	*Clypeina jurassica* (Pl. XI, photo 23), *Valvulinella jurassica, Bankia striata, Favreina salevensis.*
Lias	955	Partly chalky and fractured limestones, interbedded with marl, in the upper and lower levels.	*Macroporella pigmaea* (Pl. XI, photo 25), *Lituola* sp., *Cayeuxia* sp., Solenopora spicules.

Although Jurassic strata were not passed during the drilling, it is clearly understood that the Geniz Limestone, which is represented by Upper Jurassic-Lower Cretaceous formations, descends down to the Lias.

No unconformity is observed between the Lower Cretaceous, Middle - Upper Jurassic and Lower Jurassic (Lias) formations. Therefore, Geniz Limestone is a comprehensive series which has been depozited in a shallow and durable sea and continued from Lias to late Lower Cretaceous (Albian).

This conclusion is based on the following evidence:

1. The presence of the oolitic facies indicates that the sea was shallow.

2. The presence of chalky horizons, as well as thin bands of gypsum, and inter-formational conglomerate layers in limestone formation, occurring in the hole drilled close to the area under investigation, indicates a shallow sea environment.

3. The comprehensive limestone formation, produced as a result of the homogenous and monotonous sedimentation occurring during Lower Cretaceous and Lower Jurassic periods, indicates that a stable environment dominated and that the typical conditions for sedimentation did not change as the deposition took place.

Consequently, it is concluded that Geniz Limestone was deposited in a warm, shallow sea where no major tectonic movements took place. Furthermore, the presence of a limestone layer, 1985 m thick (determined at the drilling), indicates a continuous and slow subsidence.

Ophiolites cut the Geniz Limestone in the southwest part of the area. This can be easily seen at Karakaya Tepe (10B), Oturak Tepe (9A), and Kurtdeligi Tepe (PL I, photo 1J.

Geniz Limestone forms the morphologically highest mountains. Another characteristic is the presence of numerous «karstic» dolins. Evidence of erosion by winds and water is also observed.

DISTRIBUTION OF GENIZ LIMESTONE IN THE ADJACENT AREAS

Geniz Limestone covers large areas just outside the investigated area. Akbabagal Dagi, located east of the area, is formed by Geniz Limestone. Geniz Limestone is underlain by younger formations along the Tohma Çayı. Geniz Limestone outcrops at northern and southern ends of the Hasanaga Dere, one of the tributaries of Tohma Çayı.

Along the Malatya - Maras, highway, the Upper Jurassic - Lower Cretaceous limestones, which are corresponding to 'the Geniz Limestone, overlie the Permian, dark-colored limestones to the east and west of the highway and these limestones form the high hills observed in the region.

Hezanh Mountain and its vicinity, situated west of the studied area, and Sinekkonmaz and Ziyaret Tepe hills, south of Giirun, are composed of the same limestone beds. Geniz Limestone occupies large areas at Tahtalı Dağları, west of the above-mentioned mountains; it is als6 widespread in the area located between these mountains and Pınarbaşı. Likewise, the mountain range, trending E-W, in the vicinity of Yılanhüyük village, which iş situated north of Gürün, is composed of Geniz Limestone. Munzur Mountain range, SW of Erzincan, trending E-W, is composed of Jurassic-Cretaceous limestones equivalent to Geniz Limestone.

The Geniz Limestone, briefly described above, forms either the highest hills or can be observed at the bottom of the valleys.

We believe that the Geniz Limestone of this and the adjacent areas was deposited in a geosyncline existing during late Jurassic and early Cretaceous time.

2. UPPER CRETACEOUS

Upper Cretaceous formations are found around Karahan Çeşmesi (1A), which is in the northwestern part of the studied area, and between Yukarı Ulupınar (11C) and Yenice villages (8A) in the southern part of the area. These Upper Cretaceous formations are distinguished as the following lithostratigraphic units (from bottom to top) :

a) Tohma Reefs,

b) Ulupınar Formation,

c) Kırankaya Limestone.

The relations between the Upper Cretaceous formations, ophiolites which form the basement, and Eocene formations which cover all, these, are very well seen in the cross-section between Kara Tepe and Asar Tepe (Fig. 6).

A. TOHMA REEFS $(KrÜ)_r$)

These are found as lenses in the valley east of Karahan Çeşmesi, which is on the Ayvalı road, in the northern part of the examined area, and at the bottom of the coarse elastics that constitute Ulupınar Formation to the north of Kara Tepe (10C). As seen at the localities south and north of the examined area, they give a typical section along Tohma River, outside of our area. In relation to this place, in which typical reef examples are seen, the limestones are named as «Tohma Reefs». Their general schematic view is seen in Figure 7.

Tohma Reefs are transgressive type of reefs that have organic or biohermal characteristics. They are covered by partly deep-sea elastics and limestones. There is no regressional evidence, such as evaporites, etc. They are formed especially by deposition of Rudists, Brachiopods, Lamellibranchs and Foraminifers. Bedding has been poorly developed and ,is generally absent.

In our area, the thickness of the reefs varies between 5 and 10 meters and their lengths range from 5 to 500 meters. Without being continuous, they appear as small lens intervals (Pl. I, photo 2). Bioherms seen outside of our area, along Tohma River, are better developed. The thickness of these bioherms varies between 25 and 50 meters, the lengths range from 40 to 1,500 meters (Pl. I, photo 3).

The Tohma Reefs are usually found at the bottom of variegated, weakly cemented, coarse elastics. They are covered by coarse elastics and bedded limestones of the same age (Fig. 7).

The organic content of the Tohma Reefs is considerably rich. Whether in our area or in the vicinity, the exposures contain abundant amounts of the fol-

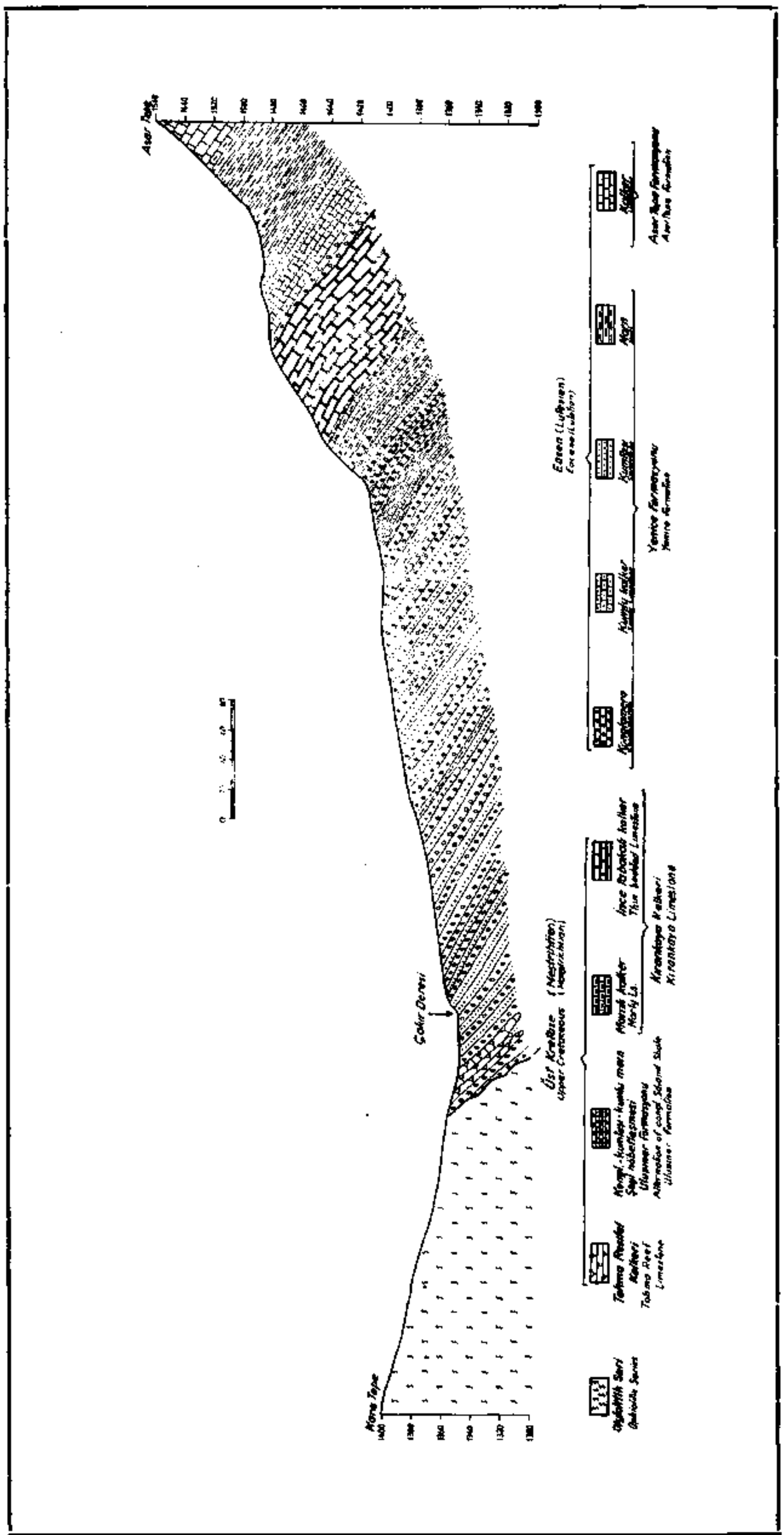

Fig. 6 - Geologic cross-section between Kara Tepe and Asar Tepe.

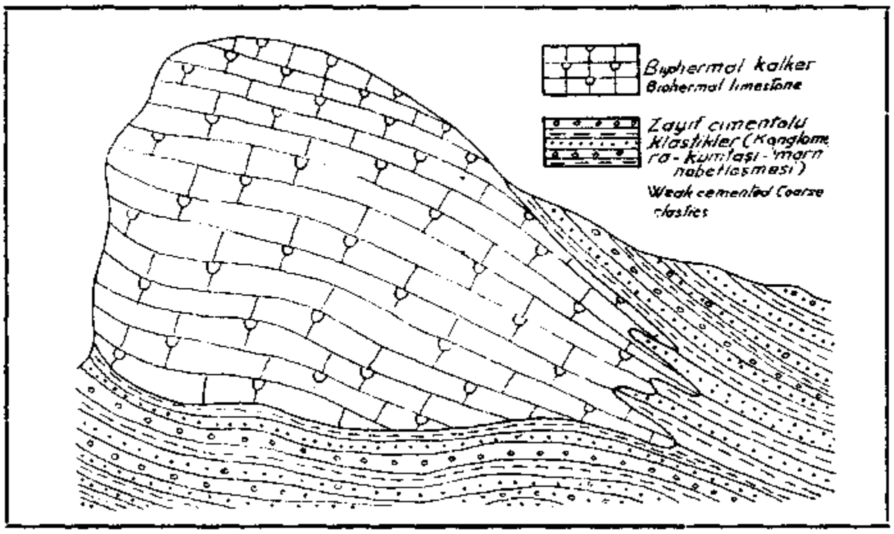

Fig. 7 - General schematic view of the Tohma Reefs in the coarse clastics along Tohma River.

lowing fossils:[2] *Hippurites (Vaccinites) ultimus* Milovanovic,, Cyclolites, Actaeonella, *Orbitoides apiculata* Schlum., *Orbitoides media* d'Arch., *Loftusia* sp.

According to the available fossil association, the reef limestones are Maestrichtian in age. These are shore-line reefs that had been developed in a warm sea.

Because the elastics overlying these reefs are weakly cemented and, thus, easily eroded, while the underlying limestones are more resistant, sharp-edged protuberances are formed, which constitute the characteristic topography of this area.

B. ULUPINAR FORMATION (KrÜU)

This formation outcrops between Yukarı Ulupınar (11C) and Yenice villages (8A), in the southern part of our area, and in the northern semi-area around Karahan Çeşmesi (1A), situated on the road to Ayvalı. It is named «Ulupınar Formation» because it is best observed in the neighborhood of the Ulupınar village, through which passes Malatya highway.

A typical section of the formation can be seen in the Çakır valley (10C) between Kara Tepe and Asar Tepe, NNW of Yukarı Ulupınar village (Fig. 8).

The Ulupınar Formation generally consists of coarse elastics in alternations of variegated conglomerate, sandstone, sandy marl and shale. The conglomerate and sandstone layers are so poorly cemented that they can be crumbled by hand. Conglomerates and sandstones contain grains of green rock and massive limestone. The variegated color of the formation also results from grains of green rock. The formation can be easily recognized in the field by its special color. The sandstones are medium (0.50-0.25 mm) and coarse (1.00-0.50 mm) grained. The grain size and thickness of the layers decrease gradually from bottom to top. The sorting and roundness of the grains have been fairly well developed. Lateral facies change is seen between Karahan Çeşmesi (1A) and north of Geniz Tepe (1B) in the northern part of the area (Fig. 9).

This formation was considered as «flysch» deposition in previous studies, but taking into account the special conditions of flysch deposition we consider it as detrital coarse elastics which were deposited in a shallow and active water.

In the type section, the thickness of the formation is 285 meters. This value decreases or increases in various places.

The formation rests transgressively upon the ophiolitic series in the southern part(Fig. 6), but it rests transgressively upon the Jurassic - Lower Cretaceous formation (Geniz Limestone) in the northern part of the investigated area (Figs. 9, 10). The upper part of this formation gradually and concordantly passes into the Kırankaya Limestone of the same age. Hence, the bottom of the formation is discordantly bordered with ophiolites and Geniz Limestone, while its top is bordered concordantly with Kırankaya Limestone.

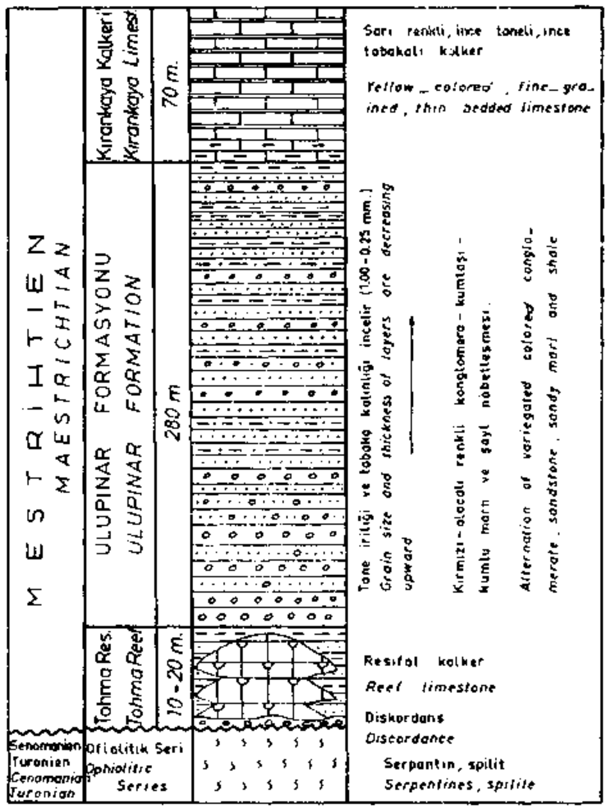

Fig. 8 - Typical section of Upper Cretaceous formations between Asar Tepe and Kara Tepe.

The fossil content of Ulupınar Formation is quite rich; it comprises microorganisms determined by E. Öztümer: *Globotruncana stuarti* de Lapp., *Globotruncana rosetta* Carsey, *Globotruncana area* Gushman, *Gaudryina* sp., *Clavulinoides trilatera* Gushman, *Marsonella oxycona* Reuss, *Robulus munsteri* Roemer, *Allomorphina* sp., *Cibicides* sp., Ostracods, determined by N. Solak: *Cytherella* sp., *Cythereis* sp.; and macroorganisms, determined by N. Karacabey: *Gryphaea (Pycnodonta) vesicularis* Lam., *Hippur it es (Vaccinites), Nerita* sp., *Actaeonella* sp.

According to the above fossil content Ulupınar Formation is Maestrichtian in age.

C. KIRANKAYA LIMESTONE ($KrÜ_K$)

Coarse elastics that form the Ulupınar Formation pass vertically and gradually into a limestone facies (Figs. 6, 8, 9,). The Upper Cretaceous deposits also terminate with these limestones. The formation received its name from the hill which is formed by this limestone, outcropping just to the north of the Yenice Şuğul village (8A), southwest of our area.

The Kırankaya Limestone extends as a belt with short intervals over the Ulupınar Formation between Yukarı Ulupınar and Yenice villages. It also forms the Keloğlanyurdu (1A) and Kırmızı hills, and covers large areas northwest of

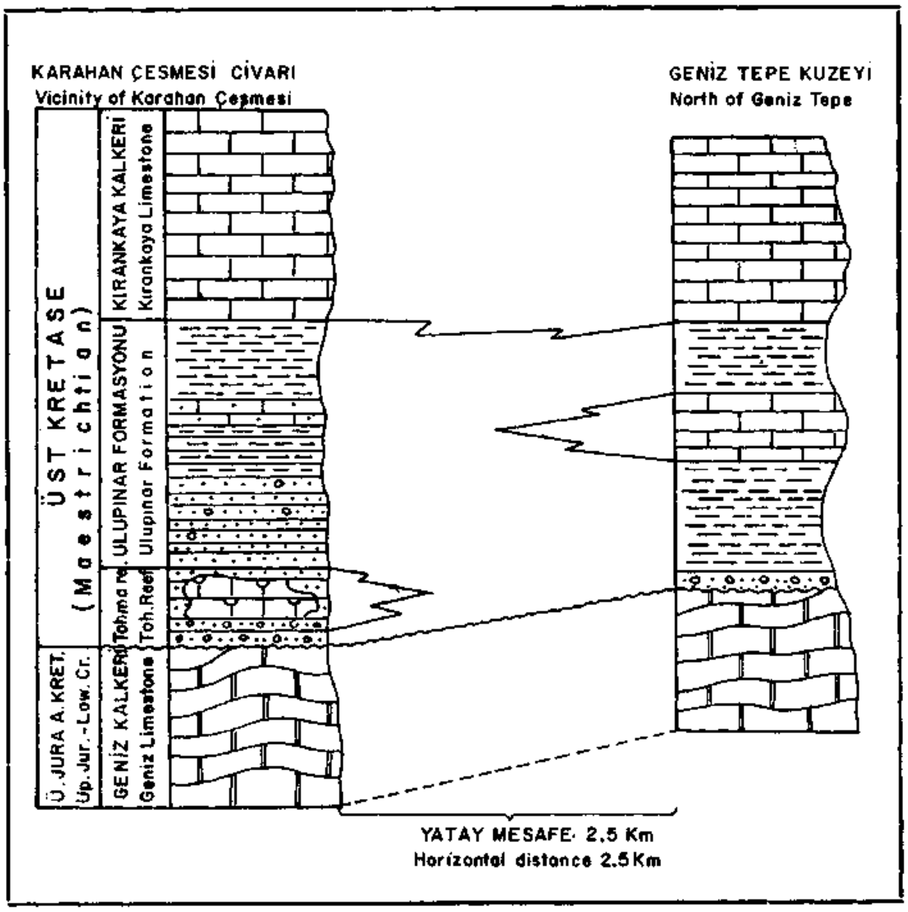

Fig. 9 - Facies changes of the Upper Cretaceous formations in the northern part of the investigated area.

our area and outside of the studied area. It generally consists of thin (5-10 cm) and moderately thick (10-30 m) limestone beds. They are light yellow or dirty white in color. At the bottom the formation begins with marly limestones and subsequently passes to hard and very fine-grained limestones. The upper horizons show porous, lacustrine limestone characteristics. These characteristics are very well seen in outcrops in the southern part. In the type section, the thickness of the formation is 70 m, but this thickness changes in places; to the northwest it reaches 250 meters.

The base of Kırankaya Limestone is limited concordantly by the Ulupınar Formation and its top is limited discordantly by Eocene (Lutetian) formation (PL II, photo 4).

Whether in the investigated area or in its surroundings, the organic content of the limestones that match with the Kırankaya Limestone is very poor. In the outcrops in the southern semi-area, only algal fragments can be seen. To the north, the exposures contain some microorganisms, such as *Orbitoides media* d'Arch., *Globigerina* sp., *Textularia* sp., which represent Maestrichtian age. Sometimes it is very difficult to distinguish these limestones from the Jurassic - Lower Cretaceous Geniz Limestone. Morphologically they always create high mountains and hills.

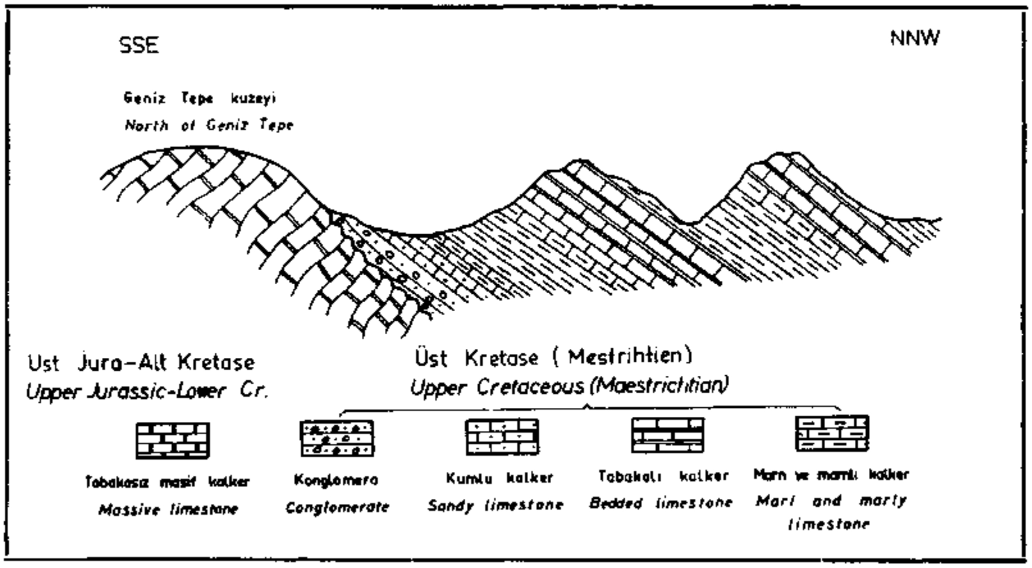

Fig. 10 - Schematic cross-section showing relation between Upper Jurassic - Lower Cretaceous and Upper Cretaceous formations north of Geniz Tepe.

If we summarize, the Upper Cretaceous formations of Tohma Reefs, Ulupınar Formation and Kırankaya Limestone were deposited in Maestrichtian sea. Reefs and coarse elastics (Ulupınar Formation) are deposited in shallow and warm water, and the Kırankaya Limestone developed in deeper water of this sea.

The Upper Cretaceous deposits and the Geniz Limestone (Jurassic - Lower Cretaceous), north of the studied area, were both considered in previous studies as Nummulitic. They are distinguished and proved as Upper Cretaceous and Jurassic - Cretaceous by our investigation.

EXTENSION OF THE UPPER CRETACEOUS FORMATIONS IN THE ADJACENT AREAS

The Upper Cretaceous formations, represented by the Maestrichtian strata in the studied area, are common in the adjacent areas. The Ulupınar Formation, which is composed of ultrabasic (ophiolitic) rock fragments, and alternating loosely cemented conglomerates, sandstones (sand), marls and sandy marls, outcrops with similar characteristics at Hacılar Deresi, northwest of Darende (E. Demirtaşlı & T. Ayan, 23); in the vicinity of Kalolar village, situated along Tohma Çayı; and in the Ayvalı - Hekimhan district (E. İzdar, 29). Biohermal reefs are present in the formation, in the vicinity of Tohma Çayı, as is the case in the area under investigation. Reefs and elastics contain the following macrofossils: *Hippurites (Orbignya) colliciata* Woodward, *Actaeonella* aff. *gigantea* d'Orbigny, Natica, Pecten, and Cyclolites (T. Ayan & C. Bulut, 8).

Similar clastic rocks and reefs (at the Dogankayası locality) occurring in the vicinity of Hacılar village, northwest of Darende, contain abundant Orbitoids.

Clastic rocks and reef limestones occurring near Hekimhan - Ayvalı district contain the following fossils determine'd to be of Maestrichtian age: *Hippurites colliciatus* Woodward, *Hippurites vesiculosus* Wbod., *Inoceramus regularis* d'Orb., *Cyclolites ternuiradiata* de Fom., Orbitoids.

Echinoids of Maestrichtian age, listed below, were found in a sequence of alternating sandy limestone, marl, marly limestone, conglomerate and sandstone at the same stratigraphical level between Kızılören and Davulhüyük villages, north of Gürün: *Hemiaster* aff. *amygdala* d'Orb., *Hemiaster* aff. *sexangulatus* d'Orb., *Micraster* sp., *Echinocorys* sp., *Ovulaster* aff. *obtusus* Cottreau & Blayac, *Ovulaster* aff. *auberti* Gautier, *Cottreaucorys (Homocaster) blayaci* (M. Akkuş, 5).

The sandy limestone and marly limestone layers of the same series contain the following microfauna: *Orbitoides media* d'Arch., *Siderolites calcitrapoides* Lam., *Lepidorbitoides* sp., *Globotruncana stuarti* de Lapp., *Gl. lapperenti tricarinata, Gumbelina globulosa, Globigerina* sp., *Robulus* sp., *Textularia* sp.

This series outcrops in the vicinity of Alkayaoğlu, southwest of Hezanlı Dağı and at Güldede village and south of Ulu Dirsek Dağı southwest of Gürün. No Echinoids are observed in the outcrops occurring to the south.

Overlying the elastics is the Kırankaya Limestone, which is equivalent to limestone facies and can be traced to a lesser degree. They outcrop in the vicinity of Hacılar village (Darende), along the Ayvalı road, to the north and in the Kızılburun - Karakuyu area, just southwest of Gürün.

Although Upper Cretaceous sediments are represented by the Maestrichtian formations in the area under investigation, a limestone facies formed during Senomanian through Santonian is present in the vicinity of Gürün (M. Akkuş, 5). These limestones are usually light gray to tan-colored and have cryptocrystalline texture; they show the characteristics of a comprehensive series. Although usually massive, well-developed bedding is observed in places. These limestones contain the following microfauna which, characterize Senomanian-Santonian age: *Cuneolina pavonia* d'Orb., *Dicyclina* sp., *Coskinolina* sp., *Dukhania* sp., *Spiroloculina* sp., *Nummuloculina* sp., Quinqueloculina, Valvulina, Textularia, Miliolidae, Ophthalmidiidae.

It is very hard to distinguish these limestones -which can only be classified based upon their fossil content- from the Jurassic - Cretaceous limestones. It is not possible to separate Jurassic - Lower Cretaceous, Senomanian - Turonian, Turonian - Santonian formations from each other. Consequently, comprehensive limestone formations occurring in this area are the product of a sedimentation process which took place from Lower Jurassic to Santonian.

The Upper Cretaceous formations, represented by the Maestrichtian (probably Campanian) in the investigated area, are common in the adjacent areas; they descend to the Senomanian, which is represented by the limestone facies.

CENOZOIC

Cenozoic sediments occurring in the area are composed of: 1) Tertiary and 2) Quaternary formations.

1. TERTIARY

Tertiary sediments are represented by: 1) Eocene and 2) Miocene formations.

1) EOCENE

Eocene sediments observed in the area under investigation are represented by the Middle Eocene (Lutetian) and Upper Eocene (Bartonian) formations. These formations deposited in the subsidence basin, located between the uplifts formed by the Jurassic - Cretaceous and Upper Cretaceous formations at north and south, and around the uplifts. Since they have different lithological characteristics, they are divided into lithostratigraphical units. It is important to note that the Lutetian sediments occurring in the area under investigation were distinguished as limestone and flysch during previous studies also. The overlying gypsiferous formation was considered to be Oligo - Miocene or Oligocene. During our studies, the gypsiferous series, which was considered to be Oligo - Miocene or Oligocene, was determined to be Upper Eocene (Bartonian).

As will be stated later, sediments of the Lutetian sea were uplifted as a result of the Pyreneic phase of the Alpine orogenesis and the sea was gradually changed into an inland sea. In this inland sea —which is the remnant of the Lutetian sea and which existed also during Bartonian— was deposited a formation composed of gypsum and alternating conglomerate-sandstone and marl beds, with fine-grained layers accumulated in the central part. It is believed that the formation in question can be accepted as «molasse» facies, which was deposited in an inland sea and formed as a result of the gradual regression of the Lutetian sea in relation with the orogenesis.

Eocene formations occurring in the area under investigation are represented by the marine Lutetian sediments and Bartonian gypsiferous «molasse» facies deposited in an inland sea, remnant of the Lutetian sea. Sediments which are represented by the Lutetian and Bartonian formations are divided into the following lithostratigraphic units and described under the names given to them:

B. Bartonian	b. Darende Formation a. Balaban Formation
A. Lutetian	c. Asar Tepe Formation b. Yenice Formation a. Korgan Tepe Conglomerate

A. LUTETIAN

A. KORGAN TEPE CONGLOMERATE (${}^{Te}K$)

This conglomerate is observed at the base of the northwest-trending Korgan Tepe (2D), İncebel (2D), Sersi Tepe (1D), and Köseoğlu Çalı Tepe (1C) range formed by the Asar Tepe Formation in the northeast of the studied area. East of the Kantaruz Boğazı (3D), where the Ayvalı Tohması Çayı flows, this formation, trending northwest, can be traced at the. bottom of the above-mentioned hills. The conglomerate, forming the basal part of the Lutetian formations, is named after the locality where outcrops are best observed.

The Korgan Tepe Conglomerate is composed of dark green-greenish conglomerate, poorly cemented, fine-to medium-grained sandstone and sandy marl layers. The conglomerate also contains partly silicified limestone gravels as well as volcanics composed of underlying basalt, hyalobasalt, pyroxene basalt and tuff. The underlying volcanics constitute also the major part of the material formed by the sandstone and sandy marl layers. Consequently it is clearly understood that the sandstone and conglomerate beds were formed at the expense of the underlying volcanics. They are dark green-greenish in color. The thickness of the conglomerate and sandstone beds is 2-4 m, and 1-2 m, respectively. Coarse volcanic pebbles observed in places in the sands and conglomerate pebbles are well-rounded.

The maximum thickness of the formation is 100 meters.

The formation overlies the pre-Lutetian volcanics transgressively (Fig. 11).

There is an unconformity between the Lutetian strata and Karakayalar Volcanites which are seen in Figure 11. This unconformity can be observed distinctly 500 m east of Kantaruz Boğazı and at the bottom of the Sersi Tepe, located northeast of Kantaruz Boğazı (Pl. II, photo 5; PL III, photo 6).

The Asar Tepe Formation which gradually grades into sandy limestones with a conformity, forms the upper horizon of the Korgan Tepe Conglomerate (Fig. 11).

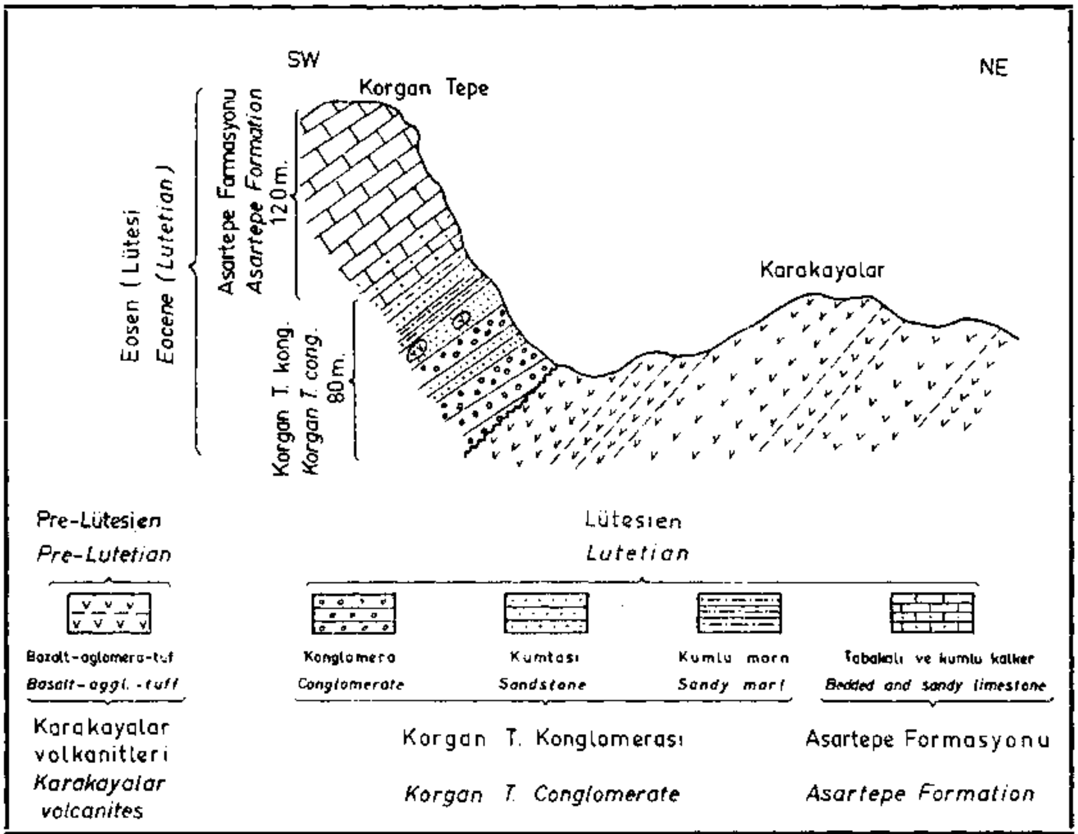

Fig. 11 - Schematic cross-section showing the relation between Lutetian formations and pre-Lutetian volcanites in the northeastern part of the investigated area.

The Korgan Tepe Conglomerate is found also at the base of Lutetian formations in the southern part of the investigated area. This formation can be very well observed at the bottom of Lutetian formations that extend from south of Asar Tepe towards northwest. This conglomerate generally contains pebbles of crystalline limestone, ophiolitic rocks.

At the southeast part of the area, limestone blocks, containing Hippurites in the Nummulitic conglomerates of the same age, overlie unconformably the variegated Upper Cretaceous elastics (Ulupınar Formation) occurring along the old Malatya road (along the Tohma valley).

The thickness of the formation is 100 meters at Korgan Tepe, which has given the type section, and in places its southern outcrops are between 4-10 meters.

The Korgan Tepe Conglomerate in this district overlies transgressively the Kırankaya Limestone and Ulupınar Formation. As a result, the unconformity between the Maestrichtian formations and the Korgan Tepe Conglomerate is easily observed. This relation is clear in the cross-section between Asar Tepe - Karatepe (Fig. 6); at Musu Tepe (8B) east of Yenice village, and south of Hüyük Tepe (8A), west of Yenice village (Fig. 13).

As will be seen in the Figure 13, Korgan Tepe Conglomerate does not follow the deposition order observed in the northern part of the area; instead, it gradually grades into Yenice Formation, which is composed of marls interstratified with sandstone, sandy limestone-marl and marls interstratified with sandstones. These beds are overlain by the Asar Tepe Formation.

The Korgan Tepe Conglomerate is not common in the southern part of the area, as is the case in the northern half. Conglomerates are not present at the southwest flank of the Southern uplift in this district and Lutetian formations begin with Yenice Formation.

Fossils are not abundant in the outcrops observed in the northern part of this formation. In the weakly cemented sandstone layers the inner moulds of Athleta and poorly preserved Lucina are found.

Microfossils are abundant in the outcrops in the southern part of this formation. Conglomerates occurring south of Asar Tepe (9C) contain the following microfauna, in grains and thin sections:[3] *Nummulites laevigatus* Brug, N. *atacicus* Leym, N. *uroniensis* A. A. Heim, Discocyclina, Pararotalia, N. cf. *irregularis* Desh., N. *lucasi* d'Arch., N. cf. *perforates* Den. de Mont., *Assilina exponens* Sow, A. cf. *douvillei* Abrard & Fabre.

According to the above fossil association, [the age of the Korgan Tepe Conglomerate is Lutetian.

The Korgan Tepe Conglomerate can be correlated with the Eocene basal conglomerates in the neighboring areas.

B. YENİCE FORMATION (Tey)

This formation surrounds an anticline, trending NW-SE, which is formed by Upper Jurassic - Lower Cretaceous Geniz Limestone and ophiolitic series, at the

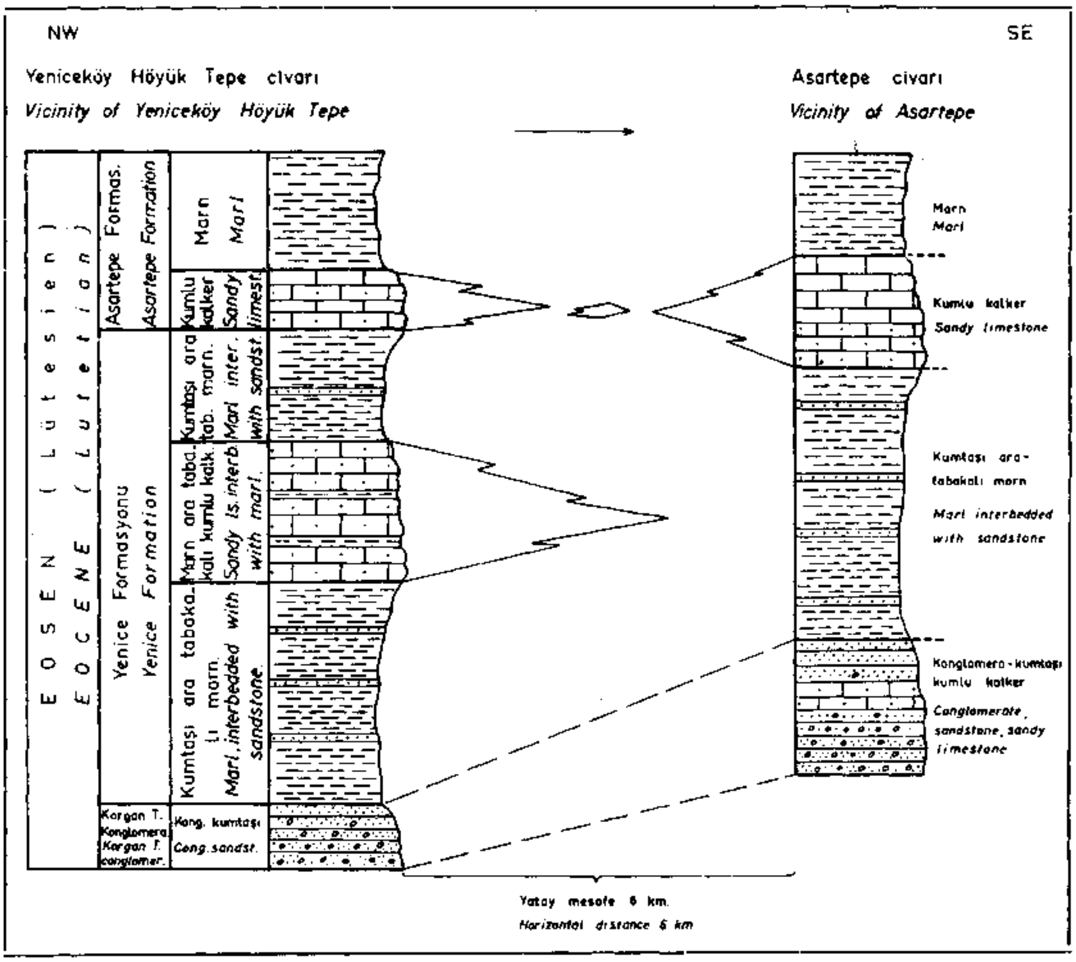

Fig. 12 - Facies changes of the Lutetian-aged Yenice and Asar Tepe Formations between Yeniceköy and Asar Tepe.

southwestern part of the area. It outcrops in the western limb and northern part of Kepez Mountain (10D). Basaltic flows, forming Kepez Mountain, cover the formation horizontally.

Typical section of the formation can be well seen in the vicinity of Yenice village, situated in a valley in the southwestern part of the area. The formation is named after this village where the outcrops are best seen.

The formation shows the following lithological succession at the typical section located at Hüyük and Musu Tepe, west and east of Yenice village, respectively:

250 m. . . . . .Marls interbedded with medium- fine-grained sandstone.
125 m. . . . . .Sandy limestones interbedded with thin marl strata.
125 m. . . . . .Marls interbedded with medium-coarse-grained sandstone.

Sandy limestone layers interbedded with thin marl layers of the Yenice Formation wedge out in the southeast direction, after forming Musu Tepe (just east of Yenice), and terminate in marl layers. This formation changes into gray-colored marls interbedded with sandstones, in the vicinity of Asar Tepe. The horizontal facies change of the formation in southeast direction can be easily observed (Fig. 12).

Outcrops found along the southwest limb of the uplift, west and north of Kepez Dağı (10D), and in the vicinity of Gavur Kalesi (8D) are composed of gray-colored marls interbedded with sandstones, as is the case in the vicinity of Asar Tepe (9C).

Sandstone and sandy limestone layers contain hornstone, hyalobasalt, andesite, quartz, hornblende and serpentine grains. The formation is light gray to tan-colored. The thickness of the sandstone interbeds observed in the marls is 5-10 cm. Sandy limestones interbedded with marls, and marls are in 10-30-cm and 5-10-cm-thick layers, respectively.

The thickness of the formation west of Yenice village and south of Asar Tepe is 500 m and 90 m, respectively, but it varies from place to place. Yenice Formation lies in SE-NW direction between the Asar Tepe and Yenice village area and overlies the Korgan Tepe Conglomerate conformably. Conglomerates gradually grade into Yenice Formation (Fig. 13).

Where the Korgan Tepe Conglomerate is missing, the Yenice Formation rests unconformably on the underlying Ulupınar Formation, Kırankaya Limestone,

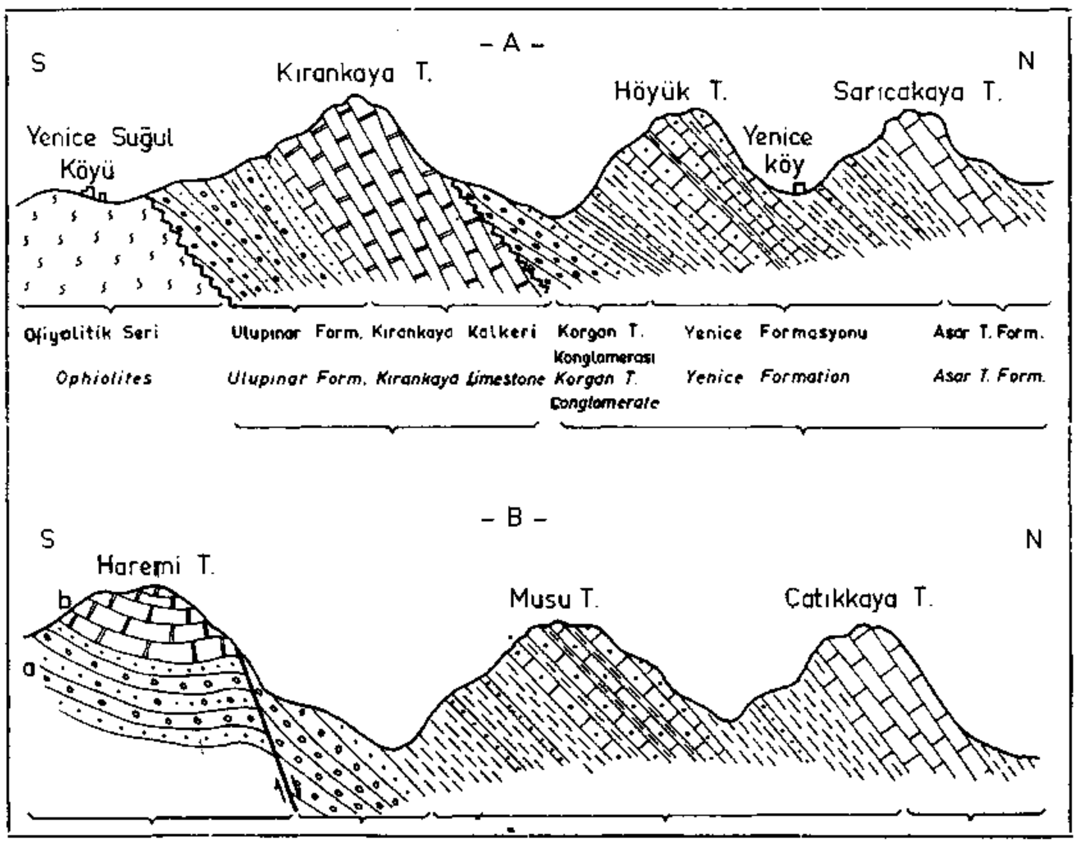

Fig. 13 - Schematic profiles of Höyük Tepe (A) on the west of Yeniceköy and Musu Tepe (B) on the east side of Yeniceköy.

ophiolitic series, and Geniz Limestone, as is observed at the southwestern flank of the uplift. Therefore, the lower level of the formation is limited by Korgan Tepe Conglomerate conformably; and by ophiolitic series, Geniz Limestone, Ulupınar Formation and Kırankaya Limestone unconformably.

The upper boundary of the formation is limited by Asar Tepe Formation, which grades conformably into sandy limestone and limestone (PL II, photo 4).

The Yenice Formation cannot be seen in the northern half of the area (See Fig. 3). The Yenice Formation which is composed of marls interbedded with sandstone, sandy limestones interbedded with marl, and marls interbedded with sandstone layers, grades into Asar Tepe Formation towards the north, as a result of lateral facies changes. The Asar Tepe Formation, represented by limestone and marl facies, replaces Yenice Formation in the northern part of the area.

Yenice Formation contains abundant microfossils.

The following are found in the sandy limestone layers of Höyük Tepe: *Nummulites* sp., *Operculina* sp., *Textularia* spp., *Asterigerina* sp., *Globorotaha* sp., *Acarinina* sp., Miliolidae, Lagenidae, Rotalidae.

Marl layers contain the following microfossils: *Hantkenina alabamensis* Gush., *Buliminella* cf. *longicamerata* Bandy, *Globorotalia crassata* Gush., *Globorotalia centralis* Gush & Bermudez, *Halkyardia ovata* Heron-Allen; *Uvigerina cocoaensis* Gush., *Bulimina jacksonensis* Gush. *Discorbis* spp., *Bulumina* spp., *Triiaxilina* spp., *TextularieUa* spp., *Nummulites* sp., *Marginulina* sp., *Pararotalia* sp., *Eponides* sp., *Anomalina* sp., *Nonion* sp., *Nodosaria* sp., *Stilostomella* sp., *Siphonodosaria* sp.[4]

According to the fossil content, the age of Yenice Formation is Lutetian.

This formation, which shows detritic character, was deposited in a shallow and active environment.

Yenice Formation can be correlated with the Eocene marls interbedded with sandstone layers, observed in Hasanağa Deresi, in the southeast and along the Darende-Gürün-Kayseri highway.

The formation forms valleys where marls, irresistant to erosion, are dominant; and again, it forms hills and ridges where sandy limestone layers interbedded with thin marl layers are observed.

C. ASAR TEPE FORMATION (Te_A)

This formation can be easily observed in the northern and southern parts of the area under investigation. It is more extensive in the northern half. This formation, which is represented by limestone-marl facies, can be clearly observed at Asar Tepe, between Aşağı Ulupınar (9C) and Yukarı Ulupınar (11C) villages. Therefore, the formation is named after the locality where the outcrops are best seen.

It outcrops in the following localities: west and northeast of Yukarı Ulupınar, situated in the south of the area; at Asar Tepe, and its NW-SE extension; at Topraklık (8A) and Sarıcakaya Tepe (8A) in the north of Yenice village; on the east slope and the north part of Gavur Kalesi (8D), east of Balaban (7G) and on the southwest limb of the uplift.

The extension of the same formation is also observed along the Darende-Ayvalı (1AB) road, in the northern part of the area. The formation covers large areas, just outside the area under investigation, at the western side of the road. East of the road, the formation trends northeast and surrounds the basin by forming Köseoğlu Çalı (1C), Sersi, İncebel and Korgan Tepe hills. Outcrops observed at Kantaruz Boğazı, Korgan, İncebel, Sersi and Köseoğlu Çalı Tepe hills, located in the northeast part of the area, were determined to be Upper Cretaceous during the previous investigations carried out by Stchepinsky (45), Wirtz (50) and Gattinger (28).

A typical section of the formation can be seen at Asar Tepe in the southern part of the area, and at Sersi and Korgan Tepe hills, north of the area.

The Asar Tepe Formation is composed of underlying limestone strata and overlying light gray to greenish-colored marl layers (PL III, Photo 7). The limestone is generally white to yellowish colored and has fine-crystalline compact texture. Bedding is well-developed and consists of 25 - 50-cm-thick layers. Upper horizons of the lower limestone layers grade into marly limestones and marls.

Measured thickness of the limestone strata is 120 meters at Korgan Tepe (Fig. 11), situated in the northeast part of the northern half; and 59 meters south of Karahan Çeşme (Fig. 14); the thickness of the layers increases towards the center of the area under investigation.

The thickness of the marl layers, resting on the limestones, varies between 20 and 40 meters, as can be seen along the Ayvalı road.

Although the thickness of the limestone strata at Asar Tepe in the south is 125 meters, its thickness decreases to 10 meters as a result of the lateral passage of the thin band trending northwest. The thickness of the overlying marl layers varies between 25 and 100 meters.

The Asar Tepe Formation forms the upper part of the Lutetian formations. The Korgan Tepe Conglomerate, at the base, cannot be observed everywhere or shows poor development. The Asar Tepe Formation, at the road bend, just before Karahan Çeşmesi on the Darende-Ayvalı road, crossing the northwestern part of the area, overlies the Ulupınar Formation unconformably. The Asar Tepe Formation starts with conglomeratic limestones at the bottom, grades into marly limestones and bedded limestone layers (Fig. 14).

It is very hard to distinguish the underlying Kırankaya Limestones (Maestrichtian) from the Asar Tepe Limestone, trending northwest at the Karahan Çeşmesi locality (1A). These two limestone strata, belonging to different ages, show only a slight color variance. Apart from this, the Asar Tepe Limestone can be distinguished based on the fossil content along the contact.

No conglomerates are found south of Geniz Tepe (IB) between the contact of Geniz Limestone and Asar Tepe Limestone. There exists no disconformity, since Geniz Limestone is massive and there is no bedding. The contact between Geniz Limestone and Asar Tepe Formation was drawn by recognizing the fossilifereous Asar Tepe Limestone from the nonfossilifereous Geniz Limestone. The limestone facies occurring in the northern half of the area was described as Nummulitic limestone in the previous studies.

The Asar Tepe Formation, which trends southeast at the south of Geniz Tepe, and forms the Köseoğlu Çalı, İncebel, Sersi and Korgan Tepe hills, continues to Kantaruz Boğazı, thus surrounding the area; it overlies the Korgan Tepe Conglomerate conformably. Korgan Tepe Conglomerate, overlying the pre-Lutetian volcanics transgressively, as indicated before, grades into Asar Tepe Formation (limestones) gradually (Fig. 11).

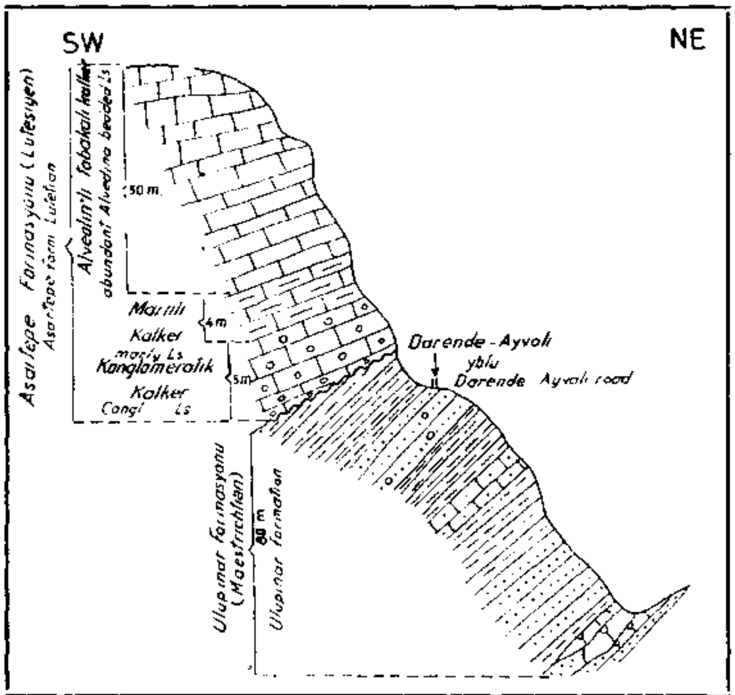

Fig. 14 - Schematic profile showing the relation between Ulupınar and Asartepe Formations around Karahan Çeşmesi on the Darende-Ayvalı road.

As will be understood from the above statements, this formation, rests upon the Maestrichtian and Jurassic-Cretaceous limestones with an unconformity at the northwestern part of the area. The Korgan Tepe Conglomerate, of the same age, grades into Asar Tepe Formation conformably in the northeastern part of the area.

The Asar Tepe Formation overlies the Yenice Formation concordantly in the south of our area. The underlying Yenice Formation grades into limestones of Asar Tepe Formation at Asar Tepe and at the southeast and northwest extensions of the same hill (see Figs. 12, 13; Pl. II, photo 4).

The Darende and Balaban Formations of Upper Eocene age (Bartonian) form the upper boundary of the formation in the northern and southern parts. It is believed that no disconformity exists between the bluish-gray-colored marls, resting on the formation and the overlying Bartonian strata.

The Asar Tepe Formation, which shows good development and covers large areas in the north, extends in the NW-SE direction by forming narrow belts or lenses, in the south of the area. The thickness of these bands or lenses varies between 10 and 80 meters. As will be seen on the geological map of the area, these limestone bands grade into marls as a result of the lateral facies changes (Fig. 12). Wedges formed by the Asar Tepe Formation in the marl layers can be clearly seen at Sarıcakaya Tepe (8A), situated north of Höyük Tepe, west of Yenice village (Pl. IV, photo 9). Asar Tepe Formation contains abundant micro- and macrofauna. These limestones can be named as Nummulitic, Alveolina, Chapmanina, Rotalia and Discocyclina-bearing limestones based on the fossil content (Pl. XII, photos 27, 28,29).

This formation, which occupies large areas at the northern part of the area, contains some microfauna which, in turn, characterizes Lower and Upper Lutetian from base upwards. The following microfauna of Lower Lutetian age arc found in the samples collected from the limestones occurring south of Geniz Tepe, northwest and in the vicinity of Kantaruz Boğazı, where Ayvalı Tohması Çayı flows: *Nummulites lucasi* d'Arch., *Nummulites* sp. (of the *N. irregularis* group), *Alveolina* cf. *oblonga* d'Orb., *Alveolina* sp., *Asterigerina* sp., *Orbitoides* sp., *Spirolina* sp., Valvulammina, Rotalia, Textularia, Quinqueloculina, Triloculina, Globigerina, Pyrgo.[5]

These limestones contain the following Lutetian fossils in the middle and upper horizons:[5] *Chapmanina gassinensis* Silv., *Chapmanina* sp., *Rhapydionina* sp., *Rotalia trochidiformis* Lam., *Acervulina* sp., *Peneroplis* sp.

The following fossils are found in the upper horizons, which characterize Upper Lutetian:[5] *Nummulites helveticus* Kauf., *Nummulites* sp. (of the *N. globulus* group), *Nummulites* sp., *Assilina* sp., *Discocyclina* sp., *Asterodiscus rotula* Kauf., *Operculina* sp.

In the Asar Tepe Formation overlying the Yenice Formation south of the area, the following fossil content of the Upper Lutetian age was found:[5] *Rotalia trochidiformis* Lam., *Eorupertia incrassata* Uhlig, *Asterigerina rotula* Kauf., *Fabiania* cf. *cassis* Oppen., *Nummulites* sp. *Rotalia* sp., *Lockharta* sp., *Discocyclina* sp., *Operculina* sp., Globigerina. Miliolidae.

The following fossils are found in the bluish-gray marls forming the upper level of the Asar Tepe Formation:[6] *Clavulinoides szaboi* Hantken, *Pararotalia armata* Terquem, *Cibicides cushmani* Nuttall, *Cibicides aleni* Plummer, *Globigerina triloculinoides* Plummer, *Robulus* cf. *limbosus* Reuss, *Marsonella* cf. *oxycona* Reuss, *Bolivina* aff. *cookei* Cushman, *Reussella terquemi* Cushman, *Gyroidina girardana* Reuss, *Pullenia* sp., *Spiroplectammina* spp., *Dorothia* sp.. *Bolivina* sp., *Dentalina* spp., *Nodosaria* spp., *Cibicides* spp., *Globigerina* sp.

The Asar Tepe Formation contains abundant macrofauna as well as abundant microfauna described above. At the lower levels of the limestone strata the following Lamellibranchia are present (Lower Lutetian):[7] *Lucina corbaricus* Leym., *Lucina immanis* Opp., Spondylus.

Bivalves such as *Campanile giganteum* Lam., Pleurotomaria, Ampullina, Ostrea; and

Echinoids such as[8] *Leiopneustes antiquus* (Agassiz) Cott., *Echinolampas* sp. are found in the upper levels of the limestone strata (Lutetian).

The age of the Asar Tepe Formation is determined to be Lower Lutetian-Upper Lutetian, based on the micro and macro-fauna content.

The underlying Korgan Tepe Limestone is well developed in the northeastern part of the area. To the northwest, conglomerates gradually disappear and as a result, the Asar Tepe Limestone overlies directly the older formations. In the southern part of the area, the Korgan Tepe Conglomerate can be observed in places, and then it gradually passes into Yenice Formation.

The Yenice Formation, which is composed of marls interbedoled with sandstone, sandy limestone interbedded with marls, and marl layers, east and west of Yenice, does not outcrop in the northern half of the area. The Asar Tepe Formation, which is better developed in the north, replaces this formation through lateral changes of facies. The Asar Tepe Limestone, which occupies large areas in the northern half, extends in the NW-SE direction forming discontinuous bands and lenses.

The Asar Tepe Limestone, which overlies the older formations in the north, contains Lower Lutetian fossils in the lower levels *(Nummulites lucasi, Nummulites irregularis, Lucina corbaricus);* Lutetian fossils in the middle levels *(Nummulites* sp., *Alveolina* sp., *Chapmanina gassiensis,* Orbitolites, etc.); and Upper Lutetian fossils in the upper levels *(Nummulites helveticus, Nummulites* sp., Assilina, etc.).

The Korgan Tepe Conglomerate, in the southern part of the area, contains Lower Lutetian fossils *(Nummulites atacicus, Nummulites irregularis);* the fossil content of the overlying Asar Tepe Formation is chiefly Upper Lutetian *(Fabiania* cf. *cassis* Opp., *Rotalia trochidiformis* Lam., *Eorupertia incrassata* Uhlig, *Discocyclina* sp., etc.).

As will be understood from the above-mentioned statements, Korgan Tepe Conglomerate, Yenice Formation and Asar Tepe Formation were deposited in a sea formed between Lower Lutetian and Upper Lutetian periods. The formations occurring in the northern half of the area, occupy larger areas and they show no discontinuity; those in the south show detrital characteristics and lateral changes of facies. Therefore, the deposition environment in the north is believed to be shallow and active, and that in the south is dominantly active and still shallow.

EXTENSION OF THE LUTETIAN FORMATIONS IN THE NEIGHBORINGAREAS

As is the case in the area under investigation, Lutetian formations are common in the neighboring areas. The Asar Tepe Formation in the northwestern part occurs between Hacılar village and Darende, and extends along the road as far as Gürün. The Tohma Çayı forms deep and steep valleys in the limestone strata of the Asar Tepe Formation. The same formation can also be seen in the northern and northeastern parts of Gürün. Lutetian formations, which can be observed along the Malatya-Kayseri highway, 15 km west of Gürün, occupy large areas north and south of the road. Just west of Osmandede ranch, located on the same road, Lutetian conglomerates can be seen overlying unconformably the chevron-folded Upper Cretaceous sandstone-shale beds. Lutetian formations outcrop around the Hezanlı Mountains, formed by the Jurassic-Cretaceous limestones, south of Gürün.

The Lutetian formations overlying the Jurassic-Cretaceous and Upper Cretaceous formations can be seen along the old Malatya highway (following the course of Tohma Çayı), southeast of the area under investigation. Limestone blocks containing Hippurites are present in the Nummulites-bearing Lutetian basal conglomerates overlying the variegated Upper Cretaceous (Maestrichtian) elastics.

The Lutetian limestones rest unconformably on the Jurassic-Cretaceous limestones in the valley, on the right-hand side of the Malatya highway, just after Karahan Çeşmesi locality (Pl. V, photo 11). These limestone beds, observed along the road in the direction of Malatya, dip beneath the Plio-Quaternary conglomerates of the Malatya plain, forming minor anticlines and synclines.

The Hasanağa Stream flows among Lutetian formations and follows Malatya highway in the NE-SW direction. At the northeastern and southwestern ends of the stream, Lutetian basal conglomerates overlie unconformably the Jurassic-Cretaceous limestones.

B. BARTON IAN

The age of the gypsiferous formations, deposited in the central part of the area and described as Darende-Balaban basin, was determined to be Oligo-Miocene or Oligocene during previous investigations. This opinion is based on the fact that other gypsiferous formations existing in Turkey are of Oligo-Miocene or Oligocene age. However the age of this formation is determined to be Upper Eocene (Bartonian), taking into consideration the fossil content. As was described above, the sediments deposited during the Lower and Upper Lutetian were uplifted by the Pyreneic phase of the Alpine orogenesis and an inland sea was formed as a result of the withdrawal of the Lutetian sea. Materials formed by the erosion process were deposited in the inland sea. As a result, the Lutetian sea was transformed thiough tectonic movements into an inland sea and gypsiferous formations were deposited in this sea, which also existed during Bartonian.

On the 1:2,000-scale detailed geological map and cross-sections (Annexes III, IV) of the area located [between Alidede Tepe (3A) and the Ayvalı road, just NNE of Darende, is shown the relationship between the overlying gypsiferous formations and the Lutetian formations at the bottom, and the occurrence of gypsum in these formations.

Gypsiferous sediments are studied in two different rock units. These are:

a. Darende Formation: Alternation of sandstone, siltstone and marl beds interbedded with gypsum.

b. Balaban Formation: Alternation of conglomerate, sandstone and marl layers.

At some places the gypsiferous formations of Bartonian age, classified in two rock units, start with gypsum (Darende Formation) or with conglomerates (Balaban Formation) over the marls which form the upper part of the Asar Tepe Formation.

A. DARENDE FORMATION (Te_D)

The rock unit, showing typical section and outcrops on both sides of the valley along Tohma Çayı and around Darende town, is named «Darende Formation» by the author. This formation covers the following areas: east of the road connecting Yukarı Ulupınar and Aşağı Ulupınar villages, situated to the southeast of the area under investigation, and the Darende-Balaban basin, including the central part, except a small area, located south of Darende-Ayvalı road. This formation, covering the major part of the Darende-Balaban basin, is the most extensive formation in the region.

The Darende Formation can be clearly observed along the Malatya highway, crossing the area, up to Aşağı Ulupınar (Aşağı Setrek) village (Pl. VI, photo 12). Typical sections of the formation can- be seen along the Darende-Ayvalı road and contact formed with the Asar Tepe Formation (Annexe IV).

The Darende Formation is composed of light-gray to tan-colored alternation of sandstone, siltstone and marl layers, interbedded with gypsum. The formation has a reddish color around Balaban town. The thickness of the sandstone layers is 25-50 cm at the edges of the area, and they form cornices. Towards the center of the area sandstone layers thin out (10-15 cm), their grain size becomes smaller and, as a result, marls are dominant. Sandstones are composed of fine- medium-grained, partly sub-angular and sub-rounded feldspar, quartz, hornblende, chlorite, serpentine minerals and fragments of magmatitic rocks, hornstone and limestone. Mineral grains of the sandstones are cemented by calcite and they are strongly cemented.

The formation contains gypsum layers from bottom to top. The thickness of the gypsum layers increases from 3 meters to 12 meters toward the bottom. The thickness of the gypsum layers in the central part varies between 20 cm and 3 meters, and the marls contain very thin (1-2 cm) gypsum layers.

The Darende Formation contains three gypsiferous strata southeast of Alidede Tepe, as will be seen on the map and cross-sections mentioned above (Annexes III and IV). The two lowest levels unite towards Ayvalı road. This bed, in turn, unites with the upper level along, the road and can be seen along the contact (Pl. VI, photo 13). We believe that the gypsiferous formations wedge out through lateral passage.

Since the lower part of the gypsiferous formations is interbedded with very thin marl layers along the Ayvalı road, bedding can be well observed (Pl. VI, photo 13). Bedding is deformed, because gypsum in the upper levels was subject to volume changes, as a result of absorbing water into mineral composition. The upper part of the gypsiferous strata (see Annex IV) is composed of alternation of sandstone and marl layers (Pl. V, photo 10). Although gypsum is not observed in these parts, gypsiferous layers are present in the central part.

The measured thickness of the formation at the typical sections located between Ayvalı road and Alidede Tepe, north of the basin, is 136-380 meters. The thickness of the formation increases towards the center.

The Darende Formation in the north and south of the area starts directly with gypsum layers over the marls in the upper part of the Asar Tepe Formation. In some places, gypsiferous layers are seen over the conglomerate and sandstone layers overlying the Asar Tepe marls.

The basal part of the formation is best seen along the Darende-Ayvalı road and along the contact between Darende Formation and Asar Tepe Formation in the northeastern direction. The Darende Formation starts with gypsum layers, as can be seen along the road, and then continues as alternation of sandstone and marl layers (see Annex III; Pl. V, photo 10). A disconformity is not believed to be present between the Darende Formation and the underlying Asar Tepe Formation.

The lover part of the Darende Formation is limited by the Asar Tepe Formation and the Balaban Formation, composed of alternating conglomerate, sandstone and marl layers. Where the conglomerates are the dominant member, the Balaban Formation gradually grades into the Darende Formation, which is determined to be of the same age. The relationship between the formations can be seen in the area between Ayvalı road and Alidede Tepe, and again along the road just north of Aşağı Ulupınar village in the direction of Balaban.

The Çaybaşı Formation overlies horizontally the Darende Formation. An angular unconformity is present between these formations.

The formation has the same lithological and stratigraphical features both in the southern and northern parts of the area under investigation.

Sandstone layers between the marly and gypsiferous levels of the formation form cornices as a result of irresistance to erosion (Pl. VI, photo 12).

Dendritic valleys are formed in the formation, due to the absence of rocks capable of controlling the direction of the valley, because of the low resistance of marls and gypsum to erosion. These valleys follow the direction of Tohma and Ayvalı Tohması which flow in typical meanders in the formation (Pl. IV, photo 8).

Towards the center of the area the formation has a gentle relief. Fractures are formed as a result of the volume increase caused by the hydration of the underlying gypsum layers on the sandstone beds. The best example of this can be seen along the road connecting Irmaklı village (just east of the area under investigation) to Darende town.

B. BALABAN FORMATION (TeB)

It outcrops in the area between Aşağı Ulupınar and Yukarı Ulupınar villages located on the Malatya highway, southeast of the region, and in a small area where the Darende-Ayvalı road enters the area under investigation (Annex I). This formation, which covers larger areas in the southeastern part of the area, can be best seen along the Malatya highway between Aşağı Ulupınar and Yukarı Ulupınar villages. This rock unit, which can be observed along the road up to Balaban town, is named «Balaban Formation» by the author.

The type section of the Balaban Formation is measured between Darende - Ayvalı road and Alidede Tepe in the northern part of the area (Fig. 15).

The formation, furthermore, can be observed along the road between Aşağı Ulupınar and Asar Tepe, in the southern part of the area.

This formation is composed of greenish - light gray-colored conglomerates containing thin beds of sandstone and marl (Pl. VII, photo 14). Conglomerates consist of rounded limestone gravels of Jurassic-Cretaceous and Upper Cretaceous age, and green rock fragments (particularly, hornblende-bearing pyroxene andesite). The grain size of the gravels varies between 0.5 and 20 cm. The thickness of the conglomerate beds is 50-80 cm, and the thicknesses of the marl and sandstone layers are 5-10 cm, and 20-30 cm, respectively. Cementing material is calc-

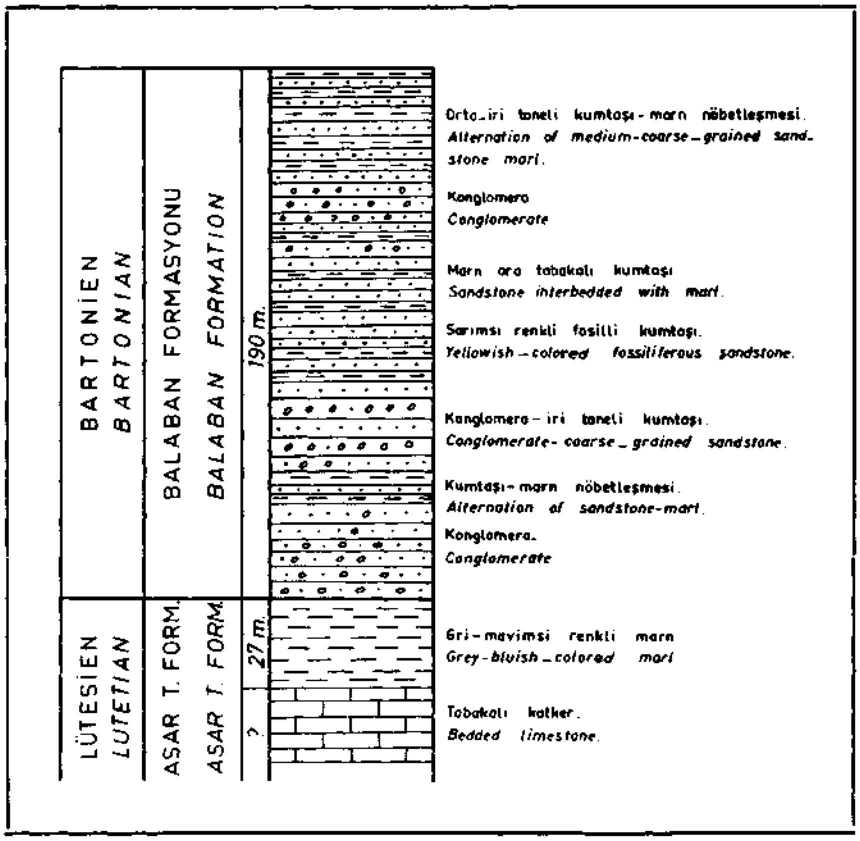

Fig. 15 - Typical section of the Balaban Formation
(Between Darende-Ayvalı road and Alidede Tepe).

areous and conglomerates are moderately cemented. In the outcrops in the northern part of the area, the thickness of the beds diminishes and the grain size of the gravels is smaller.

The thickness of the conglomerate layers and the grain size of the gravel decrease towards the center of the basin and north of the contact. The formation grades into Darende Formation along the Balaban Stream, to the north of Aşağı Ulupınar, and extends as alternating conglomeratic sandstone and sandstone-marl layers. Here, the lateral grading of grain size can be easily seen.

The thickness of the formation is 190 m in the north, while it is 375 m in the south. The Balaban Formation overlies conformably the Asar Tepe Formation in the southern (PL VII, photo 15) and northern (Annex IV) parts of the area.

The upper level of the formation gradually passes into Darende Formation in the northern and southern parts of the area; only the basalts of Kepez Dağı, located southeast of the area cover horizontally the Balaban Formation (Pl. VII, photo 15; Pl. X, photo 20).

The Balaban Formation is elongatedly developed in the south and north of the area. No gypsiferous layers occur within the formation. Since the gravels composing the layers are irregularly sorted, graded bedding cannot be seen. The fact that the grain size changes frequently and that a distinct lateral grading can be seen towards the center, shows that the Balaban Formation must have deposited in an active and turbulent environment. At the central part relatively stable sedimentation must have taken place.

The conglomerate and sandstone layers forming the formation are irresistant to erosion because they are not strongly cemented. The formation is traversed by minor creeks and makes a gentle relief.

NEW KNOWLEDGE ABOUT THE AGE OF THE DARENDE AND BALABAN FORMATIONS THAT CONSTITUTE GYPSIFEROUS FORMATIONS

In the previos studies the age of the sediments filling the Darende-Balaban basin was believed to be Oligocene or Oligo-Miocene. This assumption must have been influenced by the presence of other Oligo-Miocene gypsiferous deposits occurring in the other parts of the country and not by the existing fossil content of the formations. During the studies carried out by the author of this paper, the fossiliferous levels were determined and some encouraging results on the age were obtained.

The sandstone strata of the Balaban Formation contain abundant microfossils: *Nummulites fabianii* Prever, *Nummulites incrassatus* de la Harpe, *Nummulites* sp. (of the *N. globulus* group), *Discocyclina* sp., *Fabiania cassis* Opp., *Chapmanina* sp., *Acervulina* sp., *Gypsina* sp., Sphaerogypsina, Globigerina, Operculina, Triloculina, Peneroplis and *Coralline* sp.[9]

The presence of *N. fabiani* in the fossil content indicated that the age of the formation reaches up to Upper Eocene (Bartonian). Based on the microfauna content, the age of the formation can be accepted as Upper Lutetian-Bartonian.

In addition to the microfossils found in the Balaban Formation, some macrofossils were also found for the first time by the author in the Darende Formation. Abundant «Cardium» fossils were collected at the eastern flank of the small hill dividing Çay Dere south of Akçatoprak (Mığdı) village, located in the central part of the area under investigation. (PL XIII, photo 30/a, b). These marls contain the following Cardium fossils which indicate the Upper Eocene (Priabonian) age in Italy, Greece and western Alpine regions. (Fossils were determined at the «Centre National de Recherches Scientifiques, Institut de Paleontologie, Paris».)

Cardium cf. *granconense* Opp. (Italy and Greece)
Cardium sp. aff. *rouyanum* d'Orb. (also present in the western Alpine region)
Cardium cf. *bonelli* Bellardi

Although the Cardium specimens were determined as «cf.», «aff.», it is obvious that these Cardium fossils, according to the microfauna content and stratigraphical position, represent Priabonian—Bartonian in the area under investigation.

The inner molds of these fossils are preserved and they are abundant along the east flank of the hill, just south of Akçatoprak village. Although rare, some inner molds are also present in the marls of the Darende Formation.

Apart from the micro and macrpfossils, the following Ostracods, indicating Upper Lutetian age, are found in the marl levels of The Darende Formation:

Krithe papillosa Bosquet, *Krithe bartonensi* Jones, *Krithe rutoti* Keijj *Cytherella gatnardensis* Dentel, *Cytheropteron* sp., *Trachyleberis* sp.[10]

Based on the micro- and macrofossil content found in the Darende and Balaban Formations, which form the gypsiferous series, the age of these formations is determined to be Upper Lutetian - Bartonian.

SEDIMENTARY STRUCTURES FOUND IN THE DARENDE FORMATION

On the surface of fine-grained sandstones and siltstones forming the Darende Formation, a) load casts and b) flute casts are observed.

Some other sedimentary structures, apart from the above-mentioned, may be found in the formation, but this would need a special investigation.

a. Load casts. — Load casts are seen oh the surface of siltstone and sandstone layers, 50-60 cm thick and interbedded with marls, occurring in the vicinity of the quarry located on the road between Darende and Irmaklı village (4D). Load casts are formed as a result of the deposition of heavy sandstone and siltstone layers on the plastic marls. Due to their heavy weight, sands sink into the marls. On the lower face of the siltstone beds resting upon marls, load casts can be seen (PL VIII, photo 16).

b. Flute casts. — Flute casts can be seen on the surface of the fine-grained sandstone and siltstone layers interbedded with marls, occurring in the vicinity of Alidede Tepe (3A), east of Darende; at the quarries located along the Darende-Irmaklı village road; on the south and west flanks of Etre Tepe (5B); and west of the road junction connecting Malatya highway and Yenice village road (PL VIII, photo 17).

Sedimentary structures, such as flute casts, load casts etc., are formed on the fine-grained sandstone and siltstone layers, through the process of currents. These structures are considered important because they show the direction of the currents. The pointed sides show the direction, and the casts show the bearing of the currents. As will be seen on the photos, the direction of the currents is from left to right.

40 measurements were taken in order to determine the direction of the currents, by holding the compass parallel to the observed flute casts. The measured bearings were, then, plotted on the rose diagram (Fig. 16) and the direction of the currents was found to be N 55°W.

Other sedimentary structures also show that the direction of currents is from NW to SE (Pl. VIII, photo 17). Therefore, it is understood that during the deposition of Bartonian sandstone and siltstone layers, currents were moving N 55°W.

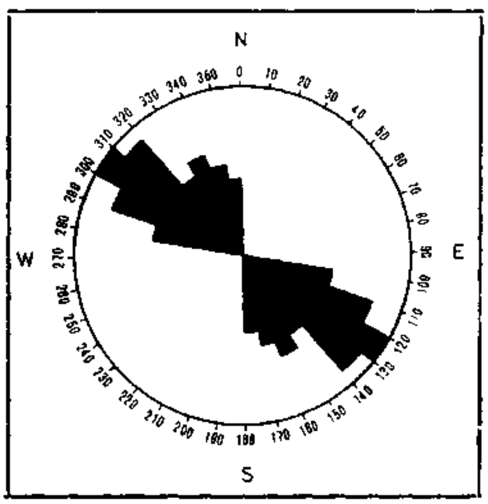

Fig. 16 - Rose diagram showing current direction of the flute casts
(average N 55°W).

CHEMICAL PROPERTIES OF GYPSUMS AND THEIR DEPOSITION ENVIRONMENT

The chemical composition of the eleven gypsum samples collected from the areas which are shown in Annex III are given below (sample numbers are from bottom to top) :

Table - 1
Chemical analysis of the gypsum samples

Sample no.	SiO_2	$Al_2O_3 + TiO_2$	Fe_2O_3	CaO	MgO	SO_3	H_2O
1	0.72	0.38	0.11	32.51	0.35	44.52	19.65
2	0.83	0.30	0.17	32.44	1.31	42.41	18.60
3	26.91	0.16	0.25	24.88	2.05	27.37	11.58
4	0.94	0.34	0.14	32.86	0.41	43.63	19.22
5	3.34	0.36	0.18	32.13	14.34	9.44	3.88
6	0.76	0.17	0.07	32.45	0.09	45.27	19.95
7	3.11	0.28	0.04	32.38	0.04	44.70	18.54
8	0.60	0.27	0.06	32.37	0.06	45.98	20.32
9	0.56	0.12	0.09	32.60	0.05	45.60	20.15
10	0.62	0.06	0.02	32.85	0.06	45.85	19.80
11	0.19	0.11	0.04	32.75	0.03	45.79	20.30

The distribution graph of the components is shown semi-logarithmically in Figure 17, based on the values given in the table. The SiO_2 content of the samples no. 3 and 5 is higher than in the other samples, as will be seen in the semi-logarithmic graph. On the other hand, the percent of the crystal water is less, compared to other samples (3-11.5 %). Furthermore, sample no. 5 contains the highest percent of MgO (14.34 %). CaO percent contained in sample no. 3 (24.88 %) is less than the average CaO content of the other samples (33.5 %).

According to the results obtained from the chemical analysis, the estimated CaO+ SO_3 values of the samples vary between 77-78 % (see Fig. 18). However, the estimated $CaO + SO_3$ values of samples no. 3 and 5 are decreasing to 40-50 %.

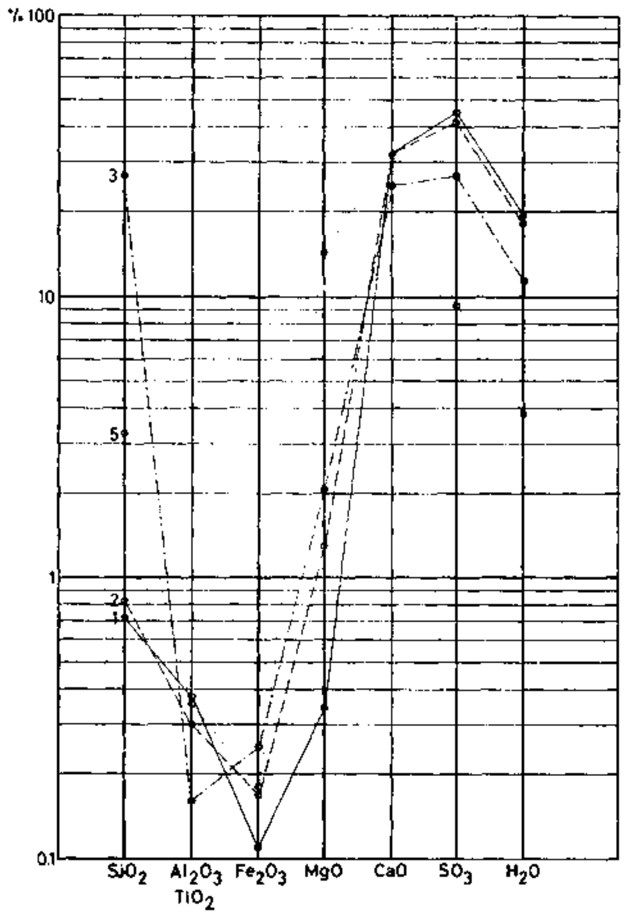

Fig. 17 - Semi-logarithmic distribution graph showing results of the chemical analysis of gypsum.

The probable error distribution of the chemical analysis of gypsum samples is calculated as shown in the following table and the average error is estimated to be + 2. But sample no. 5 is not included due to its low total value, which is 63.67 %.

Table - 2

Chemical analysis of gypsum samples and standard deviation calculations

Analysis no.	X	Γ	Γ^2
1	98.24	0.22	0.484
2	96.06	1.96	3.841
3	93.20	4.82	23.232
4	97.54	0.48	0.230
5	—	—	—
6	98.76	0.74	0.547
7	99.09	1.07	1.144
8	99.66	1.64	2.689
9	99.17	1.15	1.322
10	99.26	1.24	1.537
11	99.21	1.19	1.416
	Σ 980.19		Σ 36.442

Average $\bar{X}$: 98.02

X : Total percent of the components after the completion of each analysis.

$\bar{X}$: Average mean of 10 analyses = 98.02

Γ : $X-\bar{X}$

n : Number of analyses = 10

Standard deviation % $= \sqrt{\Sigma\Gamma^2/(n-1)}$
$= 36.442/9$
$= 4.049$
$= 2$

Standard deviation of the total analysis is $\mp$ 2 %.

As will be seen from the above analyses, no Na, K, Cl and I have been found during the chemical analysis of gypsum samples. Therefore these gypsum deposits are mainly composed of $CaO+SO_3$ and crystal water with small amount of contaminating material. The sequence in a normal evaporite basin from bottom to top is as follows :

Limestone,
Gypsum,
Salt deposits.

Similar types of sequences in this country have been observed within the variegated formations of Pliocene age around the Tuzluca area (Kars province). We found the following sequence of deposition during our studies in this area :

Gypsum (interbedded with marls),
Salt depozits,
Marly limestones which are intercalated with limestone, shale and sandstone with some gypsum.

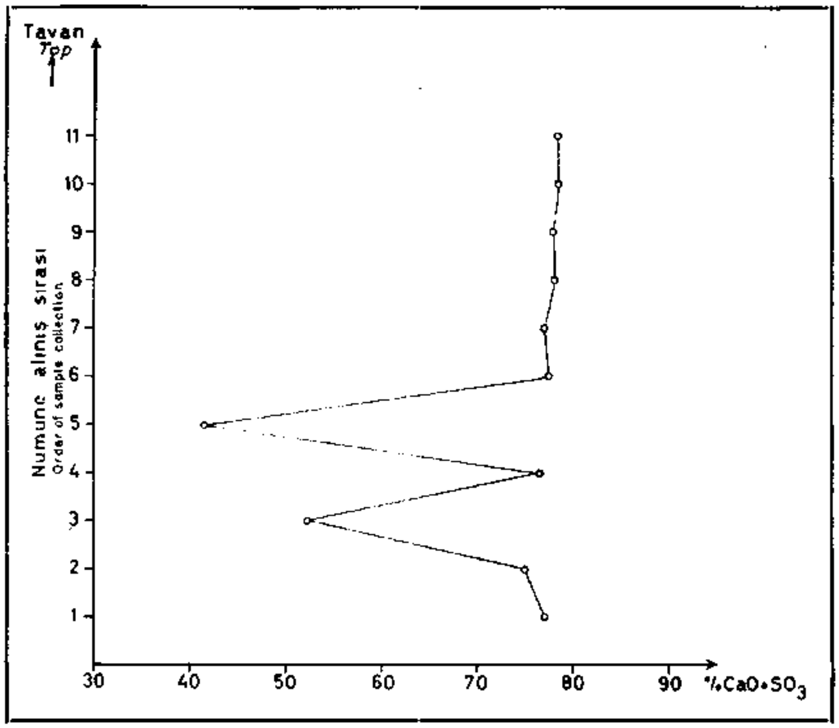

Fig. 18 - Distribution graph of $CaO+SO_3$ in the gypsum samples.

In addition to the sequence mentioned above, M.T.A.'s drilling program, which has been conducted within the Lower Miocene formations of the Çayırlı area, Erzincan, East Turkey, gave the sequence below (from top to bottom):

Limestone,
Gypsum which is intercalated with marl,
Salt deposits,
Gypsum including some marl.

However, a uniform cycle did not occur in the area under investigation. It may be concluded that the series in question is either an uncompleted series or that the sedimentation in the normal order of the layers did not take place due to the influence of certain processes.

Although the presence of high MgO values in samples no. 3 and 5 indicates the occurrence of a complete series, the fact that alternating gypsum layers are distributed within the formation at various levels, and that gypsum is not found everywhere, indicates that either the basin was connected with a sea or that an environment favorable for salt deposition as a result of fresh-water invasion from the continents was disturbed.

Due to this, salt beds were not deposited in the basin after the deposition of gypsum. Gypsiferous formations were deposited in an inland sea which was connected with sea, and was subject to fresh-water invasion from the continents.

The fact that the salinity of the water decreased from time to time, favored the survival of Cardiums. An arid climate dominated during this period.

2) MIOCENE

TAHTALI TEPE FORMATION (Tm_T)

It outcrops over a narrow area on Danğış, Tepe (9D), north of Kepez Mountain which is located in the southeast of the studied area. The formation found here, however, extends eastward in a band under the basalts. Farther east, it is well developed and covers a wide area, particularly in the neighborhood of Levent, through the east-west side of Hasanağa Stream, and near the Karahan Çeşmesi on the highway to Malatya. Typical sections taken from Tahtalı Tepe, near Kurşunlu, to where we attribute our formation, though it extends outside of our area, are shown in Fig. 19.

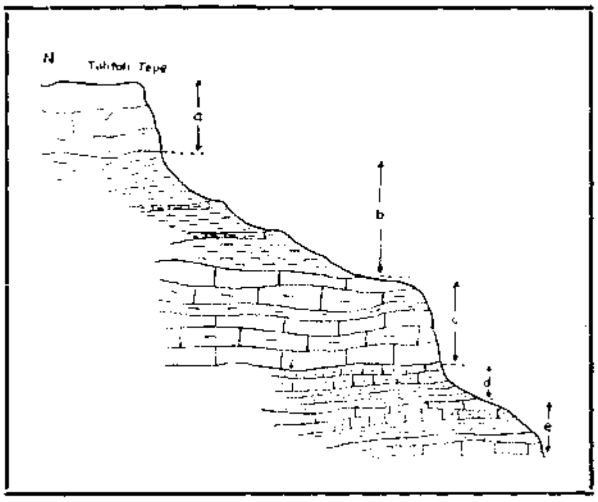

Fig. 19 - General stratification of Miocene.
a - Porous limestone; b - Shale, clayey limestone; c - clayey limestone; d - sandstone - sandy limestone; e - Sandy limestones - clayey limestone - shale (T. Ayan, 1964).

The formation in the area consists of blue marl, marly limestone at the bottom, overlain by white, partly chalky and porous limestone of medium thickness.

The Tahtalı Tepe Formation is about 30 m thick in the area. However, it thickens up to 300 m in other parts of the district.

The Tahtalı Tepe Formation extends unconformably over the Asar Tepe Formation. The post-Miocene volcanics overlie this formation horizontally in our area (PL IX, photo 18).

The formation contains abundant fossils. In the limestones the following fossils are found:[11] *Miogypsina irregularis* Mich., *Miogypsina* sp., *Miolepidocyclina burdigalensis* Gümbel, *Lepidocyclina* sp., *Amphistegina radiata* Fichtel & Moll., Miliolidae, Melobesiae. In addition to the above-given microfossils, there are fragments of shells of Lamellibranchs in this formation.

The formation, which is extensive in the east of our area, contains the following macrofossils:[12] *Lucina globulosa* Deshayes, *Lucina pragilis* Philippi, *Chlamys multistriatus* Poli, *Pecten* aff. *corsicanus* Deperet & Roman. The microfauna as well as the macrofauna show a Lower Miocene (Burdigalian) age.

2. QUATERNARY

It is studied under the following groups: 1. Plio-Quaternary, 2. Terraces, 3. Young Alluviums and 4. Travertine.

1. PLIO-QUATERNARY

ÇAYBAŞI FORMATION (PIOc)

This formation, which is horizontal in the hills west of the highway from Darende to Malatya, is extensive in the Çaybaşı area, southwest of Balaban, from where it gets its name. It is also found northwest and east of the studied area (around the Irmaklı village) and in the central part.

The Çaybaşı Formation is generally composed of polygeneous conglomerates. It includes the rock gravels of Jurassic, Cretaceous, Upper Cretaceous, Eocene and ophiolitic rocks. Gravels are slightly rounded and cemented by calcium carbonate. Cementation is of medium grade. In places, the cement is loose and gravels became free. Though the formation is composed of conglomerates in general, it also contains white lacustrine limestone. This type of formation is particularly found south of Çaybaşı and around the hot springs in the east of Balaban. The maximum thickness of the formation is 25 meters. The Çaybaşı Formation is generally horizontal, though it has a dip of 5-10°. It is tabular over the inclined formations. Therefore, the angular unconformity between Çaybaşı Formation and other formations can easily be distinguished (PL IX, photo 19).

The formation does not contain any fossils. Therefore, its age can not be decided. The strata form terraces in the valleys. But since they are also found over hills away from the valleys, and because they contain lacustrine limestone, they are regarded as lake deposits of Plio-Quaternary age, the final remnant of Miocene sea.

As described above, the formation is horizontal over the other formations. When it covers a large area it forms flat plateaus. Because the underlying formation is cut by streams (Darende Formation) in general, Çaybaşı Formation, overlying horizontally, can only be observed over slopes and at peaks.

2. TERRACES (Q_e)

These deposits are found along the Tohma and Ayvalı Tohması Streams which run through the area. In the northeast of our area, at the Kantaruz Boğazı of Ayvalı Tohması Stream, a difference of 5 m is observed between the new and old beds of the stream. The same difference is also observed in Tohma Stream, southeast of Darende.

3. YOUNG ALLUVIUMS (Qy)

They are the youngest deposits found in the Tohma Stream, Ayvalı Tohması Stream and in other stream beds. In general they are composed of gravel, sand and mudstones. This type of deposition is still taking place.

4. TRAVERTINE (Qtr)

Travertine deposits are found south of Ayvalı Tohması Stream, at Kantaruz Boğazı (3C), where the stream enters our area. The formation is formed by the residue of $CaCO_3$-rich waters near the Kantaruz Boğazı.

IV. IGNEOUS ACTIVITY

Igneous rocks in the area are studied under two groups : 1) Intrusives (ophiolitic series), 2) Extrusives (basalt, agglomerate, and tuffs).

1. INTRUSIVES

They are composed of rock groups like serpentine, gabbro, spilite, etc. These green rocks, called «ophiolitic series», cover a wide area extending NW-SE, between Yukarı Ulupınar and Yenice Şuğul villages in the south of the studied area. The Upper Jurassic - Lower Cretaceous limestones (Geniz Limestone) are cut by ophiolitic series (Pl. I, photo 1). In addition, in these series, there are individual limestone lenses.

In the contact between the limestone and ophiolitic series there are silicified and red-colored parts, as a result of metamorphism.

The ophiolitic series extending NW-SE forms the core of an anticline following the same trend. The Ulupınar Formation of Upper Cretaceous (Maestrichtian) age, surrounding this core, is unconformable on the ophiolitic series. Fragments of the variegated Ulupınar Formation consist of green rock grains (conglomerates-sandstone). The formation gets its color from these materials.

As it is observed in our area of study, the green rocks have the same kind of relationship with other formations in the neighboring areas. Comprehensive limestones of Jurassic - Lower Cretaceous age which can be observed through the Tohma valley, are cut by green rocks. The elastics found in the same district and regarded as the continuation of the Ulupınar Formation are transgressive over ophiolitic series and contain pebbles of ophiolitic rocks. Comprehensive limestones of Jurassic-Lower Cretaceous age, found on Hezanlı Mountain and Behram Çalı Mountain in the south and north of Gürün, respectively, are cut by green rocks in the same way.

According to our observations, both in the area we surveyed and in the neighboring areas, the formation of green rocks has taken place after the deposition of Jurassic - Lower Cretaceous limestones which they cut. The sedimentation of Campanian-Maestrichtian flysch-like elastics deposited after the formation of green rocks. Accordingly, ophiolitic magma activity had taken place after the Lower Cretaceous and before the Campanian-Maestrichtian. Prof. Dr. F. Baykal, who has studied in detail the Malatya-Kayseri region, indicates that this igneous activity had taken place during Turonian (12, 14).

2. EXTRUSIVES

A. KARAKAYALAR VOLCANITES (V_{Ka})

They outcrop just at the northeastern corner of the area and stretch out toward the northern border of this area. This formation fills a depression between Jurassic-Cretaceous limestones. Since the hills were formed by volcanics called locally «Karakayalar», we named the formation «Karakayalar Volcanitcs».

When seen from far off, the Karakayalar Volcanites look like serpantines because of their light green color. For that reason they were described as serpentines in previous studies. During our studies we were able to prove that they are basalts, agglomerates and tuffs.

The basalts show the following petrographic properties :[13]

Pyroxene basalt. — Contains plagioclase phenocrysts (labradorite, pyroxene, augite, hypersthene). The groundmass is composed of plagioclase, augite microlites and glassy material. In addition, it also contains minor quantities of calcite and zeolite (natrolite) as accessory minerals. Texture: Porphyritic.

Pyroxene hyalobasalt. — Contains plagioclase (with an intergrowth of labradorite), augite pheno-microcrysts. The groundmass is composed of glassy material in great amounts, and lesser quantities of plagioclase, and pyroxene microlites. It also contains chlorite, zeolite (natrolite), calcite, as cavity filling.Texture: Porphyritic-weak amygdaloidal.

Olivine-pyroxene-basalt. — Contains plagioclase (labradorite-bytownite) and phenocrysts of augite and olivine. The groundmass is composed of plagioclase, pyroxene and some glassy material.

Basalt. — Contains plagioclase (labradorite-bytownite) and phenocrysts of hornblende-pyroxene. The groundmass is composed of plagioclase and microlites of hornblende and pyroxene. It has a texture partly in the flow direction.

In addition to basalt, there are also agglomerates and tuffs. Tuff contains basalt, hyalobasalt, andesite, volcanic glass, hornblende, labradorite, bytownite and augite fragments and they are cemented with a glassy material highly calcitized. These tuffs are deposited in water and bedding is observed in places.

Volcanics show a color similar to those of serpentines because of the alteration of olivine and chlorite found in basalts.

Lutetian formations with a base conglomerate are unconformable (Korgan Tepe Conglomerate) over Karakayalar Volcanites (Pl. III, photo 6). Greenish conglomerates of Korgan Tepe contain basalt, pyroxene, hyalobasalt, and well-rounded olivine-pyroxene gravels of Karakayalar Volcanites.

Because Lutetian strata are unconformable over Karakayalar Volcanites, the volcanic activity is believed to have taken place before the Lutetian age. In general, it may be stated that Karakayalar Volcanites are pre-Lutetian in age.

B. KEPEZ DAĞI BASALT (V_{Ke})

It is extensive in the south and souhteast of the area. The Kepez Mountain (10D) plateau, east of the Yukarı Ulupınar village, and high plains in the south are completely covered by young basalts. We named these basalts «Kepez Dağı Basalt».

The Kepez Dağı Basalt extends over wide areas in the east and south, outside the borders of our area. It can easily be observed as far as Akçadağ, along the highway to Malatya.

The basalts of Kepez Dağı show the following mineralogical features:

Olivine basalt. — Contains plagioclase (basic) with flow texture and partly chloritized augite. Groundmass is composed of coarse olivine (partly serpentinized), dispersed plagioclase (labradorite, bytownite), and phenocrysts of macro and micro-augite.

Pyroxene andesine basalt. — Is composed of a plagioclase with flow texture, augite microlites and a glassy material. Plagioclase (andesine) micro-phenocrysts are fairly well dispersed and the rock is in the interphase between basalt and andesite. In some samples, the grain size of the microlites is greater. Glassy material is quite rare. The Kepez Dağı Basalt shows tuffaceous levels. It can be traced along the highway to Malatya, outside the borders of our area. The same tuffaceous levels can be distinguished around the. intersection of the Malatya and Elbistan roads.

We have found two levels of tuff in our area. These formations were deposited in the water and show a distinct bedding. From the successive deposition of basalt and tuffs it appears that at least two volcanic activities had taken place in the region. Though the crater is outside our borders, the basalts extend by flow into our area and its vicinity.

Kepez Dağı Basalt overlies the Lower Miocene (Burdigalian) and older formations horizontally and forms wide plains. It is observable along the highway to Malatya and around the Karahan Çeşmesi on the same highway, as well as in our area; these basalts overlie the formations of Lower Miocene age (Pl. IX, photo 18).

Since the basalts overlie the Lower Miocene formations, it is evident that volcanic activity had taken place after Burdigalian. Thus the basalts are post-Burdigalian in age.

V. STRUCTURAL GEOLOGY

1. GENERAL STRUCTURE

The investigated area is located within the Taurid tectonic unit according to I. Ketin's (33) Classification of Tectonic Units of Anatolia (Fig. 20). The Toros Mountains extending parallelly to the Mediterranean coast, follow NE and then E-W directions. The investigated area is in the northern edge of the virgation that Taurid unit makes in the NE direction. The region was affected by the Alpine movements in general.

The area is bordered both in the north and in the south by two uplifts of Upper Jurassic - Lower Cretaceous limestones. Limestones of the same age border our area also in the east (Akbabaçal Mountain) and in the west (Hezanlı Mountain). Thus, our area of investigation is surrounded by mountains and the central part shows basinal characteristics. In this subsidence area, Tertiary and younger formations have been deposited.

2. STRIKE AND DIPS

Because the Geniz Limestone of the Upper Jurassic - Lower Cretaceous age is massive, bedding is not well developed. Exposures found in the northern half

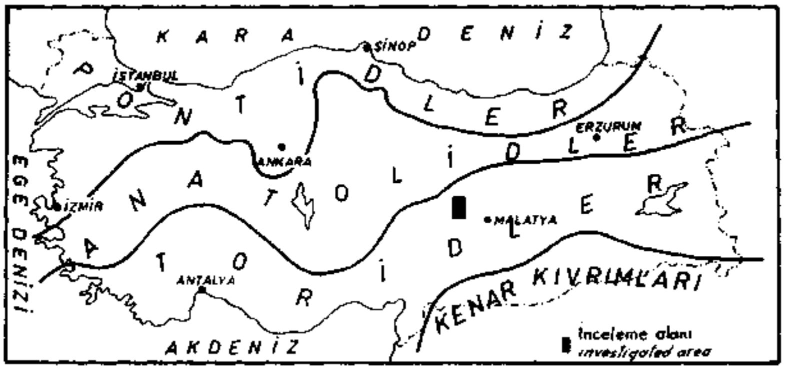

Fig. 20 - Tectonic units of Turkey and location of the investigated area (İ. Ketin, 1966).

of the area do not show any bedding at all. The exposures in the southwest are partly bedded. Their strikes are NW-SE, in general, and their dippings vary between 20° and 70°.

On the other hand, the Upper Cretaceous Ulupınar Formation, has a flysch-like appearance and its bedding is well developed. The strike of the formation is NW-SE, in general, though there are some changes in the strikes because of the plasticity of the formation. Dipping varies between 20° and 50°.

In the Eocene (Lutetian) formations bedding is perfectly developed with the medium and thick-layer characteristics. The strike of the formations in the northern area is mostly in NE-SW direction, and dipping is between 5° and 17°. The only high dips (50°-60°) observed on Korgan Tepe in the northeast of the area, resulted from a fault.

Formations of the same age strike NW-SE in the southern part of the area. Dipping varies between 20° and 60° as a result of the plasticity of the formation.

Bedding developes in thin, medium and thick layers in the Upper Eocene (Bartonian) formations found in the central part of the Darende-Balaban basin. These formations strike NE-SW in the nothern half of the area. Near the syncline, in the central part and in the southern half of the area, the strike is NW-SE, in general. Dips are between 7° and 25° in the northern half and between 5° and 50° in the southern half. In general, the formation does not show high dips. Dips higher than 25° have resulted from the effect of gypsum which has swollen through hydration.

Plio-Quaternary formation overlies the older formations horizontally. Furthermore, there are initial dips about 5°-8° (see Tectonic Map, Annex V, and rose diagrams Fig. 21).

3. FAULTS

The area does not have large dislocation lines and overthrusts. However, there are various faults around the basin. Typical examples of strike-slip faults are observed in the Eocene formations along the road leading to Ayvalı from Darende - NW of our area. Strike-slip faults are found to follow each other at various

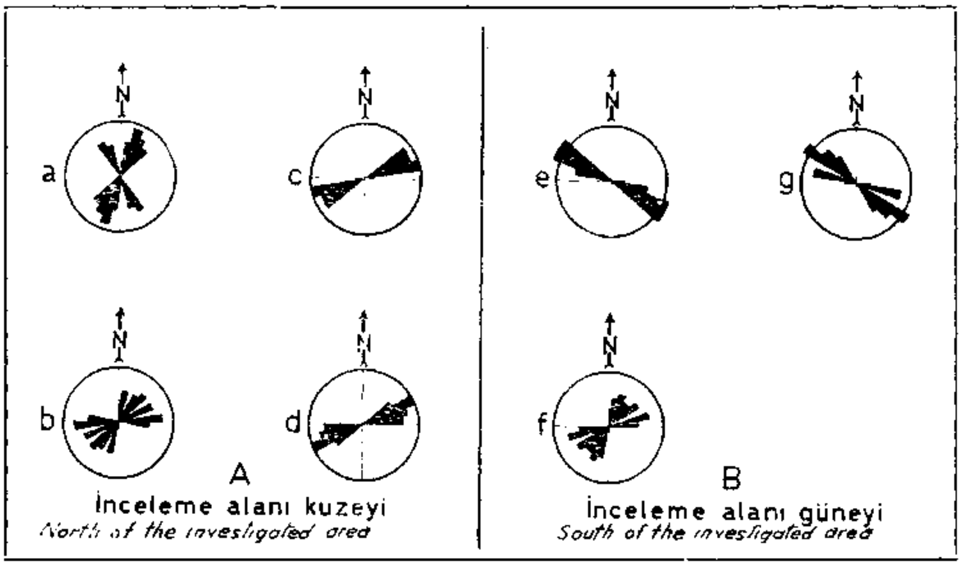

Fig. 21 - Rose diagrams showing strike directions of the formations.
A) a - Upper Cretaceous formation; b - Eocene (Lutetian); c - Eocene (Lutetian); d - Upper Eocene (Bartonian).
B) e - Eocene (Lutetian); f - Upper Cretaceous; g - Upper Eocene (Bartonian).

intervals, beginning from the point where Ayvalı highway enters the area. Since the faulting had taken place in limestone, all the lines and hollows showing the horizontal movement over the polished faces of the fault are visible in detail (PL X, photo 21). These faults strike N 5°-15°E, in general, and dip approximately 60°-87°. They could be observed for about 500-1500 meters. Faults resulted from tectonic movements in the north-south direction.

In the northeastern part of the surveyed area there is a fault following again the strata of Eocene age. This fault extends southeast from Sersi Tepe (1D). It has a length of 3 km within the borders of the investigated area and extends outside the borders in the same direction. In addition, there are normal faults on Sersi Tepe and at Kantaruz Boğazı in the Asar Tepe Limestone (Lutetian.

In the northern part, the contact between Asar Tepe Limestone, SW of Geniz Tepe, and Geniz Limestone is faulted. In the west of Geniz Tepe, the contact between Geniz Limestone and reef limestones of the Upper Cretaceous age is also faulted. Furthermore, strike-slip faults can be observed in the reef limestones.

There are various faults also in the southern half of the area. Among them, the greatest one is that striking northwestward and forming the contact of Asar Tepe Limestone (Lutetian) with Ulupınar Formation (Maestrichtian) in the west of Yukarı Ulupınar village (1-1C). At that point the Asar Tepe Limestone dips 45° under the older Ulupınar Formation along a thrust fault. This fault line, which possibly cuts the ophiolitic rocks after it left the borders of Ulupınar Formation, extends northwest along the contact of Geniz Limestone - ophiolitic rocks - Yenice Formation, on the edge of Karakaya Tepe (10B). Evidences of faulting (polished planes, etc.) are clearly seen in Asar Tepe Limestone and Geniz Limestone. On the other hand, they are lost in ophiolitic rocks, because of erosion. This fault strikes NW-SE and is about 6 km long. The dip varies between 55° and 65°.

The contact of Geniz Limestone with Yenice Formation on the Gavur Kalesi Tepe (8D), east of Balaban, is also faulted. The fault strikes N 10°E and dips 87°. In addition, there are some faults in Geniz Limestone, SW of the surveyed area; in the Upper Cretaceous formations, NE of the uplift formed by Geniz Limestone and ophiolitic series; in the contact of these formations with Lutetian formations; and in the Lutetian formations which have a length of about 500-1500 meters and strikes NW-SE, in general.

The faults found in the area are formed by tectonic movements, directed generally NNE-SSW. They affected the formations up to the Upper Eocene. However, they did not influence the Plio-Quaternary formations. The Plio-Quaternary formations are affected only by vertical movements.

4. FOLDS

Since bedding is not prominent in the massive Geniz Limestone of Upper Jurassic - Lower Cretaceous age, characteristics of folding could not be observed. However, the evaluation of measured strikes and dips in the Schmidt diagram indicate a fold axis of N 39°W and 16°NNW plunge for the Geniz Limestones (Fig. 22/A).

The Upper Cretaceous formations, outcropping over a small area in the north and around the ophiolitic series in the south, do not give any idea about the folding system. However, the evaluation of strikes and dips measured in the Upper Cretaceous formations, in the Schmidt diagram, has given an axis of folding about N 70°W and a plunge of 19° NW (Fig. 22/B).

Outside the surveyed area, the formations found northwest of Darende are folded into synclines and anticlines with NNW-SSE axes. The folds of the Upper Cretaceous in the vicinity and west of Darende —which is The Hacılar anticline— where the stratigraphic reconnaissance drilling was carried out by the M.T.A. Institute— strikes in the same direction. The folds of the Upper Cretaceous in the vicinity and west of Gürün —which is adjacent to our area— strike NE-SW. The difference between the strikes of the fold axes in the same formation has resulted from a virgation developed from west (Sarız-Gürün district) to east (Darende district).

The Asar Tepe Limestone of Lutetian age, in the northwest part of our area, generally is folded into small anticlines and synclines of small amplitudes with axes striking NW-SE. The limestone, extending from northwest to east, dips under the Darende Formation of Upper Eocene age continuing as a monocline in the south. The Yenice Formation of Lutetian age, which forms the southwest flank of the uplift found in the south, also forms anticlines and synclines of small amplitude, striking NW-SE.

Measured strikes and dips of the Epcene (Lutetian) formations are found to have an axis of folding about S 66°E and a plunge of 8°SE in the evaluation of diagrams (Fig. 22/C).

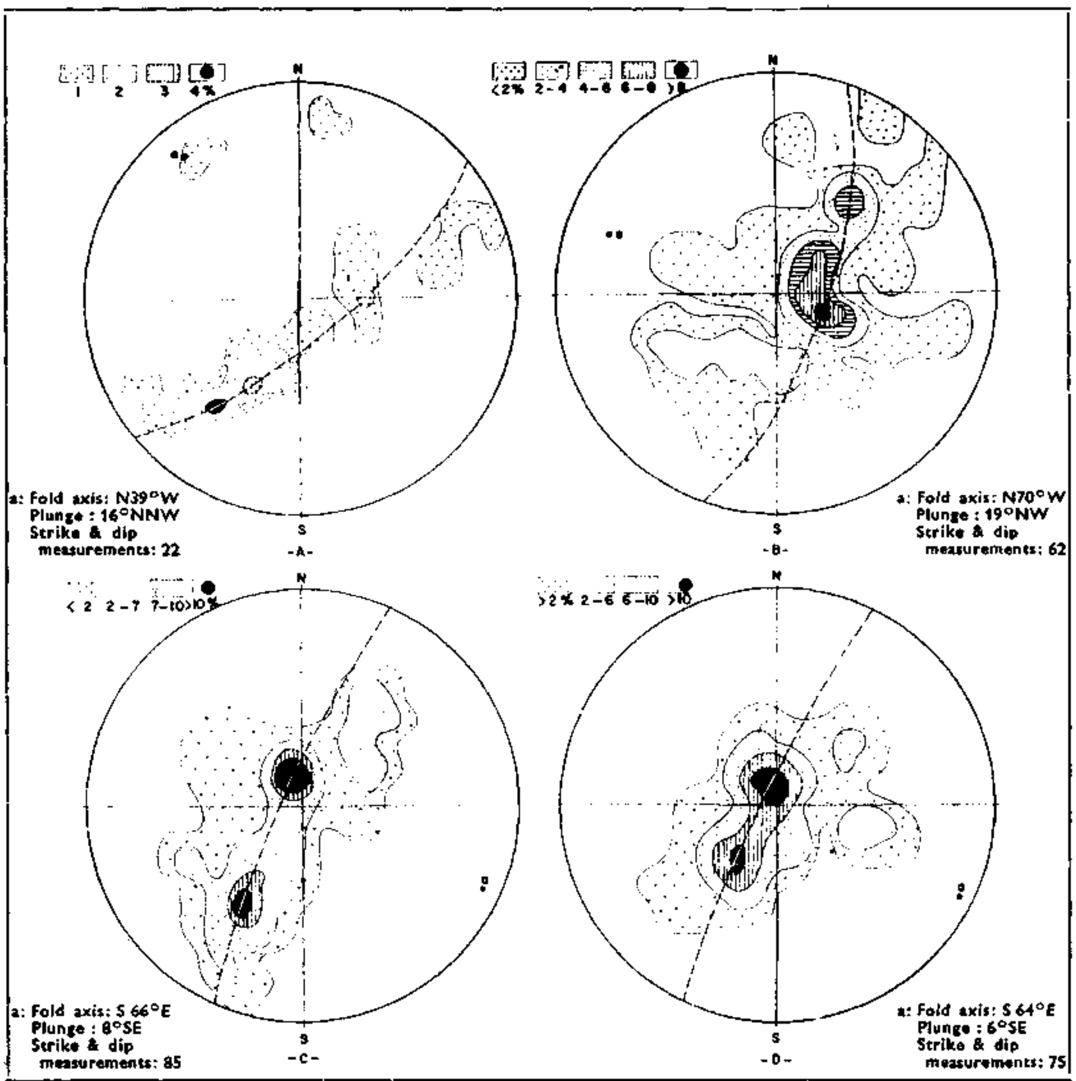

Fig. 22 - Schmidt diagrams showing average fold axes and plunges of the formations.
A - Geniz Limestone (Jurassic - Lower Cretaceous); B - Ulupınar and Kırankaya Formations (Upper Cretaceous); C - Yenice and Asar Tepe Formations (Eocene - Lutetian); D - Darende and Balaban Formations (Upper Eocene - Bartonian).

The Upper Eocene sediments found in the center of the basin form a large syncline striking NW-SE. This syncline, extending ESE from the west of the center, makes a southern curve in the north of Balaban and then continues again ESE. Apart from this large syncline passing through the Darende Formation, there is also a smaller anticline, of NW-SE trend passing through Karadeğin village and cutting Tohma Stream, and a syncline, with an axis trending NE-SW, in the north of this anticline. Additionally there are some small anticlines and synclines folded secondarily.

Measured strikes and dips of the Upper Eocene (Bartonian) formations are determined to have a fold axis about S 64°E and a plunge of 6°SE in the Schmidt diagram (Fig. 22/D).

Since the Lower Miocene formation covers a small area, the folding system could not be observed. Plio-Quaternary sediments do not have any folding because they are generally horizontal. The formation is affected by only vertical movements.

5. UNCONFORMITY AND OROGENIC PHASES

As it will be seen in the diagram given in Figure 23, there are definite dirferences between the axes of folding of Jurassic - Lower Cretaceous, Upper Cretaceous and Lutetian formations, caused by the various orogenic movements On the other hand, there is no definite difference between the axes of folds of Lutetian formations and Upper Eocene (Bartonian) formations that resulted from the same orogenic phase. Minor deviations observed in the axes have resulted from the plasticity of the gypsum of the Bartonian formations.

The Upper Jurassic-Lower Cretaceous Geniz Limestone is the oldest formation found in the area. The bottom of this formation is not seen. Therefore, a relationship between Geniz Limestone and underlying formation could not be established. These limestones strike generally NW-SE in the southern half of the area. Its northern outcrop does not show any bedding. Because they are of the same age as those found in the south, they should show the same strike. A border line between Upper Jurassic and Lower Cretaceous can not be drawn. These limestones having a comprehensive characteristic are the sediments of a sea that existed from Jurassic to the end of Lower Cretaceous.

The sea invasions and orogenic phases, which occurred in the area, are shown schematically in Figure 24.

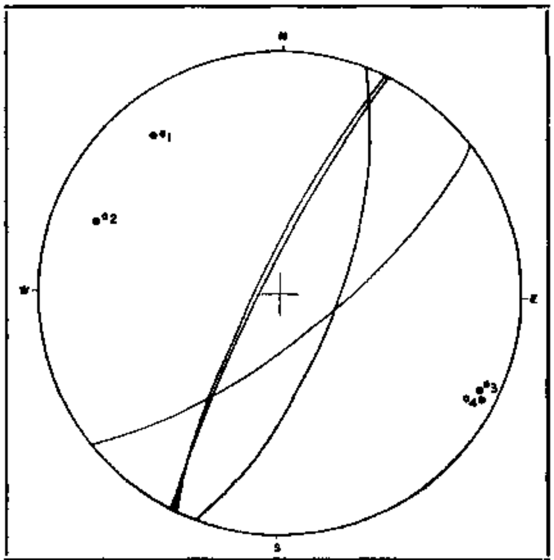

Fig. 23 - Schmidt diagram showing average fold axes and plunges of various formations.

a_1 - Upper Jurassic - Lower Cretaceous; a_2 - Upper Cretaceous; a_3 - Eocene (Lutetian); a_4 - Upper Eocene (Bartonian).

The Jurassic - Lower Cretaceous sea, in which sedimentation took place without any interruption from Jurassic to the end of Lower Cretaceous, had been transformed into a continent through the Vorgosau (Austric) phase of the Alpine orogeny. The uplifts found in the north and south of the surveyed area and the high mountains in the adjacent areas were formed at the end of Vorgosau orogenic phase.

A. UNCONFORMITY BETWEEN JURASSIC - LOWER CRETACEOUS AND UPPER CRETACEOUS

The variegated Ulupınar Formation of Maestrichtian age overlies the Geniz Limestone and ophiolitic rocks transgressvely, with a conglomerate at the bottom. The conglomerate gravels are composed of ophiolitic rocks and Geniz Limestone fragments. In the bottom of Ulupınar Formation, which overlies the Geniz Lime-

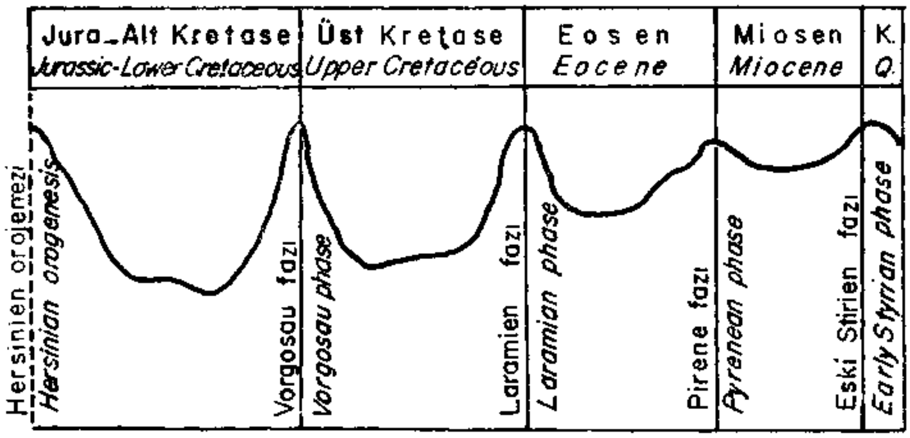

Fig. 24 - Schematic diagram showing Alpine orogenic phases in the investigated area. Pre-Jurassic formations had been subjected to the Hersinian orogenesis.

stone in the northern half of the surveyed area, some conglomerate layers are observed in places. Both in the south and north, reef limestone lenses occur at the bottom of Ulupınar Formation. Thus, an uncorformity is present between Upper Jurassic-Lower Cretaceous Geniz Limestone and Maestrichtian Ulupınar Formation which show different lithologic characteristics.

The sea bottom in which formations of Upper Cretaceous age were deposited — both in the surveyed area and in the adjacent areas — was uplifted at the end of Maestrichtian and transformed into continent during Laramian phase. Laramian movements had greatly affected the surveyed area as well as the neighboring areas.

B. UNCONFORMITY BETWEEN UPPER CRETACEOUS AND EOCENE

The Asar Tepe Formation found on the road to Ayvalı, NW of the surveyed area, overlies the Ulupınar Formation of Maestrichtian age with a base conglomerate. This conglomerate does not exist everywhere along the contact. There is a difference between the strikes of Ulupınar Formation and Asar Tepe Formation (NW-SE and NE-SW, respectively).

In the south of the surveyed area, the Lutetian formations are also found overlying Maectrichtian formations with a base conglomerate. Conglomerates contain Maestrichtian gravels and fragments of both Geniz Limestone and ophiolitic rocks. Therefore, there is a definite unconformity between Maestrichtian and Lutetian formations.

The Lutetian formations, beginning with the Korgan Tepe basal conglomerates in the northeast of the area, overly Karakayalar Volcanites composed of basalt-agglomerate and tuffs. The Korgan Tepe Conglomerates are mostly formed by volcanic material. Thus, an unconformity between Karakayalar Volcanites and Lutetian formations is easily distinguished.

Sediments of Eocene (Lutetian) sea began to fold through Pyrenean orogeny. At the same time the sea began to lose its properties as an open sea and was transformed into an inland sea in which the gypsiferous formations, found in the center of the basin, have deposited. At the end of Upper Eocene, Eocene sediments completed their folding through the final phase of Pyrenean orogeny. Eocene sediments do not have high dips and they are not sharply folded, which indicates that Pyrenean orogeny was not severe.

C. UNCONFORMITY BETWEEN EOCENE AND LOWER MIOCENE

Lower Miocene (Burdigalian) sediments, outcropping over a small area in the east of the surveyed area, overlie Lutetian sediments almost horizontally. The underlying formation, on the other hand, has a dip about 25°-30°. Therefore, there should be an angular unconformity between Eocene and Lower Miocene formations.

The formations deposited in the Lower Miocene sea have been uplifted and folded during the Old Styrian phase at the end of Burdigalian. This phase seems to have had a minor effect on the area judging from the appearance of these formations with minor dips.

D. UNCORFORMITY BETWEEN PLIO-QUATERNARY AND OLDER FORMATIONS

There is an angular unconformity between the Plio-Quaternary Çaybaşı Formation and the underlying formations. The Plio-Quaternary formations are not affected by the last phases of the Alpine orogeny but only by the epeirogenic movements. As a result, the general structure of our area is formed by the Alpine movements.

VI. PALEOGEOGRAPHY

The oldest formations outcropping in the area are the Upper Jurassic-Lower Cretaceous Geniz Limestone. Though the bottom of this limestone is not observable in our area, it is found in the deep wells drilled by the M.T.A Institute around Doğan Kalesi on the road between Darende and Gürün (7 km from Darende) where the formation includes beds of the Lower Jurassic (Lias), Upper Jurassic, and Lower Cretaceous. Thus, the area was covered by a sea which existed from Lower Jurassic (Lias) up to the end of Lower Cretaceous (Albian). Fine-grained and fractured microcrystalline limestones, pseudoolitic limestones and dolomites—which are the products of this sea—were deposited in a shallow sea of stable environment. These oolitic, chalky and dolomitic levels (found in the wells) are evidence of a warm sea, and the thick and comprehensive limestones, produced during the sedimentation from Lower Jurassic up to the end of Lower Cretaceous, are accepted as evidence of a stable environment.

We believe that the sea existed from Lias up to the end of Albian within the limits of a geosynicline. The Geniz Limestone is associated with green rocks of initial igneous activities; this confirms our belief. This geosyncline is also within the Tethys geosyncline.

The limestones deposited in the Jurassic - Lower Cretaceous sea were folded during the Vorgosau (Austric) phase of the Alpine orogeny at the end of Lower Cretaceous. An erosion follows this mountain building.

The region was again invaded by sea during Upper Cretaceous. The sea advanced from NNW toward SSE during the transgression of Upper Cretaceous. Therefore, the detrital coarse elastics (conglomerate-sandstone) were deposited in the south of the surveyed area as well as in the neighboring areas in the south. On the other hand, NNW of the area and along the road leading to Gürün, thick limestone beds, which are the deeper sea" sediments, were deposited.

The Upper Cretaceous (Maestrichtian) formations, overlying the Jurassic-Lower Cretaceous and ophiolitic rocks transgressively, are composed of rocks with different lithological characteristics. At the bottom of these formations there are coastal reefs of transgressive type, having biohermal properties and arranged in lenses. These reefs are overlain by poorly cemented conglomerate, sandstone and shale beds and then by limestone beds. This vertical facies change can be also observed laterally. They were deposited in a shallow and active environment where the sedimentation took place under different conditions. The sea deepened toward the northwest, outside of our area.

The fossil content of the Upper Cretaceous formations— such as Rudists from macroorganisms and Orbitoides, Siderolites and Loftusia from the micro-organisms—shows that it was deposited in a warm sea.

The formations which were deposited in the Upper Cretaceous sea were transformed into a continent by folding during the Laramian phase in the Maestrichtian age. After the withdrawal of seas which followed mountain building, an erosion took place in the region; this phase continued up to the Lutetian age.

During the Lutetian age the region was again invaded by sea. This sea could not completely invade the mountain ranges of Jurassic - Cretaceous in our area and in the adjacent areas, but filled only the hollows between the uplifts. Sediments of Lutetian sea are composed of a sequence of conglomerate, sandstone and marl with limestone, sandy limestone and marl. Lateral facies changes are definite in limestone and marls. The Lutetian sea is believed to have had the characteristics of neritic environment judging from its lithologic properties and its facies changes. In general, this sea had a shallow sea environment in which Nummulites, Gastropods, Echinoids and Lamellibranchs had lived. This sea was partly transformed into a continent during the Pyrenean phase of the Upper Lutetian and, losing its properties as an open sea, became an inland sea. Meanwhile the erosion began, causing its products to accumulate in that inland sea. The formations found in the center of the area are formed in this way.

Transformation of Lutetian sea into an inland sea also changed the environment. We find an environment proper for the gypsum formation as well as the formation of conglomerate, sandstone, siltstone and marl. The existence of various kinds of gypsum levels are taken as evidence of the fact that this inland sea had deepened or became shallow from time to time. Various types of sedimentary structures (flute cast, load cast, etc.) also show the turbidity currents. At the same time, the living conditions of the organisms were changed. Creating an environment proper for the Cardiums and Ostracods, which are not affected by the salinity of water. Judging from the dissemination of gypsum, it is supposed that a dry climate dominated during this period.

This inland sea existed up to the end of Upper Eocene (Bartonian). It was transformed into a continent by the end of the Pyrenean phase (the end of Bartonian). Our area of survey was not then invaded by the sea until Lower Miocene age and erosion continued for a long time.

No formation representing the Oligocene could be found in the area. Thus, the area must not have been invaded by the sea in the Oligocene.

The area which was a continent during the Oligocene was invaded by sea for the last time in Lower Miocene. Sediments of the Burdigalian sea cover only a small part in the southeast of the area. Outside of this, no outcropping exists within our area of investigation or along the road leading to Gürün. However, formations of Burdigalian age cover large areas in the ESE direction, outside of our area.

The Lower Miocene sea, in which sandstone, sandy limestone and marl were deposited, was a shallow sea. The formations deposited in this sea were folded through the Old Styrian phase at the end of Burdigalian. However, an almost horizontal position of Burdigalian formations gives the idea that Old Styrian phase had not much effect on the area. Following this orogenic phase, the post-Burdigalian volcanic activity had taken place in the area. Basalt flows produced by this volcanism cover Miocene formations as a tabular form.

After the withdrawal of Burdigalian sea through the Old Styrian phase, the area has never been invaded by the sea again. We see the Plio-Quaternary formations deposited in lakes which are the only remnants of this sea. These lakes also withdrew during the Rhodanian phase of the Young Alpine activity. From the horizontal extension of Plio-Quaternary layers, it is understood that Rhodanian phase had not been very active in the area.

VII. ECONOMIC GEOLOGY

There is no mineral deposit of great economic importance in the investigated area. In the southern part of the area some exploratory excavation for chromium ore was carried out in the ophiolitic series by private persons, which did not give encouraging results. In fact, the chrome content of the rock is quite low. The only resources of economic value found in the area are *gypsum, building stones,* and *mineral* waters.

a. Gypsum. —There are gypsum layers with a thickness of 3-12 m in the Darende Formation, in the central part of the area. The thickness and extension of these beds are suitable for exploitation.

b. Building stones. — Well-bedded sandstones which form the Darende Formation have the necessary properties as building material. They are still used in the area for this purpose.

c. Mineral waters. — A spring called locally «Balaban İçmesi» is 2 km east of the Balaban county center. The origin of mineral waters is in relation with a fault trending N-S, 250-300 m east of the spring. The water is taken from its source by simple devices and carried to a concrete reservoir situated 30 m from the source. The first chemical analysis of this water was done by the M.T.A. Institute in 1952. The latest report written about this spring is given by Tamer Ayan (1966).

Chemical analyses of Balaban İçmesi

Physical and chemical properties of the water according to T. Ayan :

Flow	0.1 sec/lt
Temperature	13° C
pH	6 (measured by Nazmi Alpman)
Radioactivity	18 Ş/AVP
Color	Not clear, due to the effect of HCO_3 on concrete.
Precipitation	Present
Smell	Abundant sulphur.

Chemical analysis of the water based on the M.T.A. report dated 25.7.1952, no. 2-1-6-6618

Carbonate hardness (German)	10.36
Total hardness	115.14
Dried residue	3202.0 mg
Calcification residue	3117.6 mg
HCO_3	225.0 mg
SO_4	1897.9 mg
Cl	79.7 mg
SiO_2	48.8 mg
Ca	596.6 mg
FeO	1.2 mg
Mg	136.4 mg
Total alkali (Na kind)	94.4 mg

As a result, the water of this spring is defined as hard (sulphate) water which cannot be used as mineral water. Nevertheless it is still used as mineral water and inhabitants of the area believe that it cures various illnesses of the skin, digestive system, etc.

The Balaban municipality has built some houses near this spring, where more than 2,000 people visit every year.

PETROLEUM POSSIBILITIES

Our area of investigation and its surroundings are located at the edge of a gcosyncline which is suitable for oil formation. Moreover, the extension of sediments in the area; the oil-bearing fractured and comprehensive limostones and dolomitic layers of Jurassic - Lower Cretaceous age; the Upper-Cretaceous reef limestone; as well as marls and gypsum forming a cap rock are all favorable conditions for petroleum accumulation. This belief is confirmed by the occurrence of oil shows in the wells drilled by the M.T A. Institute at Hacılar (Darende), and by the asphalt seepage found near Fatmacık village, east of Balaban.

Jurassic - Cretaceous limestones are fractured and show secondary porosity, therefore they can bear oil in the fractures. In the adjacent areas (Pınarbaşı-Sarız) these limostones are underlain by dolomitic limestones about 80-100 meters thick. If this dolomitic layer exists also in our area of investigation (the base is invisible) and in the neighboring areas, it most probably contains oil.

Biohermal limestones found in the coarse elastics of Maestrichtian age are very important as reservoir. These limestones are found extending over the surface of our area and around the Tohma Stream. The localities, in the adjacent areas where biohermal limestones are covered, would, no doubt, be of very great importance.

The Eocene marl and gypsum layers have the qualities of a cap rock.

The area of survey has no structures suitable for oil trap on the surface, except in small anticlines and synclines. Jurassic-Cretaceous and Upper Cretaceous formations (especially reefs) which form the uplifts in the north and south (those in the south are cut by ophiolites) are not covered by a cap rock. Therefore, they lost their oil possibilities as a structure. More important structures can be found outside of our area. For this reason, M.T.A. Institute is intensely prospecting for petroleum in the region of Malatya - Darende - Gürün.

CONCLUSIONS

We have obtained the following new data on our area of investigation:

1. For the first time the surveyed area was mapped geologically at a 1 : 25,000 scale, then the surroundings of Alidede Tepe north of Darende were mapped in detail with a scale of 1 : 2,000.

2. The formations found in the area were studied as lithostratigraphic units, according to stratigraphic rules, and were named for the first time in this area.

3. It was determined that the area is bordered by two uplifts in the north and in the south, and the area between them, where Tertiary and younger sediments were deposited, is found to have the characteristics of a basin. Therefore it is called the «Darende - Balaban Basin».

4. The stratigraphic succession in the area was studied in detail and formations found in the northern and southern halves of the area were correlated.

5. The surface exposures of Geniz Limestone were found to be of Upper Jurassic - Lower Cretaceous age. In the text they are explained as having been deposited in a sea which existed from Jurassic (Lias) up to the end of Lower Cretaceous (Albian).

6. Lower Jurassic - Lower Cretaceous comprehensive limestones are found to have deposited in a shallow and stable sea within the borders of a geosyncline.

7. Maestrichtian formations are found to overlie transgressively the ophiolitic series and Jurassic - Lower Cretaceous limestones.

8. Upper Cretaceous (Maestrichtian) sediments are divided into three lithostratigraphic units as reef limestones (Tohma Reefs), coarse elastics (Ulupınar Formation) and bedded limestones (Kırankaya Limestone).

9. Reef limestones found at the bottom of Upper Cretaceous formations are studied in detail as shore-line reefs of «biohermal» type.

10. The variegated Maestrichtian strata —described as «flysch» in previous studies— was found to be detrital, coarse elastics deposited in a shallow sea and not of flysch sedimentation.

11. The Upper Cretaceous sea in pur area was a shallow sea, which gradually deepened toward NNW.

12. The limestones found to the northwest of our area are not of Eocene age, as mentioned in previous studies; they are Jurassic - Lower Cretaceous limestones and Maestrichtian formations.

13. Eocene sediments of the area were studied as rock units and their lateral transitions are shown on the map.

14. The gypsum formations, considered as belonging to Oligo-Miocene or Oligocene age in previous studies, were found to contain micro and macrofossils. According to these fauna arid their stratigraphic position, these formations are attributed to Upper Eocene (Bartonian).

15. Various types of sedimentary structures are observed in the fine-grained sandstone and siltstone layers of Bartonian age. Graphical evaluation of measurements taken from these sedimentary structures showed that a turbidity current with a NW-SE trend had taken place in that age.

16. Gypsum formations of our area are found to contain only limestone-gypsum depositions, unlike, the evaporite basins where a sequence of limestone-gypsum-salt deposition takes place. That is, our area has not completed the evaporite cycle.

17. Ophiolitic series which is composed of serpentines, spilites, etc. cuts the Jurassic - Lower Cretaceous limestones, and this igneous activity took place in Turonian.

18. Igneous rocks found in the northeast part of our area were defined as ophiolitic series in previous studies. We have determined that they are igneous rocks of pre-Lutetian age which are composed of basalt, agglomerate and tuffs.

19. Young basalt flows of post-Burdigalian age overlie horizontally all the formations, including Burdigalian.

20. Tuffs, found at least in two levels in basalt, show that the volcanic activity had at least two phases.

21. Tectonic structure of the area is studied in detail. Approximate strikes and dips of axes of folds are evaluated by use of diagrams.

22. Tertiary formations are found to have strike-slip faults with a NE-SW trend. Accordingly, horizontal movements with NW-SE direction dominated the area. Only the Plio-Quaternary sediments are affected by vertical movements.

23. Our area of investigation was affected by Alpine orogeny and the following phases were determined: a) Vorgosau (Austric) phase, b) Laramian phase, c) Pyrenean phase, d) Old Styrian phase, c) Quaternary activities.

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B I B L I O G R A P H Y

1 — ARNI, P. (1939) : Über die tektonischen Grundzüge Ost-Anatoliens und benachbarter Gebiete. *M.T.A. Publ.,* ser. B, no. 4, Ankara.

2 — AKKUŞ, M. F. (1970) : Litho-stratigraphic units in the Darende-Balaban basin (Malatya, ESE Turkey) and new knowledge concerning the age of gypsiferous formations. *M.T.A. Bull.* no. 75, Ankara.

3 ————(1963) : Upper Jurassic in the areas of Dağakçeköy (SW Bursa) and Fındıklı (SW Gönen). *Bull. Geol. Soc. Turkey,* vol. VIII, no. 1-2, Ankara.

4 ————(1962) : 1 : 25 000 ölçekli Malatya K39-d4 paftasının detay petrol etüdü. *M.T.A Rep.* no. 4043 (unpublished), Ankara.

5 — (1963) : Gürün bölgesi genel jeolojisi ve petrol imkanları (1:25 000 ölçekli Elbistan K38-a3; dl; d4 paftaları). *M.T.A. Rep.* no. 4063 (unpublished), Ankara.

6————(1964) : 1 : 25 000 ölçekli Divriği l39-d2 paftasının detay petrol etüdü. *M.T.A. Rep.* no. 4039 (unpublished), Ankara.

7 — ; TERNEK, Z. & KURTMAN, F. (1966) Iran petrol bölgelerinde yapılan tetkikler. *Bull. Geol. Soc. Turkey,* vol. X. no. 1-2, Ankara.

8 — AYAN, T. & BULUT, C. (1964) : General geology of the area defined by the polygone Balaban-Yazıhan - Kurşunlu - Levent (vilayet Malatya). *M.T.A. Bull.* no. 62, Ankara.

9 — AYAN, T. (1963) : Darende batısındaki Hezanlı - Işkın ve Tüde dağlarının (Elbistan K38-c4, L38-a2, SE) detay jeolojisi ve petrol imkanları. *M.T.A. Rep.* (unpublished), Ankara.

10 — (1966) : Balaban (Darende) içmecesi hidrojeolojik raporu. *M.T.A. Rep.* (unpublished), Ankara.

11 — BAYKAL, F. (1948) : Paleontoloji (omurgasız fosiller). *İst. Üniv. Yayınl.,* no. 384, İstanbul.

12 — — (1944) : Malatya - Kayseri arasındaki Toroslar'ın jeolojik yapısı. *M.T.A. Rep.* no. 1703 (unpublished), Ankara,

13 — (1945) : Darende ile Kayseri arasındaki Toroslar'ın jeolojik yapısı. *İst. Üniv. Fen. Fak. Mecm.,* ser. B, vol. 10, no. 2, İstanbul:

14 — (1965) : Malatya-Darende-Gürün bölgesindeki yeşil sahrelerle sediment kayaçlar arasındaki ilişki. *M.T.A, Rep.* no. 1257 (unpublished), Ankara.

15 —————(1966) : Explanatory text of the Geological Map of Turkey, l:500,000-scale, sheet Sivas. *M.T.A. Publ,* Ankara.

16— (1967) : Stratigrafi Prensipleri. *Kutulmuş Matbaası,* İstanbul.

17 — BENTZ, F. P. (1961) : The terms Flysch and Molasse and their application. *Bull. Geol. Soc. Turkey.* vol. VIII, no. 2, Ankara.

18 — BLUMENTHAL, M. (1938) : Şarki Toros mıntıkasında Hekimhan-Hasançelebi-Kangal irtifaında jeolojik araştırma (Malatya ve Sivas vilayetleri). *M.T.A. Rep.* no. 570 (unpublished), Ankara.

19 — (1944) : Contribution a la connaissance du Permo-Carbonifere du Taurus entre Kayseri - Malatya *M.T.A. Mecm.* no. 31, Ankara.

20 — CLOUD, P.E., Jr. (1950) : Cretaceous and Tertiary reef formations and associated sediments in Middle East. *A.A.P.G. Bull.,* vol. 34, pp. 215-238.

21 — (1952) : Facies relationships of organic reefs. *A.A.P.G. Bull.,* vol. 36, pp. 2125-49.

22 — CUMMINGS (1932) : Reefs or bioherm. *Bull. Geol. Sod. Amer.,* vol. 43, pp. 331-352.

23 — CHAPUT, E. (1936) : Voyages d'etudes geologiques et geomorphogeniques en Turquie. *Mem. Inst. Fr. de Stamboul.*

24 — DEMİRTAŞLI, E. & AYAN, T. (1963) : Darende- Gürün ara bölgesinin detay jeolojisi ve petrol imkanları. *M.T.A. Rep.* (unpublished), Ankara.

25 — DEMİRTAŞLI, E. (1967) : Mağara ve Sarız ilçesine bağlı Katarası ve Gümüşalı köyleri civarında ölçülen 1:2000 ölçekli detay stratigrafik kesitlerin korelasyonu ile Pınarbaşı - Sarız - Mağara ilçeleri arasındaki sahanın litostratigrafi birimleri ve petrol-İmkanları. *M.T.A. Rep.* (unpublished), Ankara.

26 — DUMBAR, RODGERS (1967) : Principles of Stratigraphy. J. *Wiley & Sons, Inc.,* New York.

27 — ERENTÖZ, C. (1966) : Contribution a la stratigraphie de la Turquie. *M.T.A. Bull.* no. 66, Ankara.

28 — GATTINGER, T. E. (1958) : Vorbericht über die Revisionsarbeiten des Jahres 1957—M. 1 : 100 000 im Raume Malatya-Elazığ. *M.T.A. Rep.* no. 2997 (unpublished), Ankara.

29 — İZDAR, E. (1963) : Geologischer Bau, Magmatismus und Lagerstatten der östlichen Hekimhan-Hasançelebi Zone (Ost-Anatolien). *M.T.A. Publ.,* no. 112, Ankara.

30 — KETİN, İ. (1959) : The orogenic evolution of Turkey. *M.T.A. Bull.* no. 53, Ankara.

31——————(1960) : Notice explicative de la carte tectonique de Turquie au 1 : 2,500,000e . *M.T.A: Bull.* no. 54, Ankara.

32——————(1962) : Geological Map of Turkey (Kayseri, 1 : 500,000). *M.T.A. Publ.,* Ankara.

33——————(1966) : Tectonic units of Anatolia (Asia Minor). *M.T.A. Bull.* no. 66, Ankara.

34 — KRUMBEIN, SLOSS (1963) : Stratigraphy and sedimentation. *W. H. Freemann & Company,* San Francisco.

35 — KURTMAN, F. (1961) : Geologie des Gebietes zwischen Sivas und Divriği sowie Bemerkungen über die Gipsserie. *M.T.A. Bull.* no. 56, Ankara.

36————— (1962) : 1 : 25 000 ölçekli Malatya L39-al paftasında yapılan petrol etüdü. *M.T.A. Rep.* (unpublished), Ankara.

37——————(1963) : Gürün bölgesinde Elbistan K38-bl ve K38-b4 paftaları içine giren sahanın petrol etüdü. *M.T.A. Rep.* (unpublished), Ankara.

38 — LINK, A. Th. (1950) : Theory of transgressive and regressive reef (bioherm) development and origin of oil *A.A.P.G. Bull.,* vol. 34, no. 2, pp. 263-294.

39 — MacNEIL, F.S. (1954) : Orogenic reefs and banks and associated detritic sediments. *Amer. Jour. Sci.,* vol. 252, pp. 358-401.

40 — — (1954) : The shape of atolls: An inheritance from subaerial erosion forms. *Amer. Jour. Sci.,* vol. 252, pp. 402-427.

41 — NORMAN, T. (1963) : Silurian (Ludlowian) paleo-current directions in the lake district area of England. *Bull. Geol. Soc. Turkey,* vol. VIII, no. 1-2, Ankara.

42 —(1962) : 1:25 000 ölçekli Elbistan K38-b3 ve Malatya K39-d1 paftalarının genel jeolojisi hakkında rapor. *M.T.A. Rep.* (unpublished), Ankara.

43 — PAREJAS, Ed. (1940) : La tectonique transversale de la Turquie. *Rev. Fac. Sci. Univ. İstanbul.*

44 — PETTIJOHN (1957) : Sedimentary Rocks. *Harper & Brothers,* New York.

45 -— STCHEPINSKY, V. (1944) : Rapport sur la geologie et les ressourccs minerales de la region de Malatya sud. *M.T.A. Rep.* no. 1491 (unpublished), Ankara.

46 ——————(1944) : Rapport sur la geologie et les ressources minerales de la region de Malatya nord. *M.T.A. Rep.* no. 1486 (unpublished), Ankara.

47 ——————(1944) : Geologie et ressources minerales de la region de Malatya (Turquie). *M.T.A. Mecm.* no. 31, Ankara.

48 — ÜRGÜN, S. (1963) : 1:25 000 ölçekli Elbistan K38-c3 paftası içinde kalan sahanın petrol jeolojisi bakımından etüdü. *M.T.A. Rep.* (unpublished), Ankara.

49 — WELLER (1960) : Stratigraphie principles and practice. *Harper & Brothers,* New York.

50 — WIRTZ (1955) : Bericht über die geologischen Aufnahmen im Gebiet von Malatya und der Tohmasuyu-Depression. *M.T.A. Rep.* no. 2364 (unpublished). Ankara.

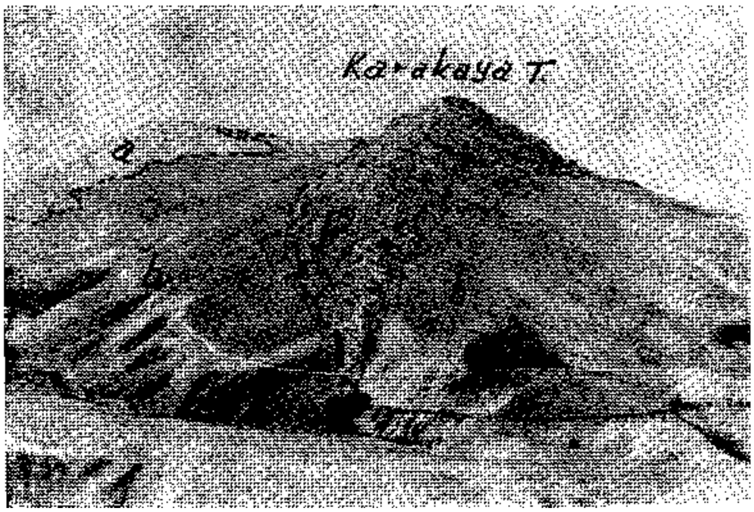


Photo 1

Cut of Geniz Limestone by ophiolites at Karakaya Tepe, south of the surveyed area.

a - Geniz Limestone; b - Ophiolitic series.

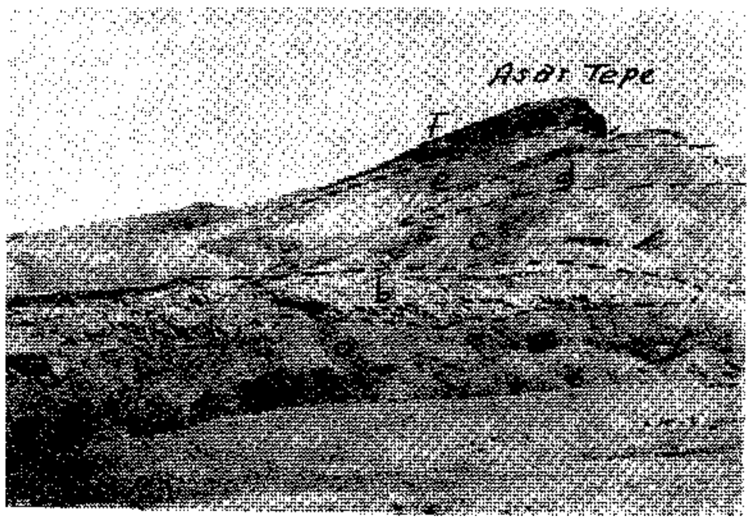


Photo 2

Tohma Reefs (biohermal) overlying ophiolites, south of Asar Tepe.

a - Ophiolitic series; b - Tohma Reefs; c - Ulupınar Formation; d - Karankaya Limestone; e - Yenice Formation; f - Asar Tepe Limestone (b, c, d Maestrichtian; e, f = Lutetian).

Photo 3

Appearance of one of the Tohma Reefs (biohermal) along Tohma Stream.

a - Tohma Reefs; b - Ulupınar Formation; c - Eocene limestone; d - Miocene limestone.

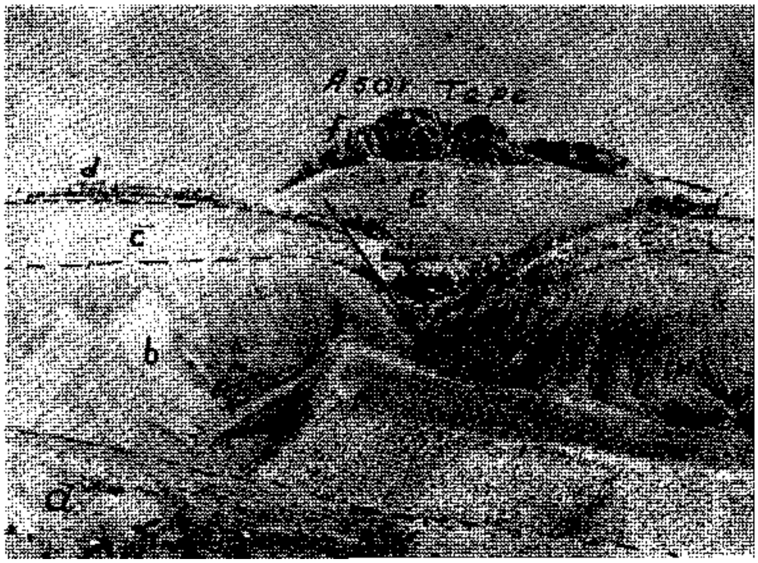


Photo 4

View of formations overlying ophiolitic series south of Asar Tepe.
a - Ophiolitic series; b - Ulupınar Formation; c - Kırankaya Limestone; d - Korgan Tepe Conglomerate; e - Yenice Formation; f - Asar Tepe Formation (b, c = Maestrichtian; d, e, f = Lutetian).

Photo 5

View east of Kantaruz Boğazı, pre-Lutetian. a - Karakayalar Volcanites overlain by b - Korgan Tepe Conglomerate and sandstone beds (Lutetian); c - Jurassic-Cretaceous limestone.

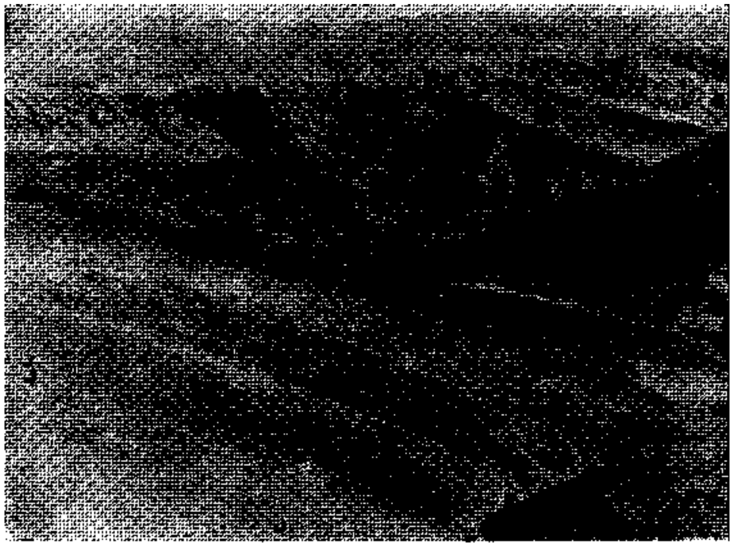


Photo 6

a - Karakayalar Volcanites at Sersi Tepe overlain by b - Korgan Tepe Conglomerate and c - Asar Tepe Limestone.

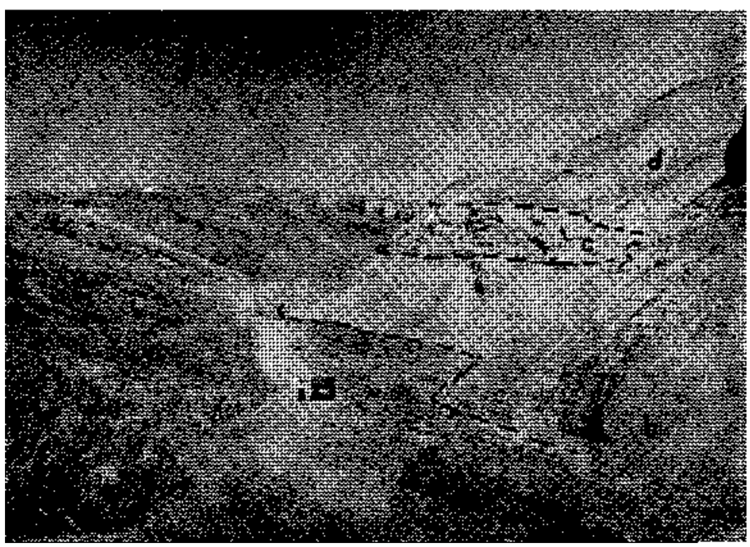


Photo 7

Asar Tepe Formation along the road between Darende and Ayvalı.
a - Limestone; b - Marly limestone; c - Gypsum; d - Alternation of sandstone-marl (c, d = Darende Formation).

Photo 8

Ayvalı Tohması meander which flows in the limestones of Asar Tepe at Kantaruz Boğazı. a - Asar Tepe Limestones; b - In the background the synclinal in the Darende Formation.

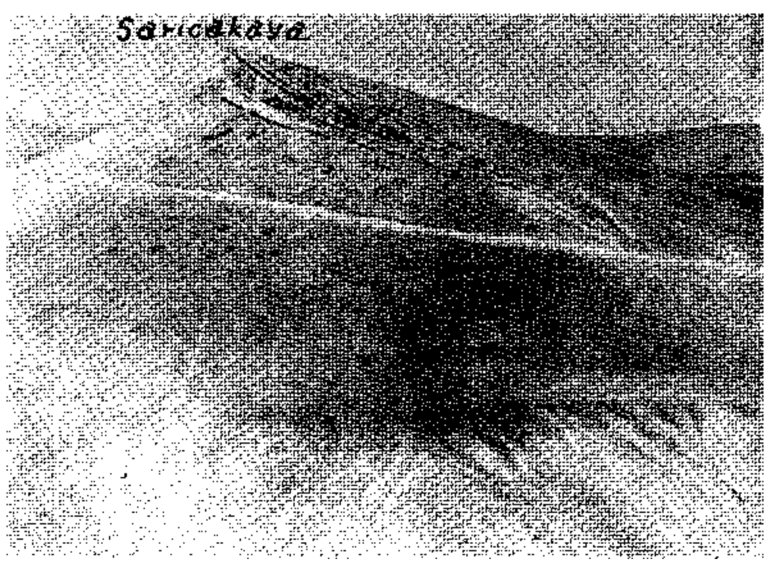


Photo 9

Wedging out of Asar Tepe Limestone in marls, northwest of Yenice village.

Photo 10

Front view of Darende Formation overlying conformably the Asar Tepe Formation along the road leading to Ayvalı from Darende and which begins with gypsum.
a - Limestone; b - Marl (a, b Asar Tepe Formation Lutetian); c - Gypsum; d - Sequence of sandstone-marl (c, d Darende Formation Bartonian).

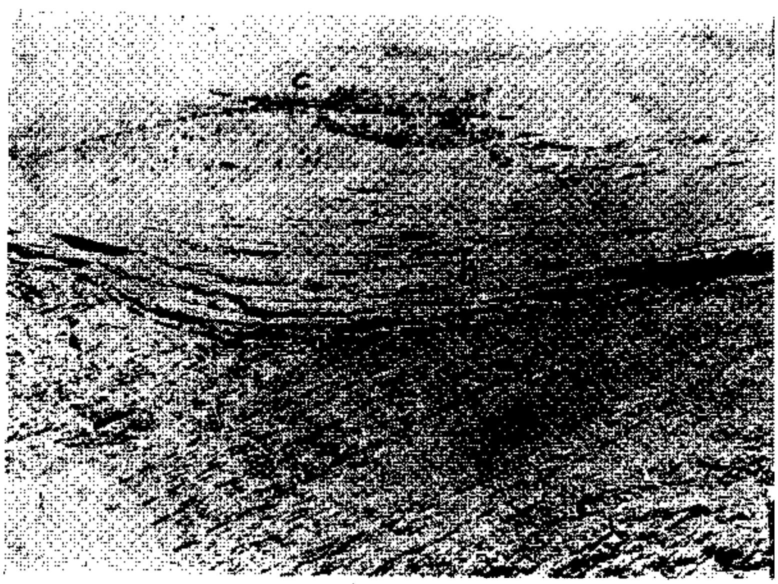


Photo 11

View of Lutetian limestones overlying unconformably the Jurassic-Cretaceous limestones on the road leading to Malatya (near Karahan Çeşmesi), and of horizontal Burdigalian limestones.
a - Jurassic-Cretaceous limestones; b - Lutetian limestone; c - Burdigalian limestone.

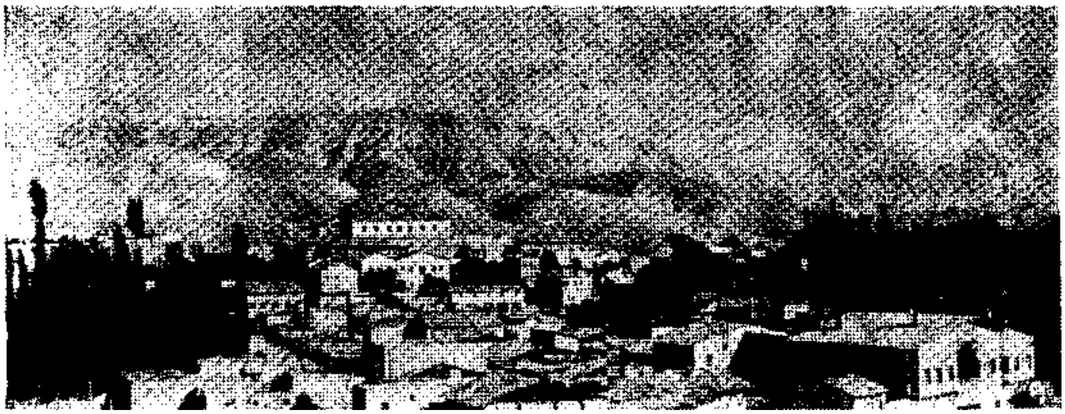


Photo 12

View of Darende and in the background sequence of the Darende Formation.

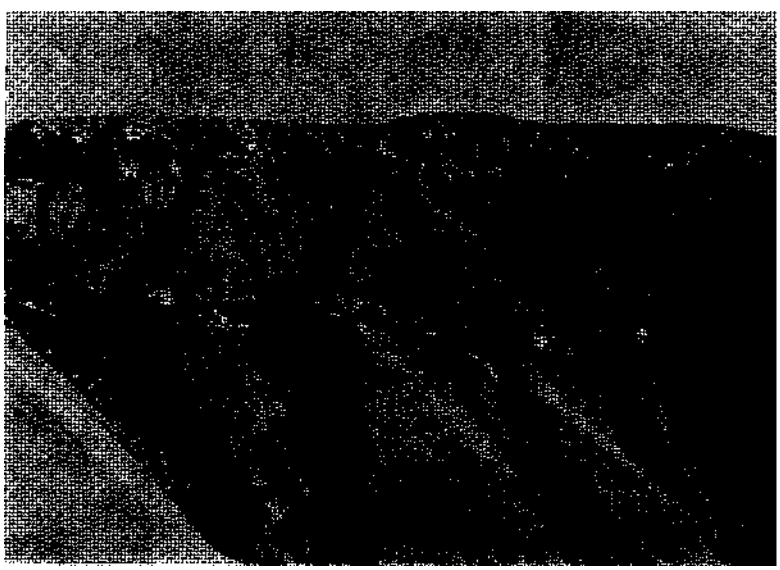


Photo 13

A view from the Darende - Ayvalı road. a - Asar Tepe marls overlain conformably by b, c - two gypsum layers of the Darende Formation.

Photo 14

Conglomerate-sandstone-marl sequence of Balaban Formation (between Aşağı Ulupınar and Yukarı Ulupınar villages, on the road to Malatya).

Photo 15

a - Yenice Formation east of Asar Tepe; b - Asar Tepe Limestone and c - Balaban Formation lying conformably over it; d - in the background the view of basalts overlying them horizontally.

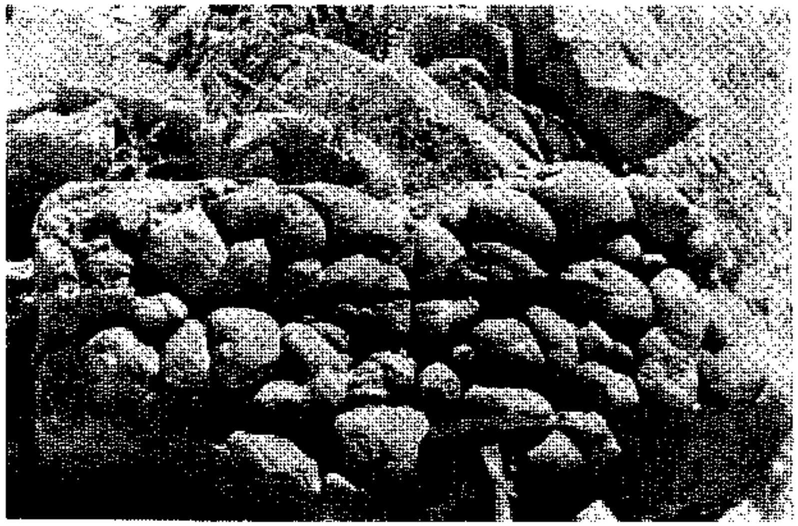


Photo 16

Load cast of the Darende Formation over fine-grained sandstone-siltstone layers.

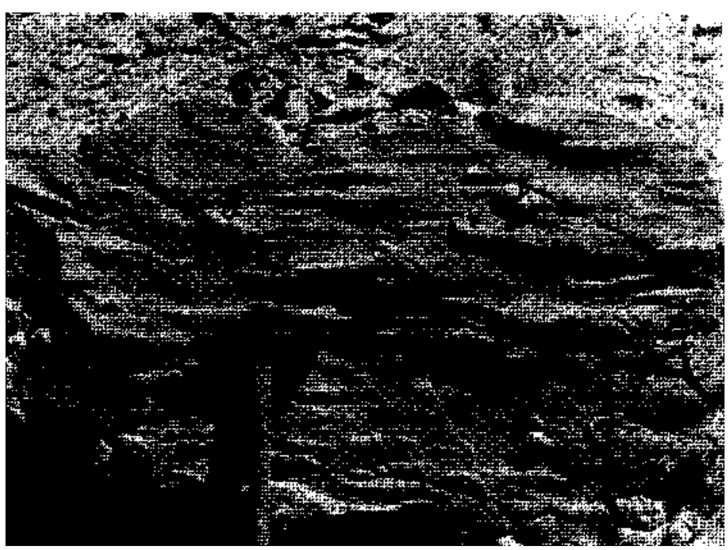


Photo 17

Flute cast of the Darende Formation over fine-grained sandstone-siltstone layers.

a - Wedges; b - Flute openings. (Flow is from left to right.)

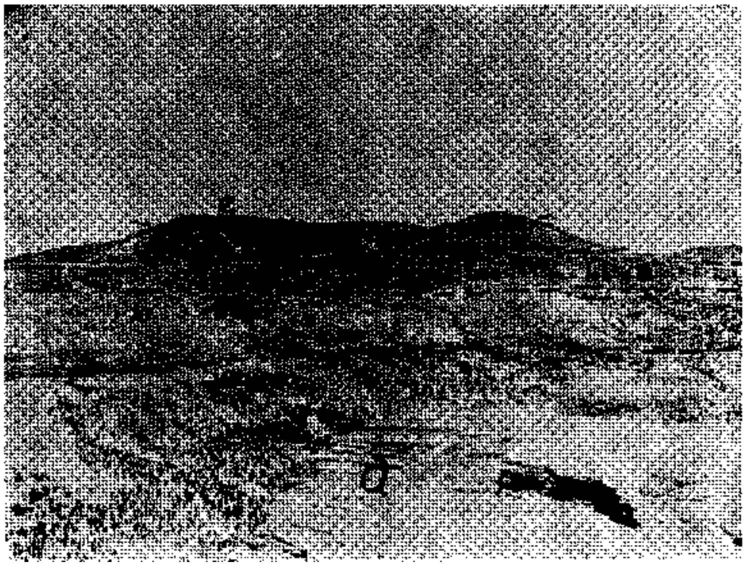


Photo 18

Horizontal position of Burdigalian limestones over Lutetian limestones and of post-Burdigalian tuffs and basalts overlying them (west of Hasanağa Stream).

a - Lutetian limestones; b - Miocene sandstone-marl beds; c - Miocene limestones; d - Post-Burdigalian tuffs; e - Post-Burdigalian basalts.

Photo 19

Angular unconformity of Plio-Quaternary beds horizontally overlying the Asar Tepe marls at Darende.

a - Asar Tepe marls with sandstone intercalation (Lutetian); b - Plio-Quaternary layers.

Photo 20

Maestrichtian (a), Lutetian (b), and Upper Eocene (c) formations overlain by Kepez Dağı basalts (d) east of Yukarı Ulupınar village.

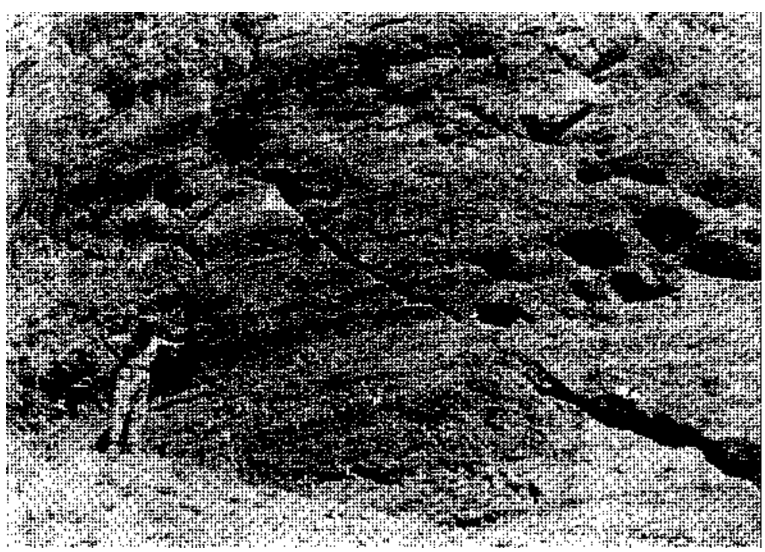


Photo 21

Strike-slip fault plane observed in the Asar Tepe Limestones at the Darende-Ayvalı road.

a - Lines showing horizontal movement over polished surface.

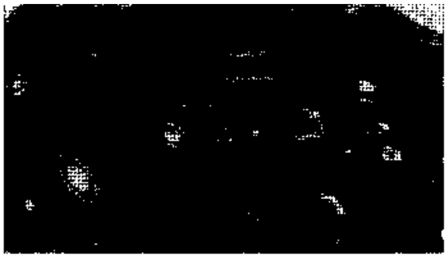


Photo 22
a - *Hensonella cylindrica* (Algae);
b - *Salpingoporella* sp. (Algae)
(Neocomian-Barremian).

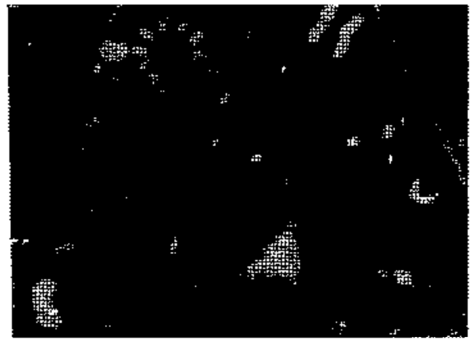


Photo 23
X - *Clypeina jurassica* (Algae) (Dogger-Malm).

Photo 24
X - *Valvulinella jurassica*
(Dogger-Malm).

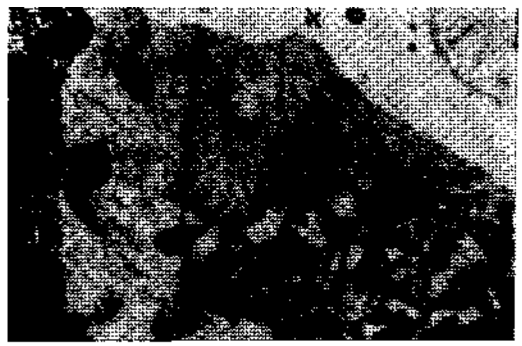


Photo 25
X - *Macroporella pigmaea* (Algae) (Lias).

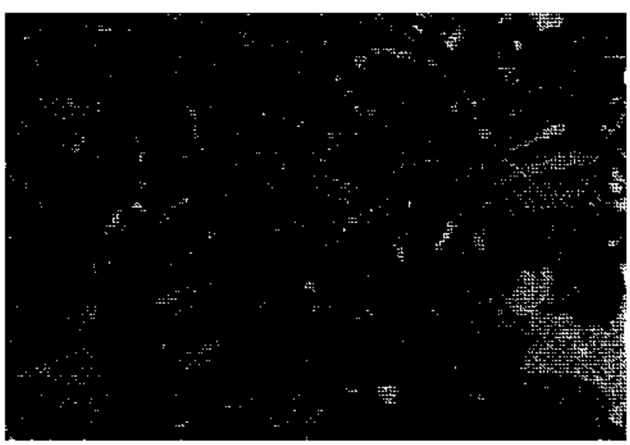


Photo 26
Thin section of orbitoidal limestone. a - *Orbitoides media* d'Arch. (Maestrichtian).

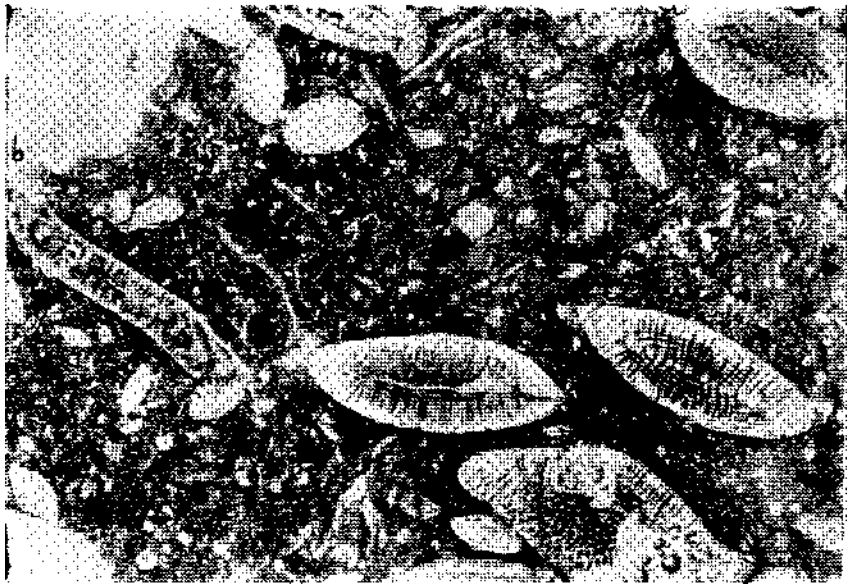


Photo 27
Thin section of Nummulitic limestone (south of Asar Tepe).
a - *Nummulites uroniensis;*
b - *Assilina* sp. (Lutetian).

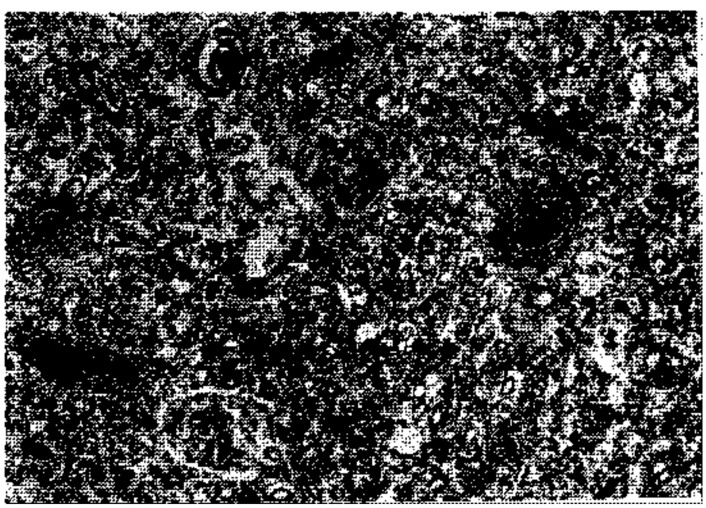


Photo 28
Thin section of limestone with Alveolina of Eocene age (south of Karahan fountain).
a - *Alveolina* sp.; b - Miliolidae (Lower Lutetian).

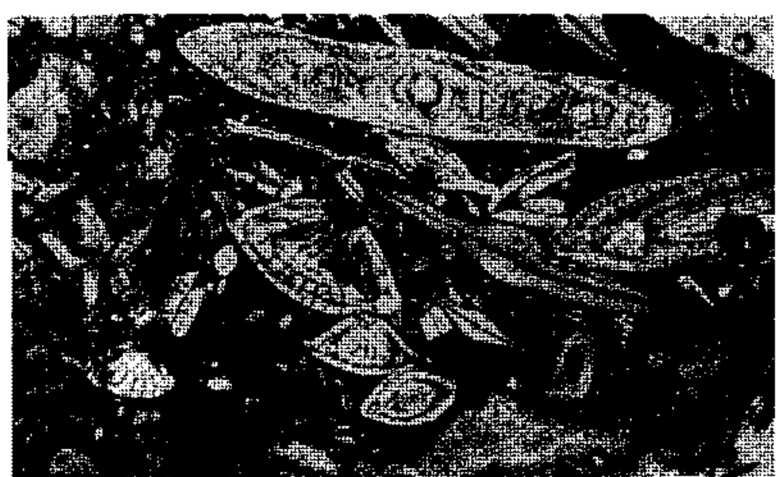


Photo 29
Thin section of limestone with Nummulites and Discocyclina (Büyük Çorak plain).
a - *Nummulites helveticus* Kauf.;
b - Discocyclina (Upper Lutetian).

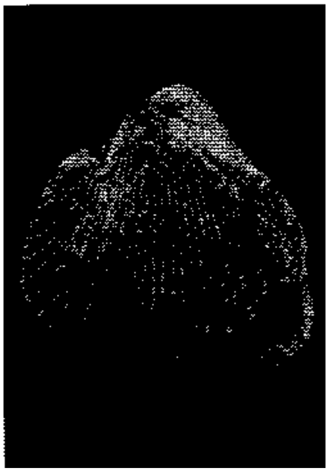


Photo 30/a

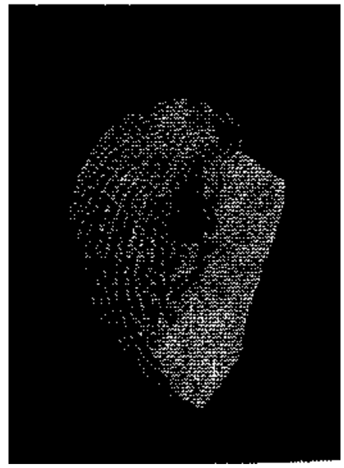
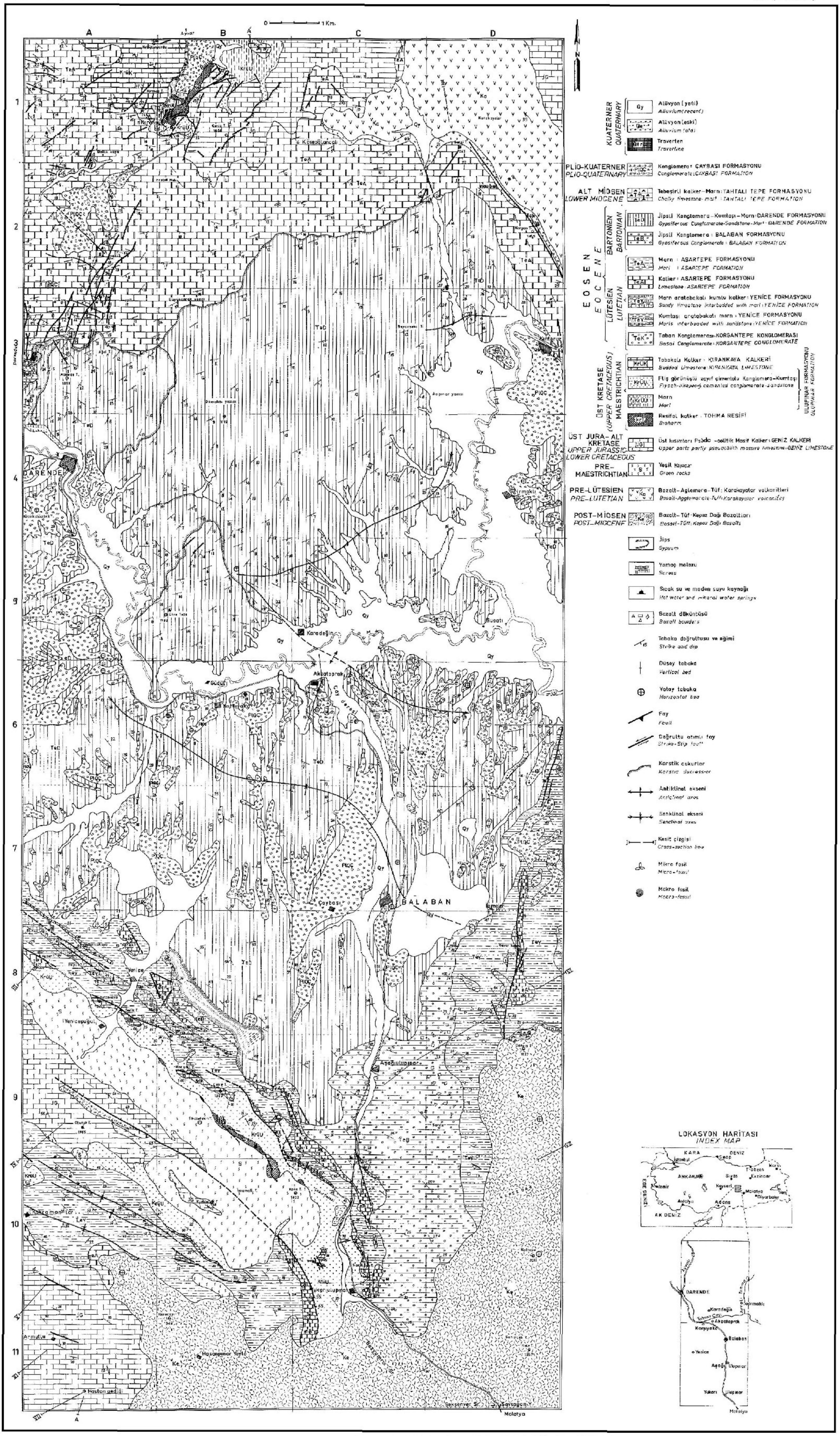


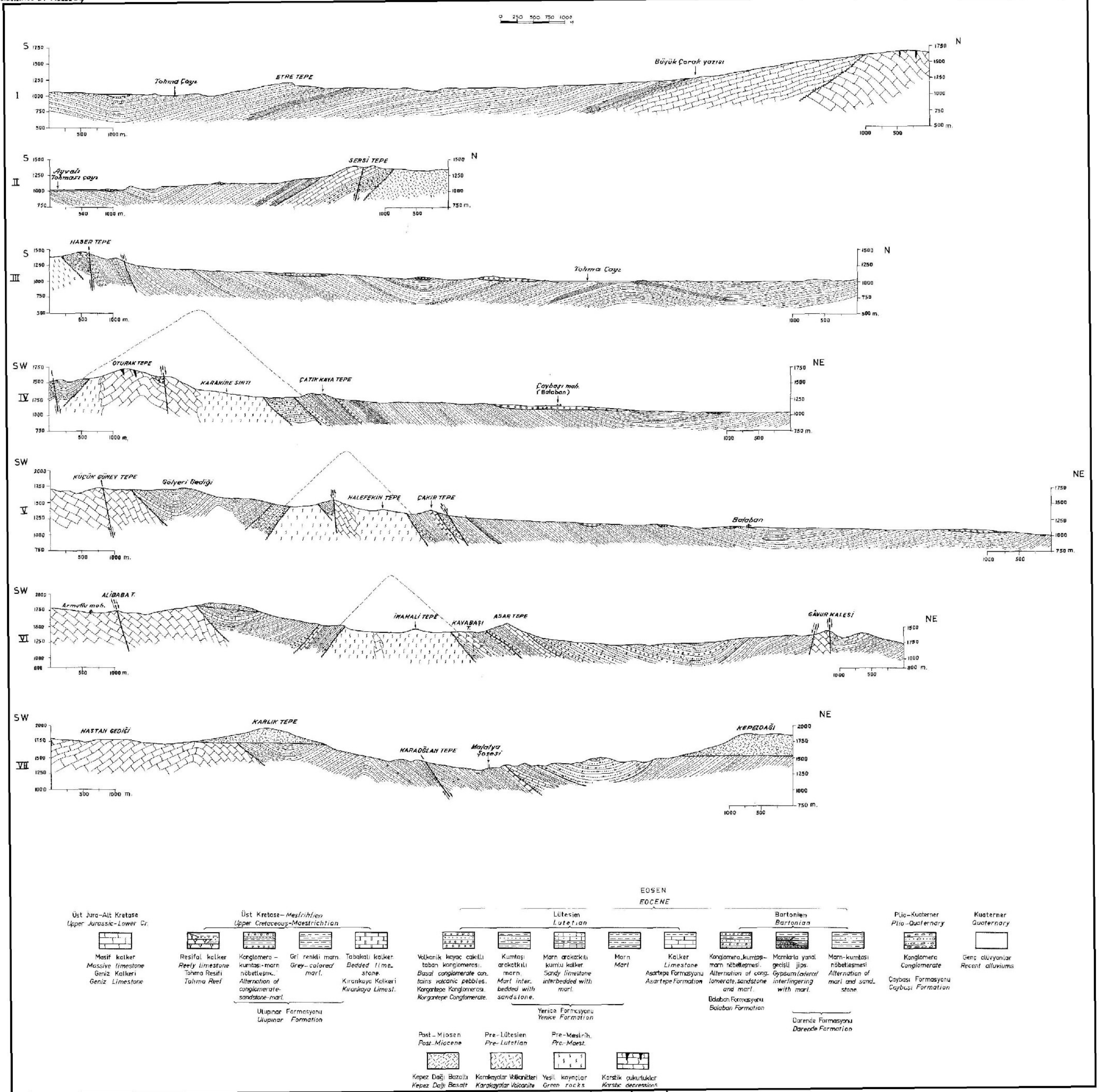
Photo 30/b

Cardium cf. *granconense* found in the marl levels of the Darende Formation (Bartonian).
a - Two valves seen from above; b - Lateral view of a single valve.



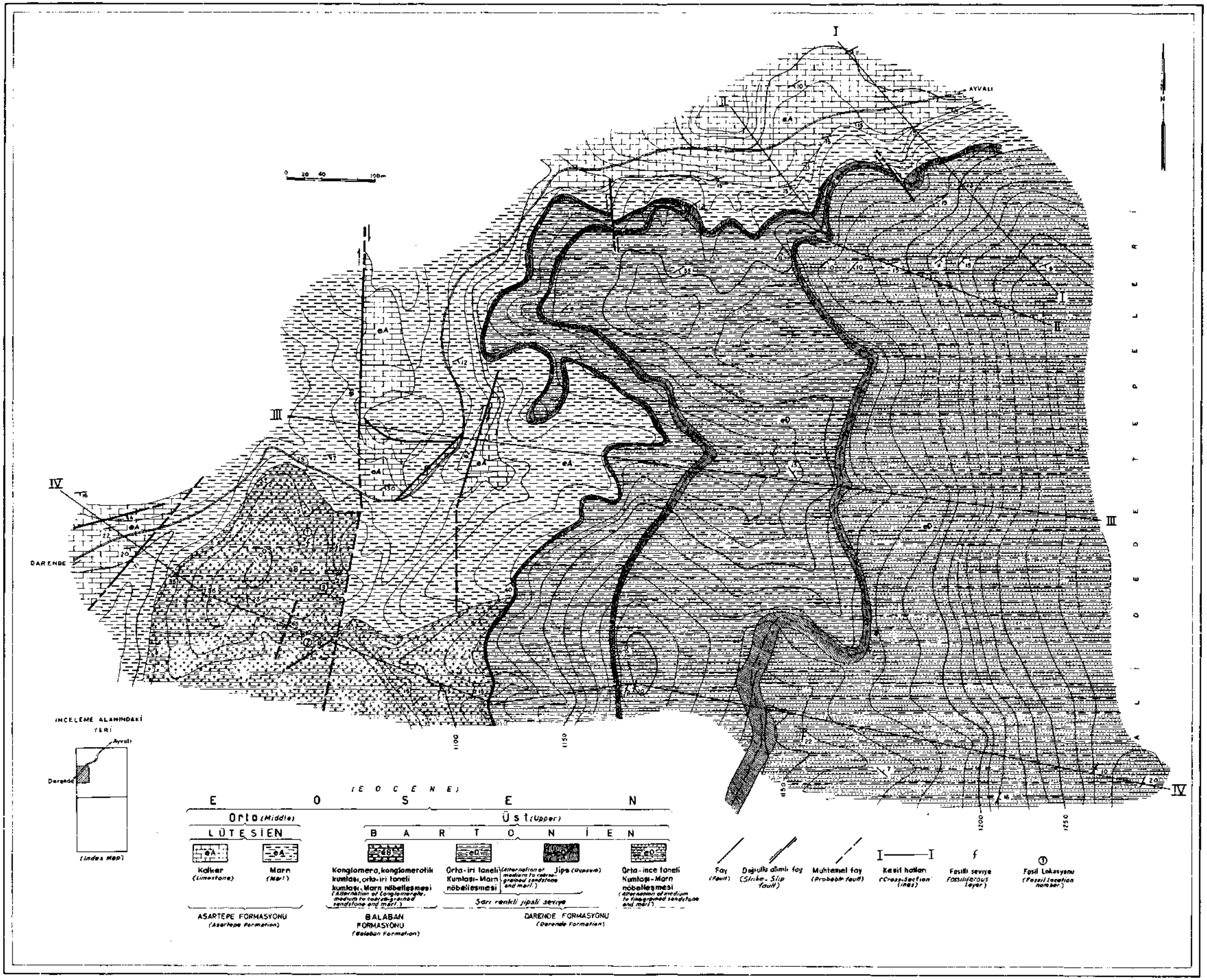
DARENDE - BALABAN HAVZASININ (MALATYA) JEOLOJİ HARİTASI

(GEOLOGIC MAP OF THE DARENDE - BALABAN BASIN, MALATYA - ESE TURKEY)



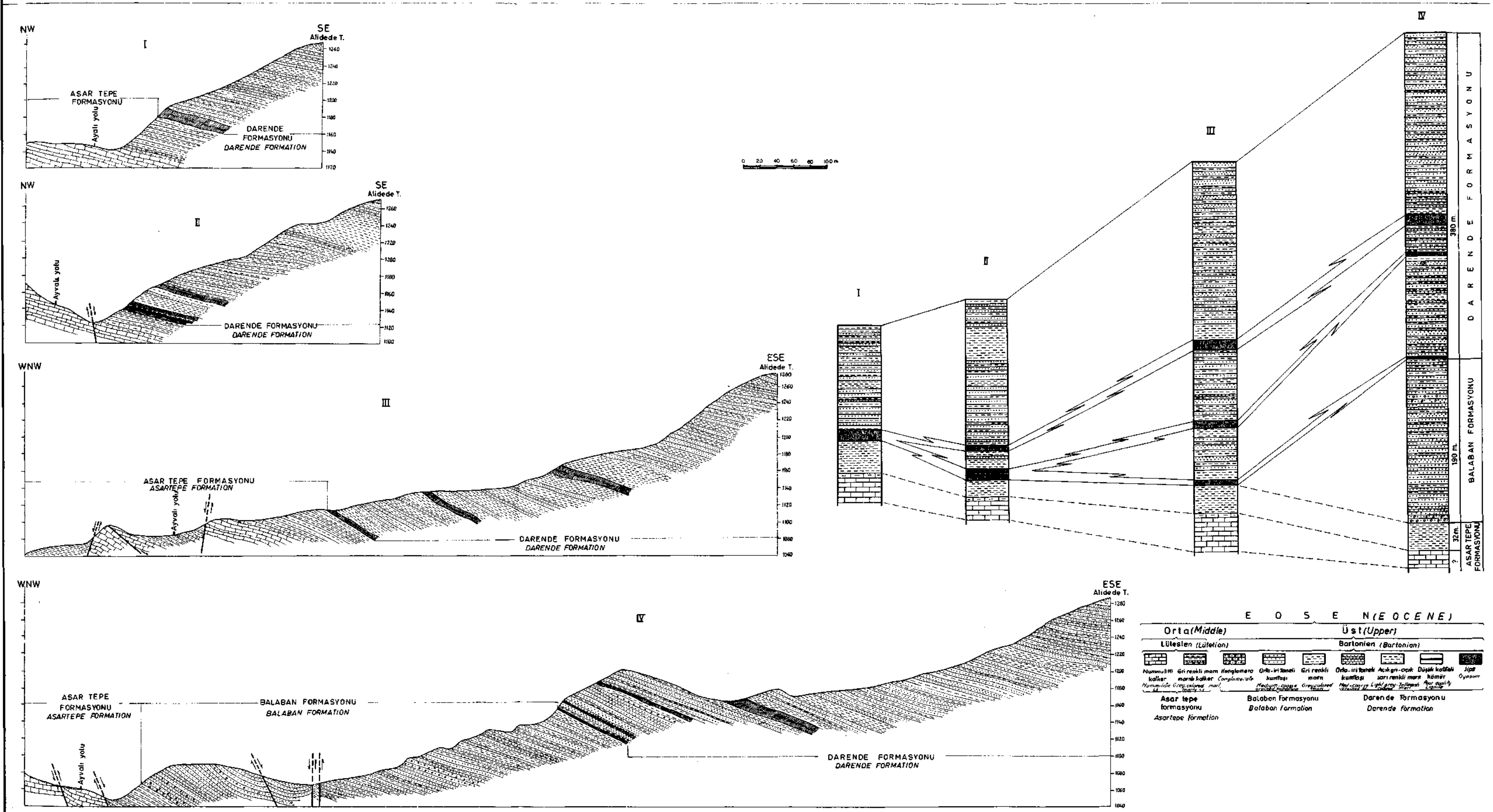
İNCELEME ALANI JEOLOJİK KESİTLERİ

(GEOLOGIC CROSS-SECTIONS OF THE INVESTIGATED AREA)



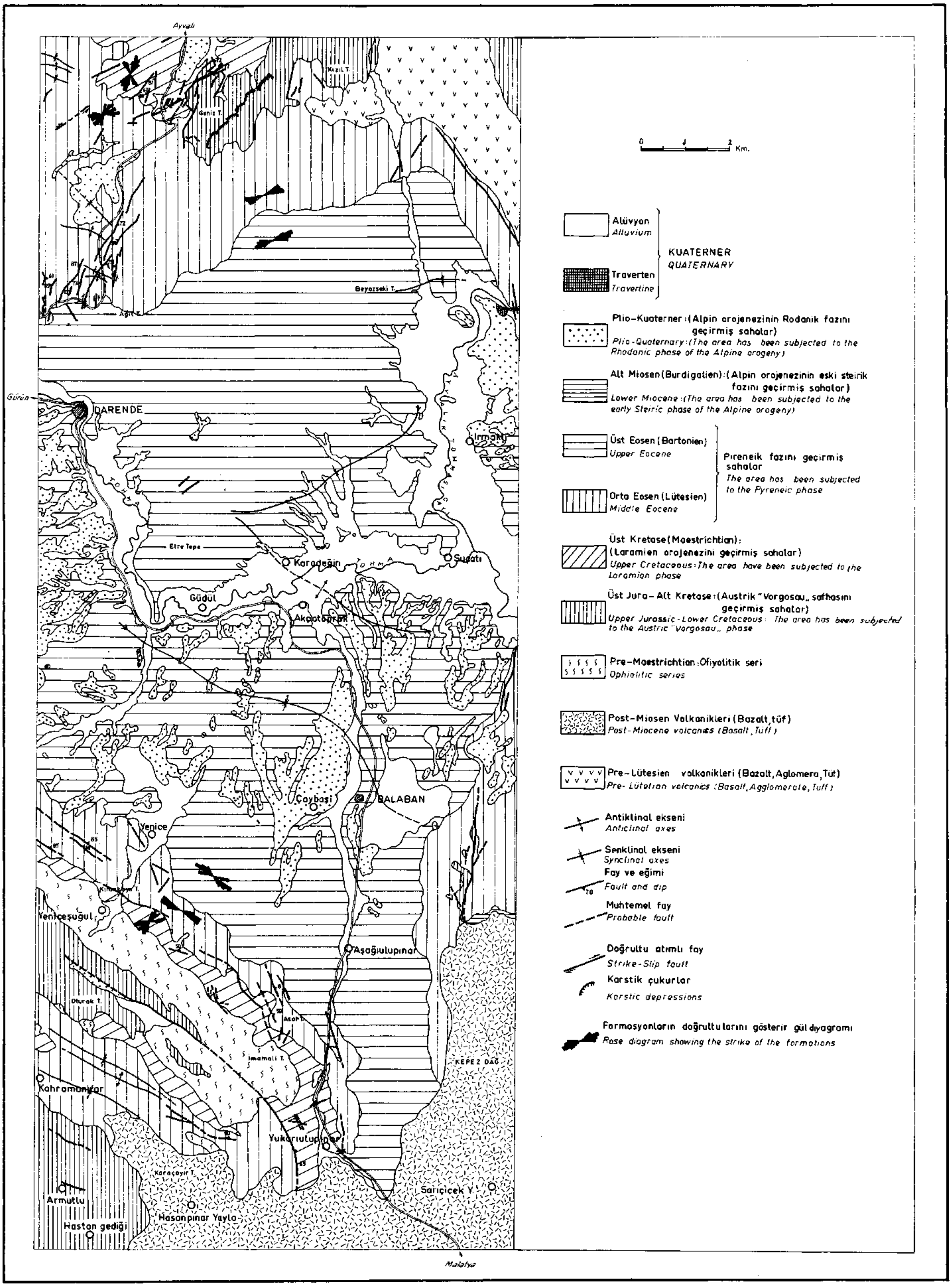
DARENDE - AYVALI YOLU ILE ALİDEDE TEPESİ ARASINDAKİ SAHANIN JEOLOJİ HARİTASI

(GEOLOGIC MAP BETWEEN THE AREA OF DARENDE - AYVALI ROAD AND ALİDEDE TEPE)



DARENDE - AYVALI YOLU İLE ALİDEDE TEPESİ ARASINDAKİ SAHANIN JEOLOJİK KESİTLERİ VE STRATİGRAFİK KORELASYONU

(GEOLOGIC CROSS-SECTION BETWEEN DARENDE - AYVALI ROAD AND ALİDEDE TEPE AND THEIR STRATIGRAPHIC CORRELATION)



DARENDE - BALABAN HAVZASININ TEKTONİK HARİTASI
(TECTONIC MAP OF THE DARENDE - BALABAN BASIN)