# GEOLOGY OF THE ÇANDIR (KALECİK) AREA

Şuayip ÜŞENMEZ

*Geology Department of Ankara University, Faculty of Science*

## INTRODUCTION

The area under investigation is Malı Deresi and the nearby regions. It is located around the road between Ankara-Çankırı and includes the Kalecik - Çandır sector (Location map, Fig. 1.) The studied area is generally made up of ophiolitic formations which are recognized as chromite-bearing rocks in Turkey and in the neighboring countries. The ophiolitic rocks are well exposed along the Malı Deresi, since the Malı Valley cuts across these formations forming cross sections up to 400 m in thickness. The formations are also tectonically complicated. Therefore it is thought that it would be interesting to study these rocks along the Malı Valley in order to work out its tectonism and to evaluate its potential from the economical geology point of view.

The field work started in December 1967 and was carried out until December 1972. The area is 260 $km^2$ and covers the Çankırı H 30-$b_3$, H 31-$a_4$, H 30-$c_2$, H 31-d1 map sheets. The results of the field and laboratory studies were submitted as a Doctorate Thesis to the Geology Department of Ankara University, Faculty of Science. It is hoped that this research would be a starting point for more detailed work in the area which is geologically very complex in nature.

## I. GEOGRAPHICAL SETTING

The studied area is situated in the northern part of the Ankara region. It is characterized by the mountain ranges and the plains amongst the mountains, which generally lie in the NE-SW direction. It is also known as a part of the typical Anatolian plateau. The area is bordered by the Terme Stream in the north, the Kalecik area in the south, the Kızılırmak River in the east, and the Hasayaz area in the west (Fig. 1).

The most significant topographic feature in the area is the Malı Valley. This valley starts from the north of the Avkaz village, lying in the E-W direction, and continues until the western banks of the Kızılırmak River, for a distance of about 8-10 km. The Bostandere River, which passes to the north of the Avkaz village, joins the Malı Valley. The continuation of the Bostandere River, called the Özdere River, and the Handere River, which starts from the Hacıköyhanı, both join the Malı Valley lying in the NW-SE direction. In addition, Sarıindere and Karakaya can be mentioned as the most important streams in the area. All of these rivers feed the Malı Valley with the alluvial materials and the water derived from seasonal rain and snow. It appears that the erosion on the slopes of the valley is a slow process due to the fact that these slopes consist of igneous rocks. The sedimentary rocks in the valley arc the products of a very young deposition.

The vegetation cover in the area is very poor. The landslides are frequent, especially in the rainy seasons. These landslides are caused by the following factors: a poor vegetation cover,

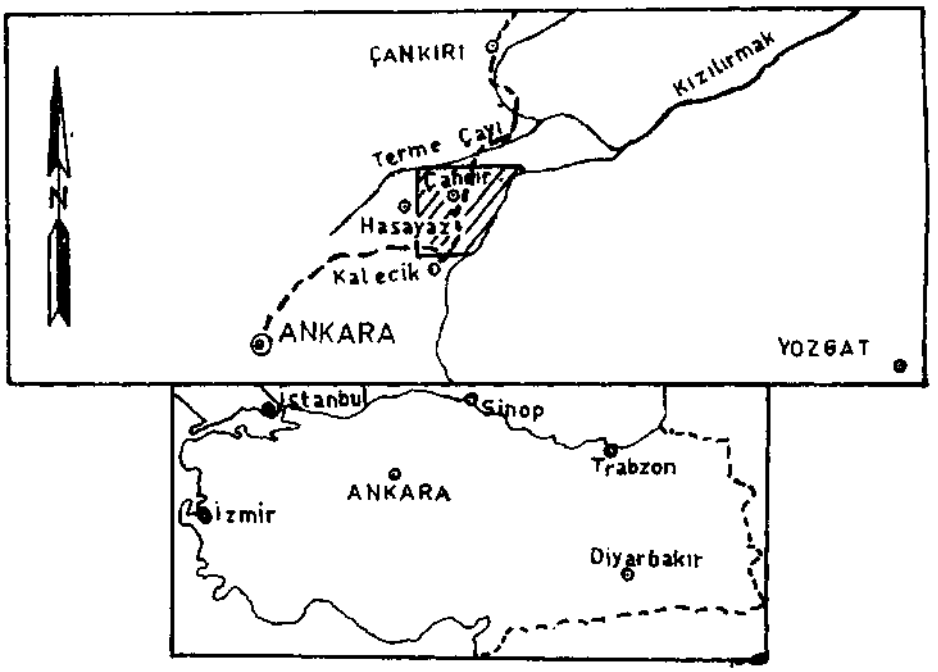


Fig. 1 - Location map of the studied area.

a high-grade of porosity in the top layer, a suitable angle of slopes, an abundance of tectonic disturbances, the presence of a permeable top layer and a non-permeable layer underneath, and an excessive amount of waterfall and snow in spring.

The locality of the Kılçak village—which was previously situated in the eastern part of the Leblebici and the Fincantepe hills, at the western side of the Ankara-Çankırı highway—was removed from its original place to a new position at about 2 km further in the NE direction, because of the landslides. Massive landslides in the form of mudflows are observed to the north of the old Kılçak village, especially at the locality where some lignite deposits exist. It was observed in the tunnels of these lignite beds that the bottom layer is made up of serpentinitic peridotites, while towards the top the rocks gradually become a porous layer. The same type of structure has also been observed at various localities along the Malı Valley. Therefore it is concluded that the water is collected between a permeable top layer and the peridotitic rocks at the bottom which cause the water to act like a slide surface (Ann. I).

## II. STRATIGRAPHY

No Paleozoic occurrences have been observed in the area. The Mesozoic, especially the Jurassic and the Cretaceous systems, the upper parts of the Paleogene and the Neogene with the young Quaternary deposits are all present. In this chapter, we are going to refer frequently to the measured section of the Malı Valley, which was described previously, as a supporting source of information (Ann. II).

## A. MESOZOIC

### 1. Jurassic - Cretaceous systems

*a. Ophiolitic complex.* — Ophiolitic series occupy large areas in Turkey. They are generally of ultrabasic character and in other forms of ultramafic rocks. Apart from some areas in Turkey, the ophiolitic rocks can be encountered almost everywhere in the country. It led the geologists to investigate these rocks mainly because of their ore-bearing characteristics. The ophiolites have been studied in considerable detail in Turkey and especially in Europe. M.G. Rutten (1969), who studied extensively the ophiolitic occurrences in the Alps, classified these rocks as the basic groups (including gabbros and dolerites) and the ultrabasic groups (serpentinites and serpentinitic peridotites). The same worker suggests that the ophiolites are the equivalent of the «roches vertes» (greenstones). He also mentions that the basic and ultrabasic rocks have been formed in the eugeosynclines, as well as outside of the geosynclines.

Views differ with respect to the stratigraphical age of these occurrences. For example V. Kovenko gives a Middle-Eocene age to the peridotites of the Fethiye area, while G. van der Kaaden suggests a Paleozoic age for the same peridotites. An explanation can be put forward that the uncertain results concerning the age of the occurrences are caused by the very complex structure of these formations. However, suggestions of such workers as P. Arni, L. Dubertret, A. Helke, P. de Wijkerslooth, M. Blumenthal, and W.E. Petrascheck as to the age of the ophiolitic rocks vary between the Jurassic and the Upper Cretaceous. It appears that every geologist came to a certain conclusion about the age of ophiolites after investigating the local geology where these rocks exist, but so far all these observations have been unsuccessful and no general agreement has been reached.

It is suggested that the ophiolitic rocks in our area are the basic and ultrabasic products of a normal differentiation process of a magma derived from the sima. The serpentinized peridotites generally represent the ultrabasics. Their color varies between green to blackish-green. These rocks were dislocated and brecciated and acquired a compact state by the tectonic movements. They were serpentinized as a result of autohydration processes. The gabbroic magma, which is formed at lower temperatures than the peridotitic one, produced the basic extrusives and their equivalent occurrences. The gabbroic rocks in our region are not exposed in large areas, like peridotites, but are found as lenses within the peridotites. The gabbros—like peridotites—were also subjected to autohydration and even underwent the autometamorphic processes. In the field they are distinguished with difficulty from the ultrabasic rocks. The extrusive basaltic rocks, which have a similar chemical composition to the essexites, are mainly composed of basalts and alkali-basalts (PI. I, photo 2). The alkali-basalts are grouped as follows: leucite tephrites, basanites, leucitites.

These rocks are not the normal differentiation products of a basic magma but are formed by assimilating a syenitic magma on their way up to the surface. In the field especially the coarse-grained leucitites are well recognized. These rocks display a characteristic cabbage-like structure; this appearance is due to ellipsoidal cracks which were formed by the contraction produced by rapid chilling effects. In the field it is not possible to find distinct contacts amongst the leucite tephrites, basanites, and the leucitites. Apart from the alkali-basalts, the normal basalts are also present in the area. They are altered to diabases, albite diabases and spilites as a result of the autohydration processes. Occassionally, the picrite basalts are also observed. The picrite basalts can be called the holomelanocratic olivine diabases. Some samples of the latter rock types suggest the trachytic characters and were altered to the albite porphyries as a result of the autohydration and the autometamorphism processes. In some places, the quartz albite porphyries and the dacites are observed in the field.

In the studied area the contacts between the ophiolitic occurrences and the radiolarites and limestones are usually hidden, and even when exposed in some places, show the tectonic contact characters. However, the following arguments can be put forward about the nature of contacts between these rocks:

— The magmatic rocks were formed before the sedimentary rocks.

— The magmatic rocks were formed at the same time as the sedimentary rocks.

— The magmatic rocks were formed after the sedimentary rocks.

In the first case, the magmatic rocks would not show any effects of magmatism on the sedimentary rocks which overlie them. Therefore it is not considered like a real contact between the magmatic and the sedimentary rocks. In fact, one can expect the fragments of the magmatic rocks within the sedimentary rocks at the top, and this is observed at the Malıboğazı.

The second case could only be accepted if the synchronal magmatism and the sedimentation were both affected by each other. The various types of pyroclastic rocks and especially the presence of intercalating lava flows, the spilites and the pillow lavas are considered as evidences supporting the second case. Although such types of occurrences are distinctly observed in our area and especially at the Kepez anticline, it is also noticed that the presence of Orbitolina-bearing limestones indicates an uninterrupted sedimentation process.

In the case of the third alternative, if the magmatism occurred after the sedimentation, then all the sediments would be affected by the magmatism. Our observations in the field do not support this case. We did not find any evidence backing the third alternative directly or indirectly.

From the stratigraphical point of view, the relationship between the peridotites and the platy limestones is tectonic. There are two cases to be considered here, as follows:

— The peridotites are older than the Upper Jurassic.

— The peridotites are younger than the Upper Jurassic.

In the first case, after the formation of peridotites, the deposition of the platy limestones on the rocks and the ensuing autohydration process can be considered.

In the case of the second alternative, the platy limestones should have been pushed over the serpentinitic rocks, as a result of a large-scale overthrusting.

The observations around the Orçantepe, Azıtepe and the nearby regions did not supply us with any evidence in order to prefer one of these two alternatives. At Malıboğazı, the relationship between the serpentinitic rocks and the platy limestones is best exhibited by the faults which can be considered as the overthrust faults.

Blocks of dolomitic limestones are emplaced on top of the diabasic series to the west of Çandırhanı. From the stratigraphical point of view, these limestones can be considered as the youngest rocks, since they contain some fragments of basic and ultrabasic rocks.

The brecciated limestones at Kızıksivrisi and at the Kepez anticline, and other limestones occurring as lenses, are buried within the basalts. The spotty appearance of these rocks is caused by the presence of basic and ultrabasic rock fragments. These limestones must be older than Middle Cretaceous since they contain fragments of Orbitolina. The fact that they are buried within the basalts may be attributed to tectonism.

The stratigraphic relationship between the İnkaya limestones and the alkali-basalts is clearly observed at Malıboğazı. Here the limestones overlie the basalts. These basalts must be older than the Upper Cretaceous since the limestones are of Maestrichtian age. In fact, it is inferred that the alkali-basalts are a little older than Upper Cretaceous because there is a sandy level between the limestones and the basalts.

As regards the siliceous rocks, they are considered as the sedimentary occurrences which were deposited on top of the serpentinitic rocks. These siliceous rocks were formed by the Radiolaria remains after the formation of serpentinites. Occasionally it is observed that the traces of Radiolarias completely disappear and the rocks become totally silicified. This is caused by the recrystallization of Radiolaria fragments as a result of tectonic movements, which also created the shearing planes within these rocks. The planes are filled with some secondary quartz veins giving to these siliceous rocks a cataclastic texture. This kind of cataclastic texture is best represented within the recrystallized radiolarites to the south of the Tilki village.

*b. Dolomitic limestones.* — Outcrops of dolomitic limestones observed in the studied area are particularly noticeable to the east of Hacıköyhanı. They are encountered as blocks and lenses in some other places, especially to the west and the northwest of Çandırhanı. These rocks are fine-grained and of pale yellow color. Under the microscope, the diameter of grains varies between 0.02-0.05 mm; they occur generally in hypidiomorphic forms with some smaller cryptocrystals which have a sugary texture. The residual material which cannot be dissolved in the acids within the dolomites consists of serpentinite, chlorite as microflakes, and a very small amount of albite as microfragments.

The dolomitic limestones are encountered underneath the platy limestones, so that they have an age corresponding to the lower levels of the Upper Jurassic. The dolomitic limestones which outcrop east of the Hacıköyhanı do not have any lateral relationship with the platy limestones. Only the top levels of dolomites are overlain by the platy limestones. The dolomitic formations have a direct contact with ther volcanic breccias to the west and the northeast of Çandırhanı. The presence of volcanic materials within the dolomites and the corrosive character of their surfaces, indicate a younger age of the limestones in comparison with the volcanics. These rocks contain the following microfossils: *Protopeneroplis* sp., *Robulus* sp., Radiolaria, Lagenidea, Echinoidea, etc.

*c. Upper Jurassic platy limestones.* — The Jurassic series are represented by platy limestones. The best outcrops of these rocks are observed around Orçan Tepe and in the nearby regions. These limestones exhibit large outcrops in an area which starts from the south and the west of Tilkiköy—including the Orçan Tepe and the Bozkaş Tepe areas—then it continues until the Handere Stream. Generally these limestones have a creamy-white color with a fine-grained, compact texture. The diameter of grains varies between 0.01-0.1 mm. They contain such microfossils as *Calpionella alpina* Lorenz and Radiolaria (Sphaerellaria).

Ultrabasic and basic magma strongly affected the platy limestones and the repeated tectonic movements had dislocated and folded these rocks. For example, these characteristics can be observed at the slope of a hill which is situated some 500 m east of Hacıköyhanı and also along the road between Hacıköyhanı and Gökçeviran village and at a locality of a southerly slope where Malıboğazı takes a turn before reaching Tilkiköy. The average thickness of the platy limestones varies between 250-350 m.

O. Erol, who studied the geology of the Ankara region—including the area under investigation—classified the platy limestones into two stratigraphical groups. Based on my own investigations as well as on my discussions with this author, it may be assumed that the platy limestones of Yaprakçık and the platy limestones of our area can be correlated lithostratigraphically, and their age may be, probably, accepted as Upper Jurassic-Cretaceous. This correlation is rather a lithologic one.

However, an evidence for a stratigraphical correlation can be put forward, since the fossils which were collected by A.S. Erk at Yaprakçık and our fossils from Orçan Tepe indicate the same level. While T. Yücel did not encounter any fossils within the platy limestones of our area, F. Baykal collected near Kalecik some *Calpionella alpina* from the green-colored series which are intercalated with the limestones. F. Baykal suggested an Upper Jurassic-Cretaceous age for these formations.

*d. Brecciated, massive and block limestones.* — These formations are observed at the following localities:

— at the Kepez anticline, which is situated in the area between Çandırhanı, Çandır Bağları and the Kürtköy village,

— at the Kızıksivrisi Tepe, northwest of Çandır,

— to the southwest of Avkaz Bağları,

— at the Fincan and Leblebici hills.

These rocks are generally associated with the ophiolites such as serpentines, radiolarites, etc. The massive type of brecciated limestones generally has a strike in a N-S direction, with some varying dips, while the block types appear to be wedged within the ophiolites, as observed for example to the southeast of the Bulhal Tepe, to the southeast of Azı Tepe and to the northeast of Karanlık Tepe. The limestones are of light-brownish color when observed macroscopically; they are compact and fine-grained with an irregular crack systems and calcite veins. These rocks have an extremely heterogenous character from the texture and composition point of view. For example sometimes they show pseudoolitic textures, while in other places they display an organic texture. This type of texture is due to various kinds of Coelenterates which also contain fragments of some green Algae. The rocks are cut by calcite veins of variable thicknesses and a yellowish to dark-colored limonite is injected into the stylolite-like cracks (PI. IV, microphoto 2).

A microbrecciated texture is observed within the limestones of Kızıksivrisi Tepe, near Çandır and at the Kepez anticline, which is situated between Çandırhanı and Çandır Bağları. It can also be observed that fragments of magmatic greenstones are present within these limestones. Laboratory tests have revealed spilitic and diabasic rock fragments in the samples taken from these localities. The massive, brecciated limestones show the effects of jointing, crushing and dislocation. This makes identification of any remains of fossils to be a difficult matter. Nevertheless, the remnants of identifiable macro- and microfossils are listed as follows:

Macrofossils:

Echinoidea spines

Lamellibranchiatashells

Microfossils:

*Orbitolina* sp. (fragments)

*Spirohculina* sp.

*Textularia* sp.

*Quinqueloculina* sp.

*Dicyclina* sp.

The lithology of the limestones—generally overlying the ophiolitic formations—which were encountered in various localities of our area of study, was described previously and the fossils collected from these formations were identified. Therefore it may be assumed that these limestones

stratigraphically represent a period between the Upper Jurassic and Lower Cretaceous, according to their microfossil content. The lower members of these limestones contain fragments from the basement, so that the basement rocks chronologically are older than the limestones and this feature excludes the presence of any tectonic disturbances.

## 2. Upper Cretaceous

The Upper Cretaceous series in the studied area are observed as follows: The platy limestones of Azı Tepe, to the northeast of Çandır; the conglomerates, limestones and sandstones of the Malıboğazı area which are described as the Malıboğazı Formation.

*a. Platy limestones of the Azı Tepe area.* — The platy limestones which cover the Azı Tepe area northeast of Çandır overlie the serpentinized peridotites. These limestones, like the serpentines, show an equally complex structure which includes fracturing, crushed zones and dislocations. This uneven terrain makes any investigations and measurements carried out in this area very difficult. The lithologic features of the platy limestones to the north and southeast of Azı Tepe are similar to the platy limestones observed in the vicinity of Orçan Tepe, which is situated to the south of Malıboğazı. However the microfossil content of samples, which were taken going from the east towards the peak of the Azı Tepe, suggests that these limestones are stratigraphically younger than the platy limestones at and around Or9an Tepe.

These limestones generally have a creamy color and are compact and fine-grained. Their thickness varies between 150-250 m. The following remnants of microfossils were identified in this formation:

*Rotalipora (Ticinella) roberti* Gandolfi
*Rotalipora appeninica* Renz
*Rotalipora alpina* Bolli
*Globigerina* sp.
*Globigerinoides* sp.
*Gumbelina* sp.
*Globotruncana lapparenti inflata* Bolli

As the microfauna content above indicates, this series of rocks has a Senomanien age.

*b. Malıboğazı Formation*[1] is the name of the stratigraphic unit which is mainly composed of limestones. It is situated within the Çankırı H30-$c_2$, H31-d1 map-sheets of our area of study. The type section was measured from a point at the pass, northwest of Malıboğazı. This formation which consists of three members is over 800 m thick at the type locality.

The relationship of Malıboğazı Formation with other stratigraphic units can be seen on the stratigraphic section which was measured along the Malı Valley (Ann. II). The formation extends from the type locality in two directions: E-W and N-S.

The limestones start with a lense-type occurrence at a locality which is about 200 m south of Sarintepe (913 m) in the valley; it is situated at a distance of 1.5 km from Malıboğazı, in the southwesterly direction. The same limestones again start in the N-S direction, from a locality which is about 500 m away from the Sarintepe, and then continue in the SW-NE direction until Malı-

[1] v

boğazı. Further these limestones can be observed along the left side of the Malı Valley trending in the N-S direction, passing over the Karakaya Tepe, for a distance of about 1 km. The extension of this formation is about 2.5 km in the SW-NE direction. As a whole, this formation is only observed in the Malıboğazı area.

Generally the lower boundary of the Malıboğazı Formation is formed by the thick basaltic rocks, while the Kızılçukur tuffaceous conglomerates form the upper boundary. The lateral extension and the boundaries of this formation are described above. The fossil assemblage of this unit will be given later on, together with the description of the members of this unit. The age of the unit is Upper Cretaceous (Ann. III).

From the composition and the fossil-content points of view, Malıboğazı Formation appears to have been a bioherm which developed on a submarine ridge. We compared the platy limestones of Azı Tepe with the Malıboğazı Formation although the former type of rocks represents a deep-sea facies.

In the field, as a lithostratigraphic unit, Malıboğazı Formation can be identified from its topographical features and its geomorphological appearance. This formation is cut by narrow gorges with steep walls (for example Malıboğazı). A number of hills, such as Karacakaya and Kocakaya, are also observed here. This feature is especially caused by the nearly vertical dip of the limestones which represent the main member ofthis unit.

Conglomeratic member of the Malıboğazı Formation.—The conglomeratic member of the Malıboğazı Formation, which generally lies in the northeasterly direction, covers a large area starting from the curve ofthe Malıboğazı gorge (at Tilkiköy) until the banks of the Kızılırmak River. It does not show any distinct bedding, but has a massive appearance. The conglomerates, which are situated to the NE of Malıboğazı along the banks of Kızılırmak and also at Dedelik Tepe and the nearby regions, are usually red. It is suggested that this red color is due to the submarine eruptions and the subsequent formation of tuffs which took place during the sedimentation period. On the other hand, dark green conglomerates are also observed in the area. They start again from the Tilkiköy curve of the Malıboğazı gorge until the Gökçeviran village and then continue as far as the hills of the Dedelik Tepe, Pugur Tepe, Nizah Tepe, and along the banks of the Kızılırmak River. Although this variation in the color of conglomerates gives an impression that there are two types of conglomeratic series, a close examination reveals that these conglomerates are of the same type, both macroscopically and microscopically. The grain sizes of these rocks vary between 1-25 cm. The grains are made up of cryptocrystalline limestone, spilite, radiolarite, peridotite, basanite, tephrite, leucitite, dolerite, and quartzitic sandstone fragments, which are tightly cemented within a calcitic matrix. The shape of grains in different sizes varies between subrounded to rounded forms. The matrix of conglomerates also contains quartz, sericite, biotite, feldspar and chlorite fragments. As a rule, these conglomerates are compact and the grains which are strongly cemented, also show tightly spaced textures. Sometimes, the conglomerates are altered by the natural agents and the blocks which are broken off from the main body of conglomerates have been carried away. Some of the minerals within the matrix of conglomerates have been decomposed and the iron has been oxidized within the sedimentation environment. This process stained the conglomerates with a red color, as observed to the southeast of Malıboğazı and along the banks of the Kızılırmak River. Besides these red conglomerates, the grayish-green to ash-colored conglomerates are also observed in our area. This indicates that the greatest part of the elements comprising these latter conglomerates are of the greenstone family and their color may be attributed to the oxidation processes described above.

The sedimentary sequence is clearly observed within this series of rocks. At Malıboğazı this sequence is represented by alternations of conglomerates, conglomeratic limestones and limestones. This feature may suggest a type of uncomplete but positive and active process of stratification, or it may represent a process of complete grading within these rocks.

The limestone member of the Malıboğazı formation. — The limestones have the same NE-SW direction as the conglomerates. The dip of beds is as much as 85°. They overlie the basalts (basanites). The age is Macstrichtian. The field observations in this area show that the effects of volcanism were very mild or non-existent after the Maestrichtian.

The limestones are almost whitish-cream-colored, thick-bedded and contain abundant Rudistidae shells. Some tectonic evidences, such as tectonic brecciation and crushed zones, indicate that after its formation the limestone was subjected to tectonism. These limestones also show some erosion and corrasion surfaces as a result of the work of natural agents. Study of five different cross-sections taken in five different localities shows that the Malıboğazı limestones have lithological and faunal similarities with each other. Therefore it is suggested that although these limestones have the same origin, they were later dislocated and separated by tectonic movements. The limestones show the following sequence from bottom to top:

— Limestones with coquina (biosparites): They consist of creamy-colored, compact limestone concretions which are cemented by a marly limestone and show evidence of brecciation, crushing and mylonitization processes.

In thin sections nearly 90 % of these limestones are seen to be composed of Lamellibranchiata shells. The thickness of this formation is 15 m. These beds contain the following macrofossils and microfossils: fragments of Lamellibranchiata, Gastropoda and Rudistidae shells, Annelid tubes, and *Lepidorbitoides* sp.

— Calcareous sandstones: These beds are whitish-gray in color, compact, fine-grained, with uneven surfaces. They contain fragments of radiolarite, quartzite, basanite, tephrite and altered greenstone as sand grains. The grain size varies between 0.1-0.5 mm. These grains are cemented by limestone. Shells of Gastropoda, Lamellibranchiata and Echinoidea and some microfossils such as: *Siderolites* sp., *Orbitodies* sp. and *Textularia* sp. were identified in this formation.

— Microbrecciated limestones (a distinct biosparite): This rock type often shows brecciation and crushing features. The rocks are dark-reddish, compact and fine-grained; the sand grains of different types and shapes have *a* diameter varying between 0.1-1 mm, the space between these grains is filled by a well-crystallized calcite cement. The grains are composed of the following: zeolitized diabase, aegirine-augite, zeolite, and fragments of volcanic glassy rocks which show a clay mineralization. As macrofossils this formation contains some Lamellibranchiata shells and fragments of Algae with a microfossil fauna as listed below:

*Orbitoides* sp.

*Siderolites* sp.

*Operculina* sp.

*Globigerina* sp.

*Globotruncana* sp. (fragments)

*Nodosaria* sp.

*Stomiosphaera sphaerica* Kaufmann

*Siderolites calcitrapoides* Lamarck

*Lepidorbitaides* sp.

*Omphalocylus* sp.

*Siderolites heracleae* Arni

— Micro-coquina limestones (biosparite): These limestones have a pinkish-yellow color with a compact and fine-grained texture; massive in appearance; the elements of these limestones are cemented by calcite. The upper parts of the limestones show a pseudo-oolitic structure. The fossil content of these beds is as follows: Lamellibranchiata and Gastropoda shells, some fragments of Bryozoa, as macrofossils; and as microfossils: *Orbitoides* sp., *Siderolites* sp., *Lepidorbitoides socialis* Leymerie.

Sandstone member of the Malıboğazı Formation.— The type locality of these sandstones is in the vicinity of Kızılçukur, which is bordered by the Sarin and Orçan hills situated east of the Malıboğazı Formation. These rocks—which are observed in association with the Malıboğazı limestones—represent a narrow band trending in a NE-SW direction as far as the southern outskirts of the Gökçeviran village. The basement of these sandstones overlies the Malıboğazı limestones, while the upper parts are formed by the red-colored, complex series which is intercalated by young tuffaceous rocks. However, it was observed that these red-colored formations are covered by young alluvial deposits which extend from Malıboğazı in a E-W direction; their approximate thickness is more than 50 m. In the Malıboğazı area this series is of a grayish-yellow color and displays a fractured, crushed, brecciated and nodular structure. The contacts are clear. This feature is interpreted as being caused by the faults. The sandstones have probably the same age as the Malıboğazı limestones or they may be even younger. Anyway, it is evident that this series is younger than the conglomerates, as can be distinctly observed from their relationship with the conglomerates. The diameter of grains varies between 0.01-1 mm.

These sandstones contain the following rock and mineral fragments:

*Minerals:* Quartz, chloritized mafic minerals, plagioclase (oligoclase), dark-colored opaque minerals (probably iron oxides).

*Rocks:* Decomposed greenstones and crystalline tuffs, albitized diabases, radiolarites, etc.

Remnants of some microfossils are present amongst the fragments of rocks and minerals, which are all cemented within a calcitic matrix. The sand grains are closely imbedded within the matrix but they do not show any definite orientation. These sandstones contain the following macrofossils: Rudist fragments, Echinoidea and Brachiopoda shells, Algae (Lithothamnium, Coralina).
Mrs. Necdet Karacabey, who is a Paleontologist in the M.T.A. Institute, kindly identified the following macrofossils:

*Pycnodonta vesicularis* Lamarck

*Spondylus* sp.

*Nerita divaricata* d'Orbigny

*Sphaerulites salutus* Petho

*Pseudopolyconites* sp.

*Exogyra overwegi* de Buch

*Bournonia* sp.

*Cydolites* sp.

*Pecten* sp.

*Vaccinites loftusi* Woodward

The sandstones contain the following microfossils:

*Orbitoides* cf. *media* d'Archiac
*Siderolites* cf. *calcitrapoides* Lamarck
*Orbitoides gensacicus* (Leymerie)
*Omphalocychis inacropora* (Lamarck)
*Orbitoides apiculata* Schlum.
*Textularia* sp.
*Triloculina* sp.
*Valvulammina* sp.
*Spiroloculina* sp.
*Siderolites heracleae* Ami

These sandstones have the microfaunal contents very similar to those in the Malıboğazı limestones. Therefore it is concluded that they have the same stratigraphic age as the limestones.

## B. TERTIARY

The main features of the Tertiary formations in the studied area are as follows:

— The Tertiary formations in the area are represented by the rocks which are mainly of lagunal, lacustrine and terrestrial origin.

— The Tertiary formations are listed as follows: The red-colored occurrences with tuffaceous intercalations, overlying the calcareous sandstones of Malıboğazı. Their age is Paleocene, while the marly series are represented by the upper levels of Neogene (Piliocene).

— The Tertiary formations will be described as separate units according to their localities and their age, within their own stratigraphical column, because these separate units do not geologically form any definite groups with each other.

Topographically, the red series appear to take place between the limestones and the conglomerates of Malıboğazı Formation. Their lateral relationship with the conglomerates is distinct. These red series, which are limonitized and hematitized, contain the following materials: fragments of basanite, radiolarite, hornstein and serpentinite. These fragments occur in rounded to subrounded forms. Microscopically, the matrix of the red series contains some minerals, such as aegirine augite, sanidine, biotite, analcite. The diameter of grains varies between 0.07-1 mm and they are cemented within a carbonatized glassy material which contains abundant amounts of iron oxide. Although the thickness of the red series is variable, it may be estimated at about 200 m.

### 1. Neogene

There are salt and gypsum deposits covering some large areas in the vicinity of Çankırı. These deposits are situated in the northern part of the studied area. Some of these evaporites, which are present in the neighboring part of our area, were investigated in detail by O. Erol; they are classified into various groups. However, the Neogene beds in our area are thinner than the Neogene further north, since they occur at the edge of this important sedimentary basin.

The Neogene sediments generally fill the subsidence zones amongst the topographic heights; these series are mainly observed in the following areas:

— At the Leblebici and the Fincan hills, Which represent the continuation of the Kuludağ ridges;

— Between the Çaltepe-Sarıdede hill and the township of Çandır in the east;

— Following the Alibeyli plain and along the Ankara-Çankırı railway further to the east.

The basement of these series is formed by the conglomerates which overly transgressively the serpentinites. The visible thickness of the conglomerates is more than 2 m in Hırsız Deresi, to the NW of Çandır and a decreased grading in the size of the conglomerate grains is distinct from bottom to top. The grains occur in subrounded and sometimes in spheroidal forms and their diameters vary between 0.5-10 cm. These pebbles are composed of limestone, radiolarite and greenstone fragments. In thin sections these conglomerates show that some mafic minerals are alsd present in association with quartz. These pebbles are embedded within a loose matrix and although they sometimes show a N-S direction their orientation is generally a complex one.

The red and green-colored marly series overlie the conglomerates transgressively, as it is observed to the NE of Uyurca Köyü and to the SE of Kumartaş Köyü, near the lignite mines. These series show normal stratification as well as cross-bedding. Towards the northern edge of the studied area these beds display a hilly topography. O. Erol suggests that the origins of these red and green-colored marls are the same and the difference of color is due to the change of facies from the deposits of salty lakes to fresh-water lakes. The marly series in varying color are distributed throughout the sedimentary basin without showing any signs of time gaps amongst themselves. Sometimes they show lateral transition into each other, as can be observed in the reddish-green-colored marls to the east of the Gökçeviran village. At a distance of about 2.5 km north of Termeyenice, the green-colored marls also show a transition into the white-colored limestones of lake deposits, as described by O. Erol. This locality is situated to the north and outside of the studied area.

Overlying the red-colored marly series, an alternation of whitish, creamy and gray-colored series is observed; the uppermost part of these series contains also gypsum deposits. This sequence is distinctly observed to the NE of Çandır in the Hırsız Deresi. The sequence from bottom to top is as follows: The graded conglomerates are overlain by the red-colored marls, 3.72 m in thickness, and above them the gray-colored marls which have a thickness of 0.75 m. This sequence is repeated three times towards the top and finally the white-colored marls overlie the whole unit.

The relationship between the red and the gray-colored marls, which outcrop on Küçük Boz Tepe (895 m) west of the Uyurca Köyü, is not the same as it is observed in the Hırsız Deresi. At this locality, the gray marls directly cover the red marls and the gypsum deposits are placed on top of this sequence. The thicknesses of the red and gray marls vary between 50-100 m. Finally the red conglomerates are overlain by a mixture of conglomerates and sandstones, 250 m in thickness, and then by the red and gray marls on top of this sequence, as it is observed on the Avlıca Tepe (886 m) to the northwest of the Uyurca Köyü.

İ. Tekkaya, who is a paleontologist in M.T.A., determined the bones of some Vertebrate fossils which were collected from the level of gray-colored marls along Hırsız Deresi. He attributed an age of Upper Miocene to Lower Pliocene to these fossils. This conclusion agrees with the age which was put forward by O. Erol. The Vertebrate remnants are as follows:

*Crocula* sp. (Upper Miocene - Lower Pliocene)

*Orycteropus* sp. (Pliocene)

*Lislriodon* sp. (Upper Miocene - Pliocene)

*Anciterium* (Miocene)

*Gazella deperdita* Gaudry (Upper Miocene - Lower Pliocene)

*Palaeotragus* sp. (Upper Miocene - Lower Pliocene)

The age of this formation is accepted, for the time being, as the Upper Miocene - Pliocene, according to the fossil contents as described above. It may be assumed that as long as no other stratigraphic evidence is found, the age of the Neogene transgression would be older than the Upper Miocene under these circumstances, and this age would probably be the Middle Miocene or the Lower Miocene.

### C. QUATERNARY

The Quaternary in the area under investigation is represented by alluvial deposits. Physical and chemical agents have produced important depression zones, with depths varying between 100 to 200 m, in areas where maximum erosion took place. Numerous valleys and gently sloping hills with terraces are frequently observed. The Küçük Boz Tepe and the Avlıca Tepe can be mentioned as examples of this type of hilly topography. Steep-walled valleys with broad bottoms were formed during this period. The material which derives from the parent rock, as a result of disintegration processes, forms thick layers of alluvial deposits at the bottom of the valleys and causes accumulation of alluvial cones at the slopes of the hills. Occasionally, these alluvial cones cause landslides.

Extensive alluvial deposits encountered in our area are observed along the banks of the Kızılırmak River in the vicinity of Alibeyli; they form two branches of the same alluvial formation extending towards Gökçeviran and one branch passing through the Malıboğazı region. Another branch of the valley starts at the banks of Kızılırmak and extends towards the Uyurca and Avşar areas. These alluvial deposits contain fragments of basanite, leucitite, tephrite and spilitic rocks; the fragments are cemented with fine-grained sands of the same type of rocks.

## III. TECTONICS

The geologists who have previously worked in the Ankara region suggest that this whole area underwent the Alpine and Hereynian orogenesis and various phases of these movements. Only Alpine type of tectonism is observed in the area under study, since this area is part of the Ankara region and represents a sequence in the sedimentary series which do not go below the limit of the Jurassic period.

### A. PRECURSORY TECTONIC MOVEMENTS

According to the field observations, the oldest formation in the area is the platy-limestone series. It overlies the serpentinites, containing poorly preserved Calpionella denoting an Upper Jurassic (Tithonian) age, in the vicinity of Orçan Tepe and adjacent areas. No other formation in the area was found that is stratigraphically older than these limestones. However, E. Buket—who has done a masters thesis in the Middle East Technical University, Geology Department—reports that the Upper Jurassic rocks are present on the banks of the Kızılırmak, some 5 or 6 km to the east of our area. (This data was obtained from Büket during a personal discussion with him and his work is not published yet.) If one thinks in a general way about the geology of the area, especially

in the light of this new evidence, it can be suggested that the sedimentary sequence starts here with the Triassic. The whole area was subjected to erosion as a result of uplifting and subsequent transgressions during an early tectonic stage of the old Kimmerian orogeny.

Due to repeated tectonic movements the area was invaded by the sea and the sedimentation started again at the end of the old Kimmerian movements. Nevertheless, the sedimentation of the Tithonian platy limestones, observed around Orçan Tepe, is not an extensive process in comparison with the whole area. For example, the Lower Cretaceous limestones, which contain Orbitolina microfossils, overlie directly the serpentinitic rocks found at Azı Tepe. In some other places it is also observed that the agglomerate rocks of submarine volcanic origin, which are generally overlying the Upper Cretaceous, overlie the serpentinites also. All this evidence indicates that the Upper Jurassic rocks were deposited locally in small basins and are not observed extensively throughout the area. They were uplifted and subsequently eroded partly as a result of an intermediate phase of the Austrian orogeny, which caused later on the transgression of the area by deep seas. These tectonic movements, which originated from the Austrian orogeny, were one of the most extensive movements in our area. However, it is thought that there was a basin of subsidence before the Senonian in the Malıboğazı-Tilkiköy areas and on the eastern banks of Kızılırmak, judging from the thickness of the conglomerates in these areas. It is suggested that this subsidence reached its maximum depth during the sub-Hercynian movements. During that period bioherms were formed on the uplifted areas of the sea floor, and the deposition of the Malıboğazı limestones started by the time when the sub-Hercynian movements took place. Although various types of occurrences of Cretaceous age can be observed, the Cretaceous sediments were generally folded by the Laramian orogeny. We are unable to suggest any theory with regard to the time when the younger rocks were deposited because—with only one exception—no Lower Tertiary formations were found in our area. This exception is represented by a series overlying the Cretaceous rocks in the Kızılçukur graben. This formation, which is considered as Paleocene in age, is composed of red-colored conglomerates with a tuffitic matrix. Apart from these rocks, there are no rocks representing Lower Tertiary, Paleocene or Eocene. However, according to the field studies of O. Erol, there are some Eocene limestones which contain Nummulites in the SE part of the area. We are unable to find any relationship between these yellow-colored Eocene limestones and the Lower Tertiary sediments in our area.

### B. PAROXYSMAL MOVEMENTS

It is realized that the study of a larger area than the area under investigation is necessary in order to come to a definite conclusion about the paroxysmal movements in this region. At present we are not able to make any suggestions about the paroxysmal stage of the alpine orogeny because no formations of late Eocene and Oligocene were encountered in the area.

The tectonic activities of the region which interest us are the ones that occurred as a result of the stratigraphical history of the sedimentary units existing in the area under study. Nevertheless, it must be pointed out that our area was uplifted above the sea level before the Miocene period. Finally, we must also mention that, apart from some simple folding and vertical movements, we did not observe any overthrusts, faults, or imbricate structures in the area.

### C. LATE TECTONIC MOVEMENTS

Despite the lack of any orogenic activity during Oligocene, the presence of epeirogenic movements has been felt in the area. The Ankara region and its neighboring areas have been folded and fractured during the Miocene. The tectonic movements in the Attic phase uplifted the northern

part of the area after the formation of Miocene lakes, so that these lakes shifted from the north to the south. The lakes filled small subsidence areas in the southern parts, while erosion took place in the northern parts of this region. After the Miocene period, the rivers in the uplifted northern parts carried the alluvial materials from the north and filled the depressions in the lower parts of the region and, as a result of this process, today's plains were formed.

At the end of Pliocene or at the beginning of Quaternary vertical uplifting movements (Wallachian stage) produced the Anatolian Plateau. During this period typical valleys were excavated by the streams and thus a great number of terraces were formed. The fact that alluvium deposits overlie discordantly the filling materials suggests that only uplifting tectonic movements could produce such tectonic features. No other phase of tectonic movements was observed in the area of study apart from the ones which are described above.

### D. CRATOGENIC MOVEMENTS

The studied area can be included into the Tertiary zone, which is described by O. Erol as being squeezed between the Hercynian basin and the Kırşehir massif. The direction of stress in our area caused the formation of a number of folds, anticlines and synclines with their axes running in the NE-SW directions. These anticlinal and synclinal structures formed some mountains or mountain ranges, which mainly lie in the E-W and the NE-SW directions. The formations which lost their plasticity during the process of this folding were partly fractured and brecciated.

## IV. VOLCANISM

The igneous occurrences in the area are mainly composed of intrusive and extrusive rocks. A normal sequence of rocks is observed here: The deepest rocks are ultrabasic magma, then follow the basic rocks with the uppermost layer of syenitic magma. As concerns the extrusive rocks, they can be interpreted as submarine lava flows which have two distinct types of chemical composition. The pyroclastic rocks are mainly composed of lavas, lapillis and tuffs. The study of mixed types of extrusives rocks indicates that they are of alkali-basaltic origin. However, these alkali-basalts are not a product of differentiation, but were formed when a latest fraction of a gabbroic magma assimilated the older syenites on its way to the surface. The basanites of the Malıboğazı area and also some similar rocks to the west of Malıboğazı are good examples of this type of assimilation processes. These rocks are altered into diabase-, albite diabase and spilites as a result of autohydration processes. To the north of Avkaz Köy extrusive rocks composed of picrite basalt (holomelanocratic olivine diabase) are observed. In some places, especially to the NW of Çandır, these extrusives are altered into andesitic albite porphyries as a result of the autohydration and autometamorphism processes. To the south of Kepez Tepe, these rocks are altered into trachytic natronkeratophyre spilites; they are generally in the nature of quartzalbite porphyries in the western portion of the studied area. The youngest extrusives of the area are dacites which are widespread in the Akdere area.

## V. PALEOGEOGRAPHY

The geological descriptions ofvarious authors who visited the Ankara region take up the paleogeography of the region, starting usually with 'the Paleozoic. In our particular area there is no available geological data about this early period since the oldest formations are of Jurassic age. Moreover, the paleogeographic interpretation ofthe formations is a rather difficult matter because of

the comparatively small size of the studied area. However, we are going to attempt to construct the paleogeographic history of the area by deducing it •from the available information about the series of rock formations in the region.

The Upper Jurassic series (Malm), which outcrop extensively in the Ankara region, occur as abyssal and partly as bathyal types of rock formations. They are represented by platy limestones which are transgressive in nature. It may be assumed that they were formed by a sudden transgression of the sea, since there are no basal conglomerates. The best example of the platy limestones in our area can be observed on the Or9anTepe to the south of Malıboğazı. These limestones contain some microfossils of pelagic type, such as Radiolaria and Calpionella.

After the Upper Jurassic, a regression period took place; then the area was invaded by the Lower Cretaceous sea. There are some distinctif characteristics in the nature of the seas between the Upper Jurassic and the Lower-Upper Cretaceous. The platy limestones of the Upper Jurassic are pale creamy in color with a fine-grained texture, while Cretaceous limestones have a pseudo-oolitic texture. This feature indicates that the sea became gradually shallower (neritic) during the Lower Cretaceous period.

With the deepening of the sea during the, Upper Cretaceous, the sedimented series assumed a reddish color. These series contain Globotruncana microfossils. The limestones of Senonian sea deposition occur quite extensively in the area, with an average thickness of several meters, as observed near Azı Tepe.

In the eastern part of our area, the conglomerates which outcrop between the banks of Kızılırmak and the Malıboğazı, as mentioned previously, indicate the presence of a shallow sea in this area. The shallow sea, which was bordered by basanites, formed a submarine ridge on which a bioherm has accumulated. The presence of this bioherm indicates that warm and calm conditions existed in this sea. The Laramian orogeny marked the end of the Upper Cretaceous sea. Nothing more is known about this sea apart from the sediments observed in the Kızılçukur, which are interpreted as Paleocene in age. These small outcrops of sediments give an impression of a volcanism or a regression period, but no other evidence was obtained here. The state of paleogeography is unclear during the Lower Tertiary because there are no sedimentary formations of this period. The shallow sea— which was formed by the migration of lakes from the northern areas to the south during the Miocene period— left some sedimentary rocks in our area. Later on this sea became shallower; this is evidenced by its sedimentation which shows a mixed type of red-colored series. The concretionary nature of the Malıboğazı limestones indicates an unstable type of sea floor, while the levels of conglomerates further confirm this unstability.

## VI. ECONOMIC GEOLOGY

### A. ORE DEPOSITS

The area under study does not contain any economically significant ore deposits, except some lignites occurring amongst lacustrine sediments. These lignites are observed within the young sediments of lacustrine origin. They outcrop in three localities:

1. The lignite deposit, which is situated about 200 m to the NW of Eski Kılçak Köyü, has been exploited by the methods of open-pit and underground mining. The lignite occurs in the

form of lenses and layers of varying directions. It is used as a kind of fuel by the villagers in the neighboring area. When we visited it last time the mine was blocked by a landslide.

2. Lignite exists to the SE of Kumartaş Köyü, at a distance of about 1.5-2 km from this village. The lignite occurs as an interrupted layer with a thickness of 20-30 cm. No attempt has been made here to open galleries for mining because of the danger of landslides.

3. There are some lignite occurrences to the NE of Uyurca Köyü. These deposits in the form of lenses are not operational from the mining point of view. They occupy rather large areas and occur in three different localities. These lignites were analysed in the laboratories of M.T.A.; they contain 20 % $H_2O$ and 40 % ash. This indicates a low grade of calory percentage in these lignites, which makes them economically insignificant.

The lithologic descriptions of rocks in the Kılçak and Kumartaş deposits are given as follows (starting from the top):

*a. Gray-colored marls (200 cm).* — Their color is gray, or greenish-gray and they contain occasional clayey and marly levels. These marls form the upper levels of both deposits.

*b. Clay (80 cm).* — Its color is brown, bluish or sometimes greenish-white; it passes gradually into the marls in an upward direction. This level frequently causes the landslides because of its clayey character.

*c. Lignite (25-30 cm).*

*d. Transgressire conglomerates (25-100 cm).*

*e. Serpentinites and radiolarites.* — The lower levels of both lignite deposits are made of serpentinites and radiolarites.

## B. INDUSTRIAL RAW MATERIALS

The presence of wide valley basins in our area of study contributed to important sand accumulations, which are widespread in this region. Particularly the valley of Malı Deresi can be mentioned as the most significant sand deposit. These sands are mainly of magmatic origin. They are used by the Department of Turkish Highways in the construction of bridges, and roads and for various repair jobs, since the clay percentage in these sands is low.

Equally useful for construction purposes are the gravels which consist of fragments of alkali-basalts, spilites and limestones.

Finally, it may be mentioned, that people who live in the villages around the Malı Deresi area as well as the Turkish Highway Department workers make use of various types of rocks found in the neighborhood for construction purposes. These quarried rocks are mainly crystallized limestones, spilites, alkali-basalts and massive or block limestones.

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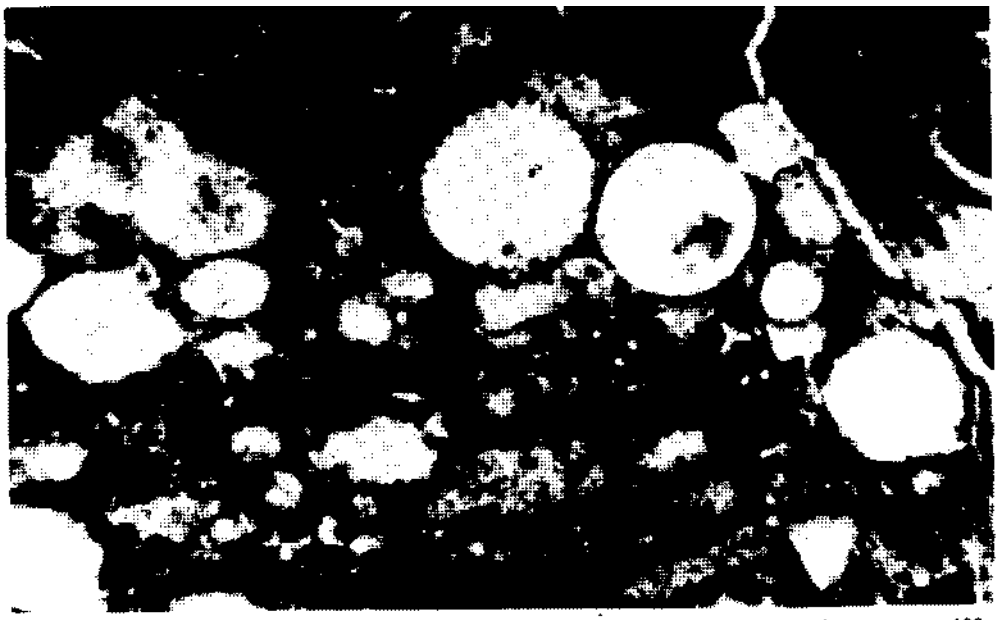
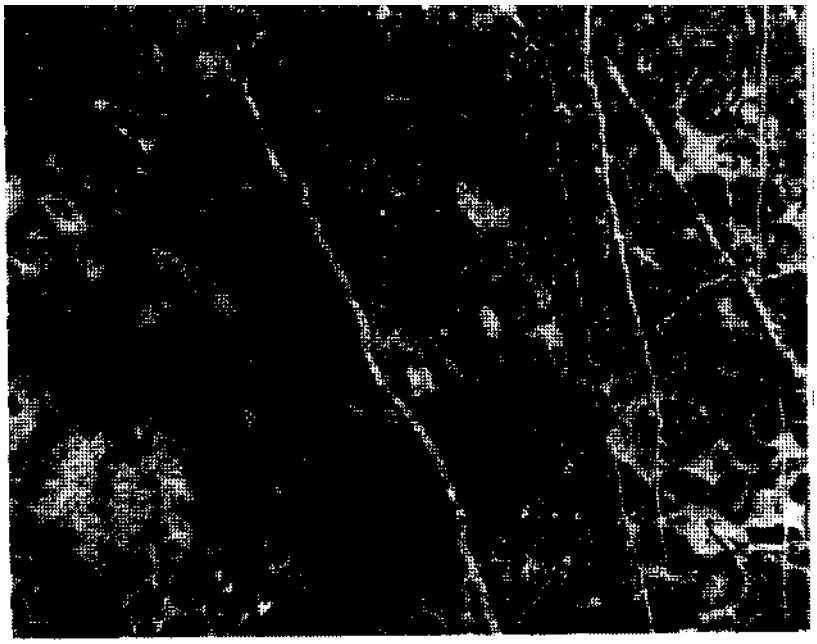
Photo 1 - Relationship between radiolarites and brecciated limestones at the Kepez anticline.
a - brecciated limestones; b - layered radiolarites.

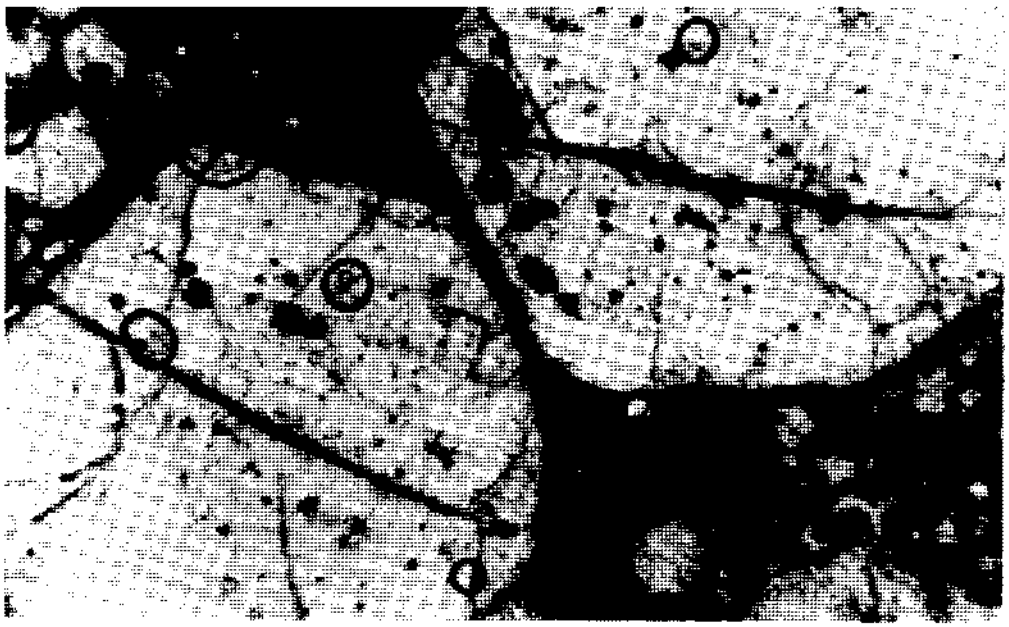
Photo 2 - Structural characteristics of alkali-basalts observed on the left side of the Gökçeviran road.



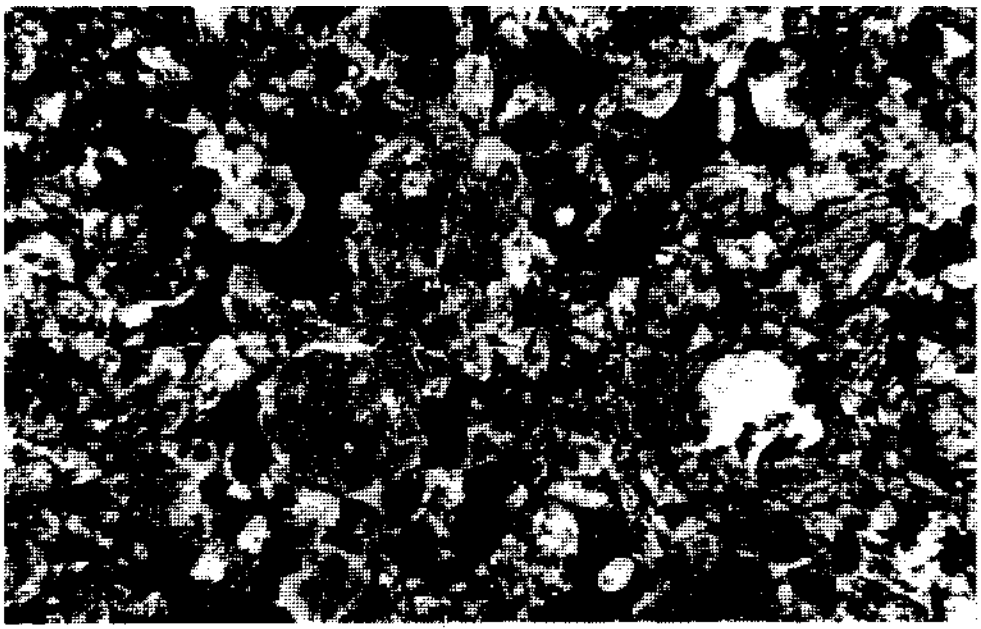
Microphoto 1 - Radiolarite. Traces of Radiolaria are seen as whitish spheres. Thin section, magn. × 100.



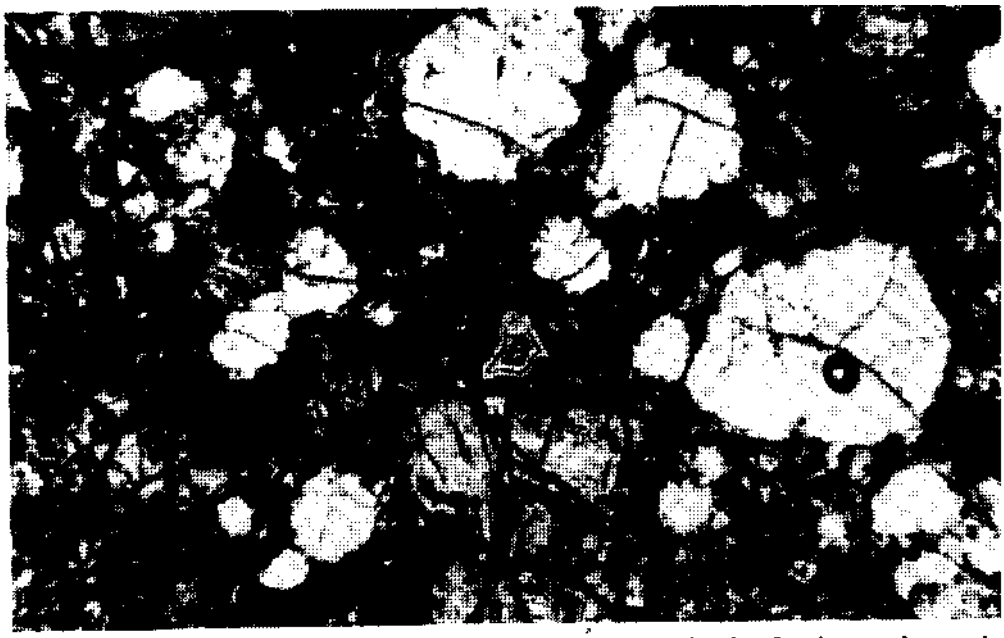
Microphoto 2 - Limestones containing Orbitolina. Thin section, magn. ×. 10.



Microphoto 3 - Leucite tephrite. Idiomorphic leucite crystals show concentric zoning and contain microscopic inclusions of glass and some magnetite. Thin section, magn. × 25.

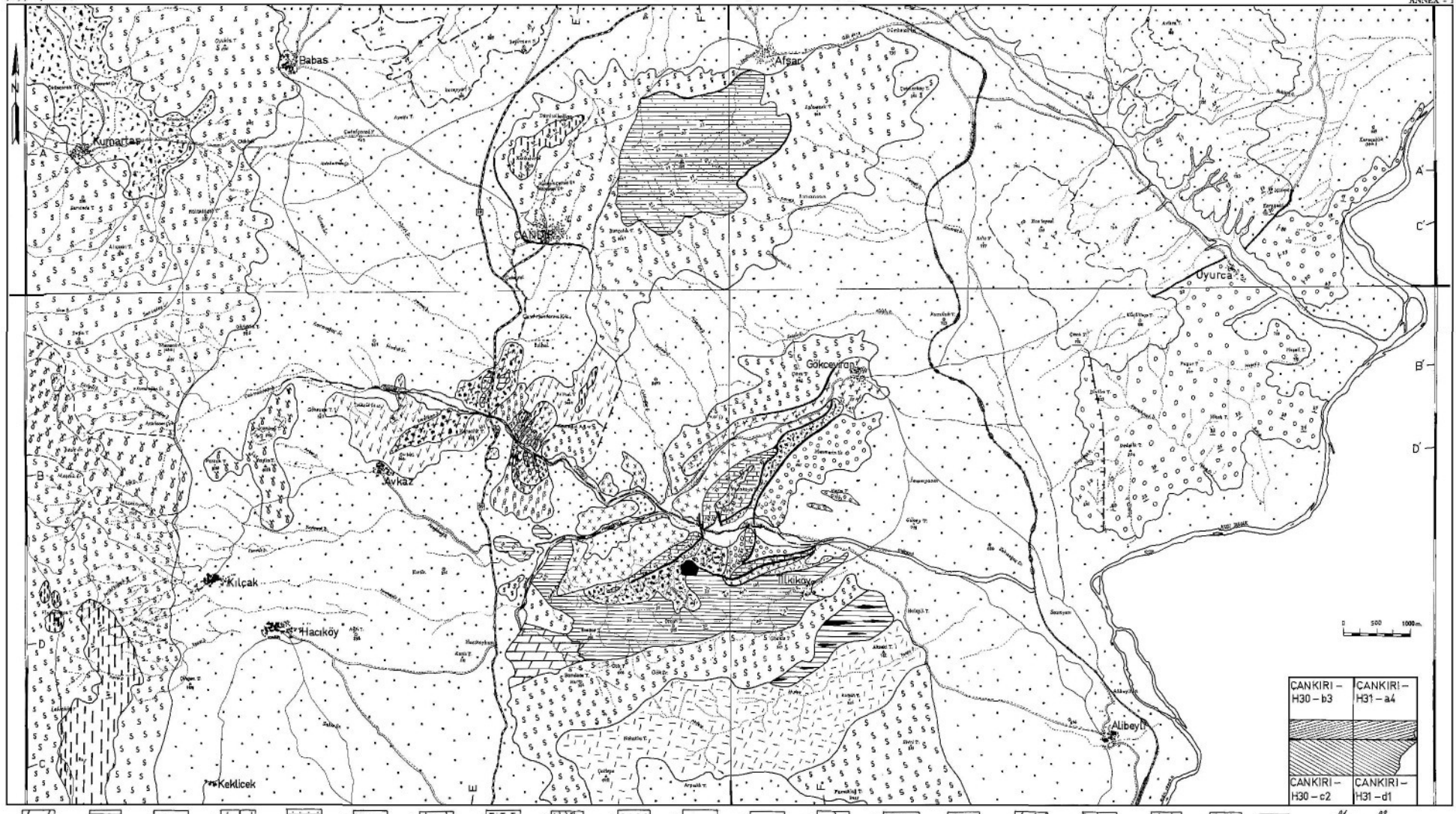


Microphoto 4 - Leucitite. Augite: occurs as phenocrystals and microcrystals with a high relief. Leucite: generally forms idiomorphic microcrystals. Magnetite: crystals are black in color. Thin section, magn. × 100.



Microphoto 5 - Leucite basanite. Aegirine augite shows a high relief, it is gray in color. Leucite crystals occur in idiomorphic forms, their color is white. Plagioclases are in the form of gray or light gray crystals. Magnetite grains are black in color. Thin section, magn. × 25.

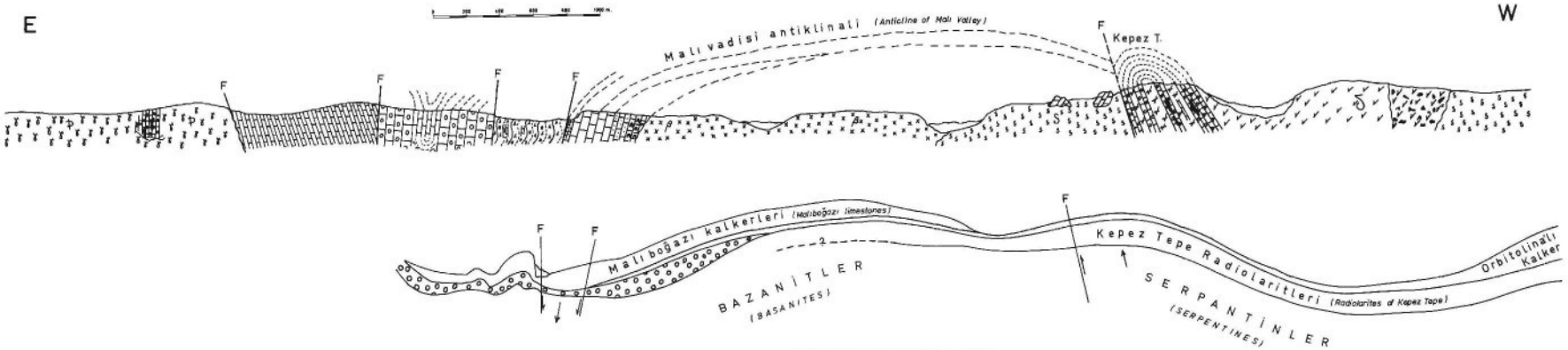
Microphoto 6 - Albite diabase. Albite forms laths of microcrystals which show ophitic texture (light-colored parts). Mafic minerals are completely chloritized while olivines are in a state of iddingsite (dark-colored). Magnetite occurs as black crystals. Thin section, magn. × 25.




1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

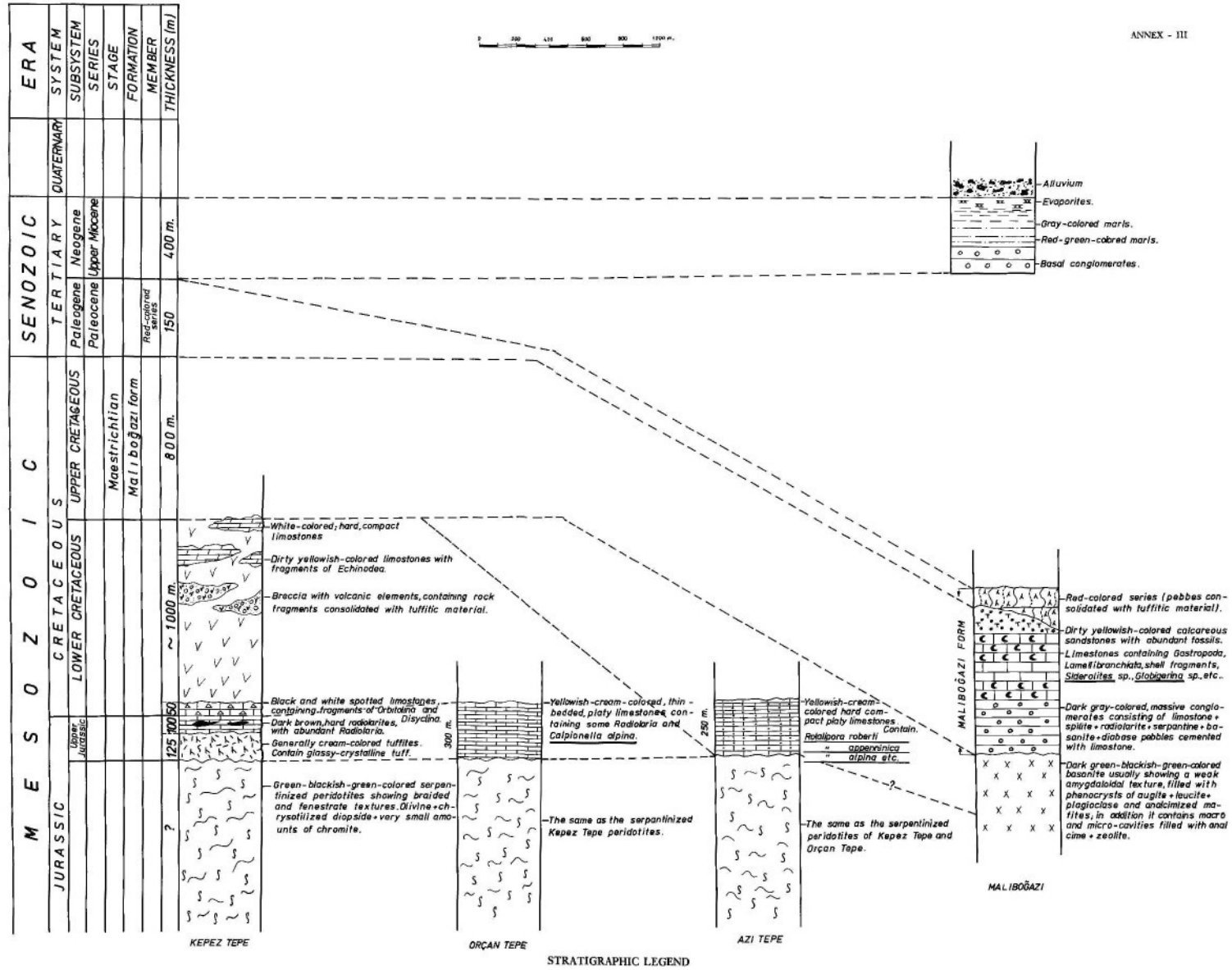
GEOLOGY OF MALIBOĞAZI AND NEIGHBORING AREAS

*1 – Dolomitic limestones; 2 – Upper Jurassic platy limestones; 3 – Radiolarites; 4 – Brecciated limestones, massive or in blocks; 5 – Upper Cretaceous platy limestones; 6 – Conglomerates; 7 – Malıboğazı limestones; 8 – Malıboğazı sandstones; 9 – Red-colored series; 10 – Neogene series; 11 – Alluvium; 12 – Peridotites; 13 – Serpentinized peridotites; 14 – Alkali basalts; 15 – Spilites; 16 – Diabases; 17 – Volcanic breccia; 18 – Tuffs; 19 – Dacites; 20 – Syenites; 21 – Faults; 22 – Inferred faults.*




MEASURED SECTION OF THE MALI VALLEY AND ITS EVOLUTION

ANNEX - III

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