GEOLOGIC AND TECTONIC STRUCTURE OF THE SİVAS-HAFİK-ZARA AND İMRANLI REGION*

Fikret KURTMAN

Mineral Research and Exploration Institute of Turkey

ABSTRACT. — The studied area covers the eastern part of Sivas Basin. Base of the basin consists of metamorphics of gneisses, quartzites, mica-schists, sericite-schists and marbles that are seen to crop out at Sakardağ. The oldest sediments seen on the metamorphics are the layers of Upper Cretaceous of limestone facies. The Tertiary concordantly starts with Paleocene layers of, again, limestone facies above Upper Cretaceous. Eocene has been developed in flysch facies which contains volcanic intercalations. Oligocene consists of gypseous variegated sandstones and siltstones. As to Miocene, there seems to be a lateral passage between gypseous variegated sandstones and limestone and marl beds. Neogene forms coarse elastics and fresh-water limestone layers.

In our area of study, as magmatic rocks, there occur ultrabasics of Upper Cretaceous age and andesites and tuffs of Eocene age.

Tectonically the area shows two uplifts between which a depression exists. Folding tectonics prevail on the whole. But it is understood that these have been affected by later fault movements.

INTRODUCTION

The Sivas region has been visited by some geologists since 1843 and various ideas have been given about the geologic structure of the region. But these studies put forward the existence of many problems in Sivas region.

For example, such problems as the age of Tecer limestone, facies changes in Eocene, the age of gypseous series and environments of sedimentation and complicated tectonic structure of the region are seen to be important.

The aim of our study has been to provide the solution of the existing problems by examining geologic and tectonic structure of the Sivas region.

Although our work has been a regional study within the scale of 1:100,000, we also made use of more detailed profile studies on some important points.

First of all, it is my duty to express my thanks and gratitude to the Directorate of M.T.A. Institute, who provided me with every means of study in carrying out this work.

Thanks are due particularly to Dr. S. Erk, C. Öztemür, Dr. Van Ginkel, M. Serdaroğlu, N. Karacabey, A. Güngör, N. Solak and Dr. T. Güvenç, who have determined fossils of the various formations.

In addition, I wish to thank Dr. F. Demirmen and T. Ayan who carried out sedimentologic determinations of some samples and Dr. O. Baysal and Dr. K. Markus who made petrographic determinations.

GEOGRAPHICAL ASPECT

The examined region is situated in the east of the Sivas Province. It comprises a great part of the Hafik-Zara and İmranlı areas (Fig. 1).

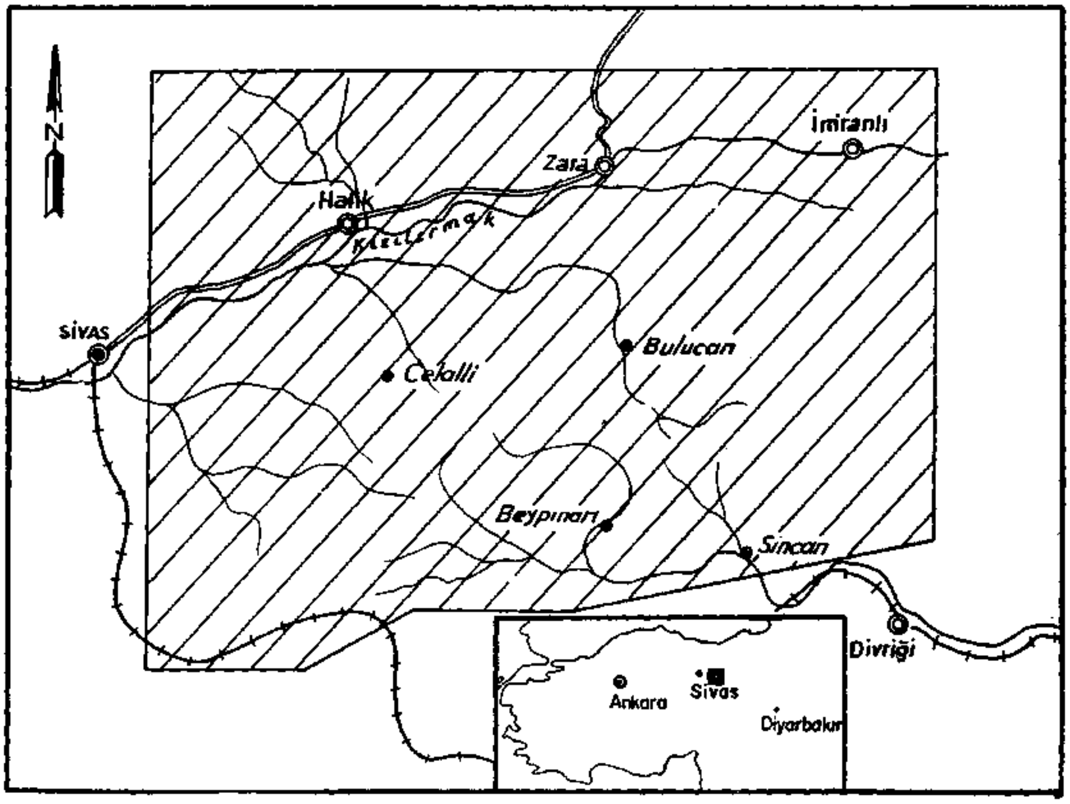


Fig. 1 - Geographic location map of the investigated area.

The area of study is generally mountainous. In comparison with the mid-Kızılırmak depression, especially the southern and northern parts seem to be much more rough.

Mountains generally extend in E-W or ENE-WSW directions and as parallel chains.

The most important rivers of the region are Kızılırmak and its branches of Acıırmak and Karasu. Kızılırmak comes from Kızıldağ, which is situated in the east, nearly outside of our region and crosses the area in the ENE-WSW direction. As to Acıırmak and Karasu, they originate in the area of study and join with Kızılırmak again in our area. On the other hand, Kuruçay and Mescitli Deresi, which originate in the southeastern part of the region, join with Fırat River.

I. STRATIGRAPHY

In the examined area, formations belonging to crystalline series (Paleozoic), Upper Cretaceous, Eocene, Oligocene, Miocene, Pliocene and Quaternary have been observed (PI. I, II, III).

1. METAMORPHIC SERIES

Metamorphic series crops out at Sakardağ in the northwestern part of our area. It forms the eastern extremity of Kızılırmak massif.

This series is made up of such metamorphics as gneiss, quartzite amphibolite-schist, mica-schist, sericite-schist and marble.

It is understood that gneisses form the core of the metamorphic series. They are exposed at 500-600 m north of Kızılca village, just outside of our area. The gneisses that are gray or beige-colored also show schistosity. The minerals are generally aligned parallel to each other. White-colored quartz minerals within the gneiss are also seen to be striated.

Quartzites are often seen above the gneisses. These are being yellowish-brown or gray and sometimes white, have abundant joints and sharp edges. They show regular bedding. They often have compact structure. These quartzites, pass upwards to predominant mica-schists and sericite-schists and show repeated intercalations with them. Also in this sequence, dark green-colored amphibolite-schist levels with schistose texture can be seen in places.

More often mica-schist levels, especially sericite-schist levels take place upwards. These dominantly beige and brown-colored levels also show alternations where sometimes thin marble levels can be seen. In these, the schistosity is developed parallel to the bedding.

The microscopic determination results of a sample of this level, which was carried out by O. Baysal, is as follows: Sampled schist shows fine-layered texture. In it, abundant quartz, lesser muscovite, sericite, very little calcite, limonite and zoisite have been observed.

Quartzes being granoblastic indicate partly parallel growths to the schistosity and a wavy extinction.

Muscovites and sericites being in the form of thin, long plates and speckles are aligned in a parallel direction to the schistosity.

Limonites show many infiltrations within muscovite plates.

Thick marble layers occupy the outmost top of crystalline series. Especially the summits of Sakardağ consist of these marbles.

The marbles more often have yellow, brown or beige and sometimes light gray appearance. When fractured, they generally show bright white color and in some places gray thin veins. They form layers with the thicknesses from 8-10 centimeters to a few meters. Frequent jointing has been developed.

It has not been possible to determine the exact age of these metamorphics. Also the age of the metamorphism is not known. However, it is certain that they are older than the limestones which overlie these metamorphics discordantly. In spite of the fact that no fossils could be found in these limestones, their age is accepted as Upper Cretaceous. This is because these limestones show great lithologic similarities with Tecer limestones which crop out in the south of our area and contain Upper Cretaceous fossils. In the northwesterly lateral extension of the same limestones, A.C. Okay (1952) has determined some Upper Cretaceous fossils.

In that case, the age of the metamorphic series is pre-Upper Cretaceous. However, it has not been possible to determine the exact age of these in our area of study. Although these metamorphics could have an age of Paleozoic, they could also have partly Mesozoic age.

The exposed metamorphics in our area represent eastern extremity of Kızılırmak massif. Therefore, it should be thought that there must be some" age relation between Kızılırmak massif and the metamorphics.

Opinions about the age of Kızılırmak massif are various. K. Leuchs (1943) argued that this massif originated as a core long before alpine orogenesis. According to him, the age of the massif should be Hercynian, perhaps Precambrian. R.F. Lebküchner (1957), who studied the Kızılırmak massif in the north of Gemerek, accepted the age of metamorphics as Paleozoic. With the studies which covered Akdağ massif in the north of Kızılırmak massif, F. Baykal (1946) and K. Nebert (1955) agreed that the age of metamorphics is Paleozoic. In addition, Nebert stated that they could also have Mesozoic as well as Precambrian age.

Observations made by İ. Ketin (1955, 1966) in the west of Kızılırmak massif near Yozgat and Kırşehir have brought different ideas about the age of the massif. Around Yozgat-Yerköy, fossiliferous Upper Cretaceous, that shows alternations with ophiolites, has been observed immediately above metamorphics. It is argued that metamorphics around Kırşehir concordantly pass up to unmetamorphic Upper Cretaceous levels with ophiolites.

R. Brinkmann (1966) stated that in Menderes massif, which constitutes the western end of the Middle Anatolian inter-massif, metamorphism ascended up to Lias.

Therefore, although we are inclined to accept the age of metamorphics of our region as Paleozoic, it is not improbable that they are younger as being the continuation of Kızılırmak massif.

2. UPPER CRETACEOUS

Tecer limestones

The oldest recognized sedimentary formation in our area of study is Upper Cretaceous limestones. These limestones are exposed extensively in Tecer Mountains that are situated in the south of the region. In addition, they crop out as small exposures at Gürlevik Mountain, at Sincan village in the southeast and near Bah9ecik village in the north. As they are best exposed in Tecer Mountains and as for a long time in literature they were known to be Tecer Mountain limestones (Blumenthal, 1957), the author gave them the name of *Tecer limestones.*

For the reason of greater resistance against erosion compared with the surrounding formations, these limestones crop out at high summits and southern outskirts of Tecer Mountains and constitute the basic structure of the steep Tecer Mountains.

The base of Tecer limestones is not exposed in our area. The oldest apparent layers came out to the surface due to the Tecer thrust, which moved from south to north.

The oldest layers which crop out along the WSW-ENE Tecer thrust, that extends parallelly to the steep northern slopes of Tecer Mountains, seem to be more massive and are gray and dark gray in color. Bedding can only be recognized from a distance. In this part karstic occurrences are seen in places. Towards upper levels bedding becomes more prominent. Here the rock has dark gray color, abundant fossils, medium to coarse grains and detritic appearance. In places dolomitic levels are observed.

As a result of sedimentologic study of thin sections of the Tecer limestone samples (taken from Tecer Mountains) carried out by T. Ayan, the typical characteristics of these limestones have been determined as follows: Allochemicals approximately constitute 3/4 of the rock. Most of the allochemicals (80-90 %) consist of organic materials such as microfossil, alga and shell fragments. The remaining allochemicals are a few intraclasts or pseudo-oolites. Orthochemicals are calcite mud or micrite which infills intergranular spaces. The distribution of allochemicals within the rock is disorderly. There is no equality of grain size. Some stylolites are also observed. The sample is either biocalcarenite or biomicrite. They had been deposited in warm and probably active and shallow sea.

The base of these limestones can be seen at Tecer Mountains in which the thickest exposures of Tecer limestones occur (approximately 750 m). In the south and southeast of Tecer Mountains, mixed occurrences of Tecer limestones with ophiolites can be found. Here and there the limestones exist as lenses within ophiolites. It is understood that ophiolites had penetrated into these limestones.

Blackish gray-colored limestones, which show great lithologic similarity to Tecer limestones and crop out at Sakardağ in the northwestern part of our region, are found to lie discordantly over metamorphics. This sequence, sometimes starts with basal conglomerate, pebbles of which are made up of metamorphics, sometimes begins with fine-grained sandstone layers and sometimes starts directly with limestone layers. Here in these limestones, in spite of the widespread search for fossils, no traces were found. But, by searching for the possibilities of comparison and correlation, we accepted it as the base of the Tecer limestones.

The ophiolites in the east of Sakardağ, between Koşudere (Çaykürt) and Bahçecik villages, as well as the gray-colored limestones in the form of lenses are all continuation of Tecer limestones. Within these, especially at the contact of ophiolites, red-colored and fine-layered radiolarite lenses are also seen. These radiolarites were not found in the west of Sakardağ and in Tecer Mountains in the south. Paleontologic and lithologic studies, carried out by us, indicate that the environments of sedimentation of these limestones of identical age are different. In other words, the Tecer limestones being more reefy originated in a shallow-sea environment around Tecer Mountains, but in the north and northeast they had been deposited in a deeper sea.

Tecer limestones concordantly pass upwards to Gürlevik limestones of Paleocene age. The boundary can only be distinguished by paleontologic means. The distinguishing of these two limestones has only been possible also by paleontologic study of the samples that have been systematically collected according to detailed cross-sections between Tecer and Gürlevik Mountains.

The samples taken from Tecer limestones in Tecer Mountains have been examined by M. Serdaroğlu and the following fossils were determined:

Orbitoides media d'Archiac
Orbitoides d'Orbigny
Siderolites sp.
Textularia sp.
Nodosaria sp.
Miliolidae

Macrofossils found in these limestones, have been determined by N. Karacabey and the following fossil has been recognized:

Gryphaea (Pycnodonta) sp. (aff. *vesicularis* Lamarck)

On the othetf hand, the samples collected from limestones around Bahçecik village in the north have been examined by A.C. van Ginkel and the following fossils were determined:

Globotruncana lapparenti lapparente Quereau
Globigerina sp.
Gumbelina sp.

In addition, radiolarites have also been determined in the red-colored radiolarite lenses that were encountered in the neighborhood of these limestones and at ophiolite contacts.

As understood from the examination of fossils, Tecer limestones are of Upper Cretaceous (Campanian-Maestrichtian-Danian) age. However, difference of fossil species is apparent between the northern and southern parts of our region. This is important as it shows the existence of an environmental change from south to northeast.

Limestone beds similar to Tecer limestones crop out in the east of Sincan village in the southeastern border of our region. These also are encountered in the neighborhood of ophiolites. However, no fossils have been found in this limestone. These limestones have been considered as continuation of Tecer limestones by keeping in mind that they belong to ophiolitic series and are found in the same zone with Tecer limestones.

These limestones have also been studied by A.C. Okay (1952) and since no fossils were found they have been recognized as Mesozoic limestones.

Tecer limestones have first been studied by geologist P. de Tchihatcheff (1867). He thought these limestones were the same as the ones seen on Toros Mountains and even compared them with Devonian limestones of Istanbul.

M. Blumenthal (1937) also examined the Tecer limestones and found in them some crinoid stems, but could not determine their age.

V. Stchepinsky (1939) studied the Tecer limestones and pointed out that their age could be Senonian or pre-Senonian.

From the other studies that were carried out in the neighboring areas, we understand that the Upper Cretaceous layers are widespread.

Upper Cretaceous limestones in Hekimhan area, which were studied by E. İzdar (1963), show strong similarities to Tecer limestones. It is possible to make a connection between them.

The limestones which crop out above metamorphics in the Gemerek area in the west were studied by R.F. Lebküchner (1957). By means of fossil determination, it was understood that these limestones, the upper levels of which are of Upper Cretaceous age, descend downwards to Malm.

In the south, in the Kangal and Gürün areas, they develop in the form of Upper Cretaceous limestones and marly limestones (F. Baykal, 1945; M. Blumenthal, 1938). These limestones are similar to Tecer limestones both from the point view of their lithology and their fossil content.

3. PALEOCENE

Gürlevik limestones

These limestones crop out in the south of Gürlevik Mountain, in the northern skirts of Tecer Mountains. High and steep cliffs of Gürlevik Mountain are completely made up of these limestones. Because these limestones are best represented here, they are named as *Gürlevik limestones.* The same limestones, on the other hand, crop out in the northern skirts of Tecer Mountains and at mountain ridges situated between Gulam, Kulyusuf, Ovacık and Ezeltere villages.

Normal contacts of these limestones with Tecer limestones (Upper Cretaceous) can be observed at Gürlevik Mountain and in the eastern part of Tecer Mountains. Gürlevik limestone layers are the continuation of Tecer limestones. The beds being concordant no prominent lithologic boundary can be observed. Drawing a boundary could only be possible by biostratigraphical and sedimentologic examinations. As to the clearly defined upper boundary, it is discordantly covered by conglomerate layers probably of Ypresian age. Maximum thickness that can be measured is 750 meters.

On the other hand, these limestone layers, which crop out at lower ridges of the northern skirts of Tecer Mountains, show no normal sequence and have been pushed over Eocene and Oligocene layers by a thrust fault of a few km thrust and have been completely bordered by tectonic contacts.

According to our macroscopic observations, Gürlevik limestones are dark gray, blackish-colored, fossiliferous, bedded and jointed kind of limestones. Interlayers of marly limestone and thin marls can be seen.

By sedimentologic studies in thin sections these limestones have shown the following characteristics: The limestone is biomicrite or biocalcilutite. Allochemicals roughly make up 1/5 of the rock. 85 % of allochemicals consist of Laffitteina and the rest are made up of Textularia and coral remains. One or two pseudo-oolites also draw attention as allochemicals. Orthochemicals consist of a fine calcite paste that is micrite. Stylolites in the matrix are observed. These point out to an epicontinental environment which had warm, shallow and non-active, probably further beach characteristics.

Thin sections of systematic samples collected from various points on Gürlevik limestones have been examined and the following fossils, which characterize Paleocene, have been determined:

Laffitteina cf. *bibensis* Marie
Textularia sp.
Biloculina sp.
Triloculina sp.
Lythophyllum sp.
Distichoplax biserialis Dietrich
Melobesiae

Determination of these fossils has been done by van Ginkel and E. Sirel.

The Paleocene layers have been recognized by us in the area for the first time. In the previous studies, these limestones were either included into Upper Cretaceous together with Tecer limestones or accepted as Eocene.

Paleocene has also been determined in the surrounding areas during studies by other authors. For instance in the Hekimhan region in the south, Paleocene limestones of Zorbehan Mountain have been distinguished by E. İzdar (1963).

4. EOCENE

Eocene deposits have considerable importance in our area. These are exposed in two different zones. The southern zone, starting in the west with the northern skirts of Tecer Mountains towards east covers Gürlevik Mountains, Karababa Mountains, Bozbel Mountains and Fıdıl Mountains in a form of a belt, Tecer Mountains together with Gürlevik Mountains form the southern flank of Eocene basin. Here Eocene discordantly starts with a conglomerate over Paleocene limestones and develops limestone, marl, sandstone, shale intercalations upwards. Especially towards east two important tuffaceous levels draw attention within the same zone.

The second Eocene zone can be seen in the northern part of our area. This zone starting from the Sakardağ flats in the west, extends up to Köse Mountain towards east. It begins with discordant thick conglomerate beds over Cretaceous deposits and the rarely exposed ophiolites. It develops in the form of alternations of andesite lavas, agglomerates and marls and shales towards east. Towards west they consist of limestone, marly limestone, marl and shale beds.

Eocene is fossiliferous in our area. It has been possible to divide the beds into lithostratigraphical and biostratigraphical units and to delineate and correlate them on the map according to their lithological characteristics (Fig. 2). So that Kozluca formation, Bahçecik conglomerates (Ypresian), Bozbel formation, Köse Dağı formation (Lutetian), and the tuff levels of Bozbel formation can be distinguished. Now, let us examine these formations in detail.

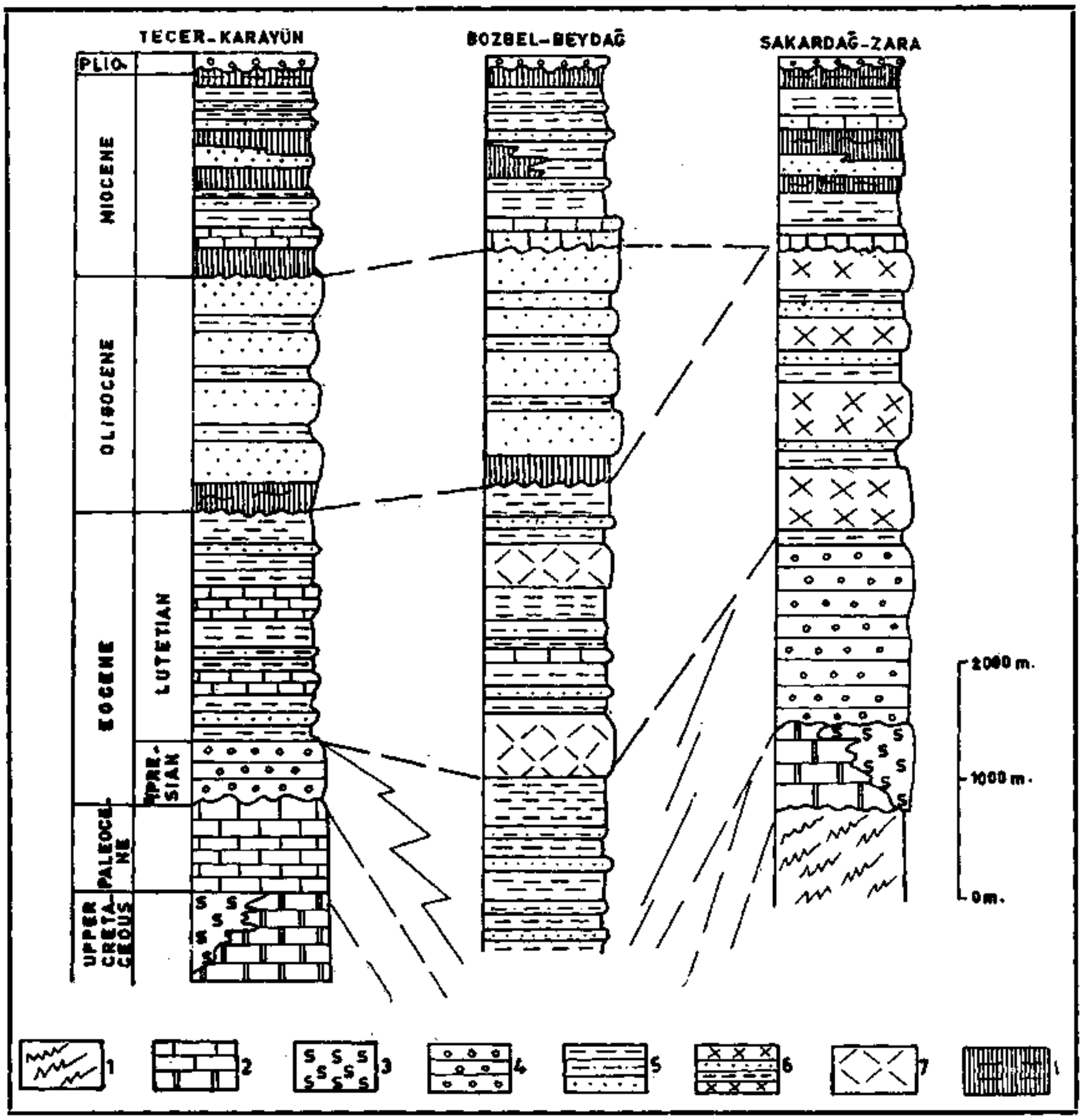


Fig. 2 - Stratigraphic correlation of the investigated area.
1 - Crystallines; 2 - Limestone; 3 - Ophiolite; 4 - Conglomerate; 5 - Marl, siltstone, sandstone; 6 - Andesite, sandstone, marl; 7 - Tuffite; 8 - Gypsum.

a. Bahçecik conglomerates

These conglomerate layers which represent the base of Eocene can be observed at the northern and southern flanks of the Tertiary Sivas basin in our area.

It crops out around Bahçecik, Karahisar and İlemin villages in the north and in the northern skirts of Tecer Mountains as well as around Gürlevik Mountain in the south. As it can best be observed near Bahçecik village, it has been named as *Bahçecik conglomerates.*

Bah9ecik conglomerate beds discordantly start above the red radiolarite layers and serpentines in the Bah9ecik stream valley, 500-600 meters north of Bahçecik village. Here conglomerates generally consist of ophiolite, marble, radiolarite, limestone and quartz pebbles and show well-defined bedding. Their thicknesses vary from 25-30 cm up to two meters. The pebbles are well cemented and their sizes change from 5-6 mm to 7-8 cm. Their outer appearance is either oval or flat. Good sorting can be seen in places.

No fossil traces have been found in these conglomerates. However, concordant fossiliferous marl layers of Lower Lutetian age were observed in the Bah9ecik Stream overlying these conglomerates, whose thickness is some 1500 meters. Therefore, it may be accepted that this formation is older than Lower Lutetian, that is its age may be Ypresian.

In the south of our region, when the conglomerate layers that are exposed at the northeastern outskirts of Tecer Mountains and around Gürlevik Mountain are compared with the ones in the north, it can be seen that these have much less thickness (about 250-300 m). In addition, especially red-colored radiolarite grains are present within the pebbles and levels made up of serpentine pebbles and conglomerates can be seen in places between conglomerate layers. So much that one hesitates to separate them from autochthonous ophiolite mass, especially around Gürlevik Mountain. Within these ophiolite boulders, the alternations can clearly be seen only in conglomerate levels around Söğütlü field in the south of Gürlevik Mountain.

We think that either serpentine boulders together with conglomerate layers have been deposited by gravitative sliding from the Upper Cretaceous autochthonous mass, widespread in this area, or because of the plastic characteristic of serpentine, the levels which are wholly made up of serpentine pebbles have been squeezed into serpentine boulders by diagenesis.

It has been observed that conglomerate layers overlie with an angular discordance the Gürlevik limestones (Paleocene) near Söğütlü field in the south of Gürlevik Mountain.

Fossiliferous Paleocene pebbles have also been observed among the conglomerate pebbles. Towards upper levels there is a gradual passage into finer-grained conglomerate and sandstone layers. Bozbel formation (Lutetian), which consists of fossiliferous shale and marl layers, can be seen concordantly above these layers.

b. Kozluca formation

This formation is exposed at the southern ridges of Fıdıl Mountain, in the deep valleys of southern Bozbel Mountains, in southeast part of our region. It has been named as *Kozluca formation* in conjunction with Kozluca village which is situated within the formation.

It is made up of alternations of fine shale, marl, sandstone and clayey limestone layers. It has generally light color and shows beige and reddish levels as well. Thicknesses of the layers change from a few centimeters up to 25-30 centimeters. It generally has flysch characteristics. The bedding shows small plicate foldings but on the "whole this formation forms here an anticlinorium.

The base of Kozluca formation cannot be seen. Above it the Bozbel tuffite layers rest concordantly.

Nummulites can especially be seen in the shale and sandstone layers. Systematically collected samples have been determined by S. Erk and the following fossils were distinguished:

Nummulites praelucasi H. Douville
Nummulites burdigalensis de la Harpe
Miscellania cf. *miscella* d'Archiac
Nummulites planulatus (Lamarck)
Nummulites globulus (Leymerie)
Nummulites sp.
Discocyclina sp.
Globorotalia sp.
Asterocyclina sp.
Cibicides sp.
Globigerina sp.

The age of Kozluca formation is Ypresian according to determined Nummulites.
The apparent thickness in our area has been measured as 1500 meters.

Lithologic characteristics of the formation and the fossils identified in this area indicate that these are deep-sea deposits. Relation of this Kozluca formation with the Bah9ecik conglomerates could not be observed within the area. However, if we consider the relations between the base and the top of both formations, we understand that they both were deposited within the same period (Ypresian).

It has been observed that Kozluca formation was deposited in the deep region at the center and Bah9ecik conglomerate layers were deposited in the northern and southern shore zones of the two basins. This situation is observed also in the correlation of Eocene layers (Fig. 2).

c. Bozbel formation

This formation crops out extensively in the southern part of our region, in the areas starting from the northern outskirts of Tecer Mountains and covering Karababa Mountain, Bozbel Mountains and Fıdıl Mountain as an east-westerly belt and at the southern outskirts of Sakardağ in the NW part of our region. It has been named as *Bozbelformation* for it is most typically observed at Bozbel Mountains.

It is generally beige and light-gray in color, with thicknesses changing from one centimeter to 8-10 centimeters, in the form of alternations of marly limestone, marl, sandstone, shale, limestone, which show very clear bedding. Rhythmic layering within the sequence indicates flysch characteristics. Over some sandstone layers turbitidy current traces and concretions have been observed. Gypseous layers with a thickness of 10-12 m had been deposited near the upper levels of this formation at southern outskirs of Karababa Mountain. But it is understood to be not widespread.

The samples collected from a limestone belonging to Bozbel formation were microscopically examined by F. Demirmen. Sedimentologic characteristics of these samples are as follows:

This is an argillaceous limestone with a grain size smaller than 5 microns of calcite crystals, including 15 % of fine-grained detritic quartz and feldspar. Sometimes secondary silicification and rare hematite spots are present. No fossils were found. It has been accumulated in the deep-sea environment probably far from the shore and in calm conditions. (A lamination in one of the thin sections was observed. The laminae are characterized by relative scarceness of detritic materials and relative abundance of organic materials.)

Two different thick, tuffaceous and volcanic breccia levels made up of volcanic materials and showing clear layering, generally of dark-gray color, are observed within the Bozbel formation. As these volcanic levels are harder and more resistant to erosion, they constitute high mountain ridges.

The first tuffite level occupies the base of the Bozbel formation and is named as *Bozbel tuffites.* They are found concordantly above the Kozluca formation. This tuffite level of Bozbel was measured as 500 meters.

The second tuffite level occupies the center of the Bozbel formation. This consists of dark-gray, well-bedded volcanic materials. To these tuffites, which developed best in Karababa Mountain, is given the name of *Karababa tuffites.* It is understood that these tuffite levels, which had been accumulated by deposition of volcanic materials in the sea, are not continuous within the Bozbel formation. Further west of Gürlevik Mountain those tuffite levels were not observed. The Bozbel formation in the form of alternations of marl, sandstone and limestone levels, rests concordantly above the Bahçecik conglomerate layers in the western part of Gürlevik Mountain and the northern outskirts of Tecer Mountain. It has been observed that in comparison to the eastern part of our region here the limestone layers have been much more developed.

At the northwestern part of our region the Bozbel formation is also in the form of alternations of marl, sandstone and limestone layers. Bozbel formation concordantly rests above the Bah9ecik conglomerate layers near Bah9ecik village. As to the southern outskirts of Sakardağ, it rests discordantly over metamorphics and Cretaceous limestones. Here, the Bah9ecik conglomerates which represent the base of Eocene layers have been accumulated.

Fossiliferous levels are present within the Bozbel formation, especially in limestone, sandstone and marl layers. The following fossils have been determined from the systematically collected samples (determined by S. Erk):

Nummulites cf. *brongniarti* d'Archiac
Niimmulites gallensis A. Heime
Asterigerina rotula Kaufmann
Discocyclina sp.
Triloculina sp.
Spiroculina sp.
Nummulites uroniensis A. Heime
Rotalia sp.
Textularia sp.

All Lutetian layers, beginning from the lower Bozbel tuffite levels, were examined and a systematic search for small Foraminifers (plankton) was carried out by making a detailed cross-section of the area between Bozbel and Karababa Mountains. The following fossils were determined by V. Karsheninnikov (Fig. 3).

Acarinina rotundimarginata Subbotina
Hantkeniya alabamensis Cushman

From evidence shown by the above fossils, it is concluded that Bozbel formation is of Lutetian age. It has flysch characteristics and was deposited in a deep sea.

The Bozbel formation reaches great thicknesses in our area. The thickest one is exposed at Bozbel Mountains and is approximately 2500, m.

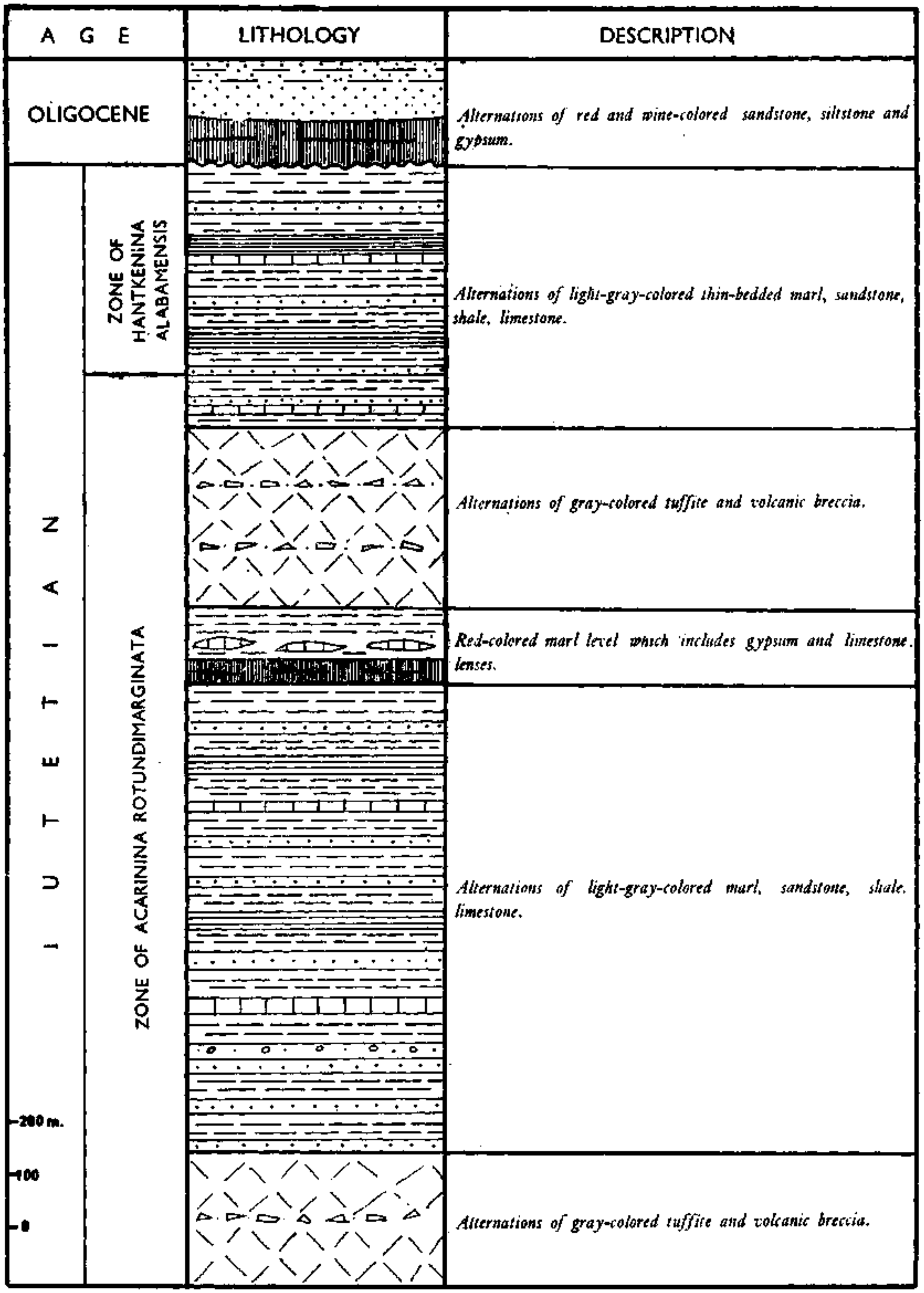


Fig. 3 - Stratigraphic section of Bozbel formation (Lutetian).
Locality : between Bozbel and Karababadağ Mountains.

d. Kösedağ formation

It occupies the northeastern part of our region, Kösedağ and its western extension. This formation is named *Kösedağ formation* as it mostly crops out at Kösedağ.

Generally it is characterized by alternations and intercalations of thin-bedded marl and sandstone levels with thin andesite, agglomerate levels.

Andesite and agglomerate levels, that make steep cornices and change from dark gray to violet-gray in color, show thicknesses from a few meters to several hundred meters. Soft and light gray-colored marl and sandstone can easily be distinguished.

It has been observed that towards east volcanic materials predominate, but towards west sedimentary layers gain importance. Thus, it is understood that this volcanic material originated further east, that is in the upper parts of Kösedağ. The volcanic activity that developed in the sea provided the deposition of alternations and intercalations of volcanic materials with sedimentary materials.

In the marl and sandstone layers of Kösedağ formation, Nummulitic levels are present. The following Nummulites have been determined from the samples collected (determination by S. Erk):

Nummulites uroniemis A. Heime (A, B forms)
Nummulites perforatus (Montfort)
Nummulites atacicus Leymerie
Nummulites brongniarti d'Archiac & Heime

The Kösedağ formation is also of Lutetian age. It has volcanic facies and is of the same age as Bozbel formation. These two formations are continuations of each other.

Thus in our region, lying above older formations, Eocene starts discordantly with conglomerate layers and develops as flysch facies of Ypresian and Lutetian age, either laterally towards center of the basin or upwards, reaching a total thickness of 4000 meters. But especially within the Lutetian flysch levels andesite, tuffite and volcanic breccia layers are also present. Expansion of volcanics towards the northeast part of our region draws attention.

It has been stated in the previous works that Eocene layers do exist in Sivas region. However in these studies Eocene has been treated in general terms.

5. OLIGOCENE

Selimiye formation

The oldest gypseous series in our region is Selimiye formation. This formation crops out in parallel depressions in the south and north of Tecer, Gürlevik and Bozbel Mountain chains in the southern part of our area. It is named as *Selimiye formation* since it has been best observed around Selimiye village.

Selimiye formation generally consists of alternations of variegated sandstone, siltstone together with gypseous layers. Sandstone and siltstone layers are generally red or wine-colored and show, in places, yellowish or greenish-gray-colored thin levels. The sandstone is fine-grained and very thin-bedded. Thickness of the bedding changes from 1-2 mm to 40-50 cm. Gypseous layers generally occupy the lower section of Selimiye formation. They are made up of white, gray and red-colored, 8-10 cm-thick layers. Gypseous layers together with some siltstone and clay layers show diapiric folding.

A sample collected from Selimiye formation has been sedimentologically examined by F. Demirmen. The sample consists of fine-grained sandy limestone with a calcite matrix of fine grain up to 70% (lithographic) and irregularly distributed detritic materials up to 30 %. The detritics are mainly made up of kaolinized feldspars and quartz and in smaller amounts of mica-chlorite and devitrified silicic volcanic glass. Rarely sphene (titanite) is present. Detritics are angular and show poor sorting. Secondarily kaolin and, locally, calcium phosphate (collophane) have also been developed. No fossils were found. This formation was formed under calm conditions in an environment of lower or higher salinity and probably in a basin of rapid accumulation. It is probable that this basin might be a hypersaline lagoon.

Selimiye formation generally begins with gypsum in our area. Often gypsum layers rest over Eocene layers (Photo 1). Sometimes they start with conglomerate and sandstone layers. A thin conglomerate level, which contains Eocene limestone pebbles with reworked Nummulites, has been observed in the base of Selimiye formation west of Karasar village in the north of Tecer Mountains. However cement of this conglomerate consists of gypsum. According to this observation it is assumed that there is a slight discordance between Eocene and Selimiye formation. Apart from this, although some discrepancy has been observed, here and there between Eocene layers and gypseous layers at the base of Selimiye formation, we attribute this to the widely different plasticity characteristic of the gypsum layers.

Selimiye formation, that reaches great thicknesses in our area, must have been deposited in a lagoon environment. No marine fossil traces have been found within this formation, but levels with Ostracods have been encountered.

The following are the Ostracods determined by N. Solak:

Cyprideis sp.

Ilyocypris sp.

Stratigraphic distribution of these Ostracods is from the base of Oligocene up to the end of Pliocene. However, above Selimiye formation marine Lower Miocene layers are present. So that Selimiye formation is situated between Eocene layers below and Lower Miocene layers above (Photo 1-2). Therefore, it becomes necessary to accept Selimiye formation as Oligocene.

Many geologists who worked in the Sivas region have also examined gypseous series that has widespread exposures. However, they could not separate Selimiye formation—what we call the first gypseous series—from the upper gypseous series of Miocene age. Both of these gypseous series have been considered together, so that the ages of gypseous series have remained vague.

The gypseous series which crop out outside of our area, in the Gemerek regions especially west of Şarkışla, have been generally accepted as being of Oligocene age (K. Leuchs, 1943; E. Lahn, 1950; R. F. Lebküchner, 1957), but information about the age could not be more than estimations, as no fossiliferous marine Miocene layers have been encountered and generally no fossils were found in the gypseous series. It is probable that at least a part of gypseous series belongs to Miocene in this region. In fact, the boundary between gypseous series of Oligocene age and gypseous series of Miocene age is very prominent in our region. It can also be possible to draw this boundary in the neighboring areas.

6. MIOCENE

A variegated gypseous series crops out in less undulated areas, especially in the central parts of our region. This series constitutes intercalations of beds of marine and lagoon facies and is of

Miocene age (Fig. 4). From the point of view of lithology and facies this series has been considered as two different formations which show two different characteristics.

a. Karacaören formation

This formation developed especially in the northern slopes of Çıralı Mountain in the eastern part of our region. The most typical section can be seen near Karacaören village. It shows lateral passage to Hafik formation by extending towards west in the form of two promontories.

Although *Karacaören formation* consists of alternations of limestone, sandy limestone, marl, sandstone and shale layers, generally beige and yellowish-colored limestone layers predominate at the base (Photo 2). These layers pass upwards into gray-colored marl and sandstone layers. An upper level, in which limestone and sandy limestone layers again dominate, constitutes the base of the second promontory of the Hafik formation, which is made up of gypseous and variegated sandstones. At the top, this formation again continues in the form of alternations of fine-bedded sandstone and marl layers and gradually passes into gypseous layers of fine-bedded and white-colored Hafik formation.

Karacaören formation rests discordantly above Selimiye formation of Oligocene age (Photo 3). The first promontory of the formation extends as a strip above Oligocene and below the Hafik formation. However, this promontory is not always continuous but appears as a line of long lenses following each other. In places these lenses pass laterally into variegated sandstone and conglomerate layers of the Hafik formation. As to the west of our region they completely pass into Hafik formation.

The samples collected in order to determine sedimentological characteristics of limestone layers, which develop at the base of Karacaören formation, have been microscopically examined by F. Demirmen. Characteristics of the sample are described as follows: The sample consists of Foraminiferal and Bryozoan biomicrite, Rotalidae and Miliolidae within fine-textured calcite matrix

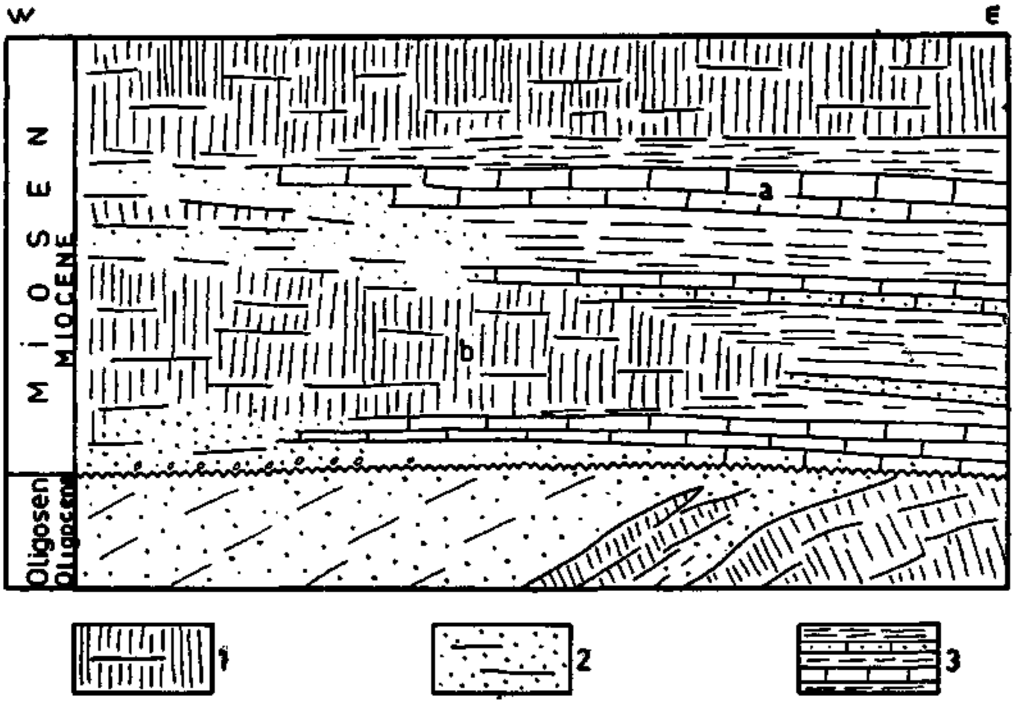


Fig. 4 - A schematic section showing the relation between Karacaören and Hafik formations.
a - Karacaören formation (Miocene), b - Hafik formation (Miocene).
1 - Gypsum; 2 - Variegated sandstone; 3 - Limestone, marl, sandstone.

and particles of Bryozoan, Echinoderm, Ostracod, Molluscs and Coralline algae. Sand-sized rare detritic quartzes, feldspars and glauconites are also present. There is a secondary and local limonitization. These were accumulated under calm conditions, probably in a sea distant from the shore but of no great depth.

Karacaören formation is fossiliferous. In addition to Lamellibranch and Gastropod macrofossils, that are found in the limestone and marl layers, abundant microfossils are also present.

The following fossils were determined from the samples taken from the lower levels that correspond to the first promontory of the formation:

Peneroplis thomasi Henson
Archaias kirkukensis Henson
Miogypsina irregularis Mich.
Textularia sp.
Miliolidae
Rotalidae

These fossils, which have been determined by C. Öztemür, represent Aquitanian and Burdigalian.

Macrofossils taken from the upper levels that correspond to the second promontory of the Karacaören formation have been determined by A. Güngör and the following fossils were identified:

Turritella crossei Costa
Ostrea aff. *gingensis* Schlotheim
Spondylus concentricus Bronn
Lithophagus sp.

According to these fossils, the upper levels, which correspond to the second promontory of Karacaören formation, pass upwards from Burdigalian to Helvetian. Therefore it is apparent that the whole Karacaören formation has Lower and Middle Miocene age with marine characteristics. This fossiliferous formation has additional importance from the point of view of determining the age of non-fossiliferous Hafik formation by their interfingering relations.

V. Stchepinsky (1938-1939) examined for the first time the Miocene fauna and Miocene layers of marine characteristics in our region. He mentioned a Miocene transgression in the Sivas region.

K. Nebert (1956) examined the marine Miocene layers in detail from the profiles of Ballıkbala and Söğütlü in the İmranlı area and determined their age as Miocene on the basis of fossils.

A. Dizer (1962) has studied Foraminifers found in our region within the Karacaören formation and determined Foraminifers of Aquitanian, Burdigalian and Helvetian age. She has also correlated the same Foraminifers with the Miocene Foraminifers of Iran, Iraq and Syria.

L. Erentöz and C. Öztemür (1964) have stated that Miocene sea of Iran extended up to the Sivas area.

We have previously explained that marine Miocene, which we named *Karacaören formation,* thins out going from east to west and laterally passes into gypseous series as two promontories in our region. Miocene, which consists entirely of fossiliferous marine beds from base to the uppermost levels in the eastern part of our region, shows alternations of gypsum and variegated sandstone beds in the western part (Fig. 5).

Therefore, it can be stated that Miocene sea had advanced from east to west and finally withdrawn from the area.

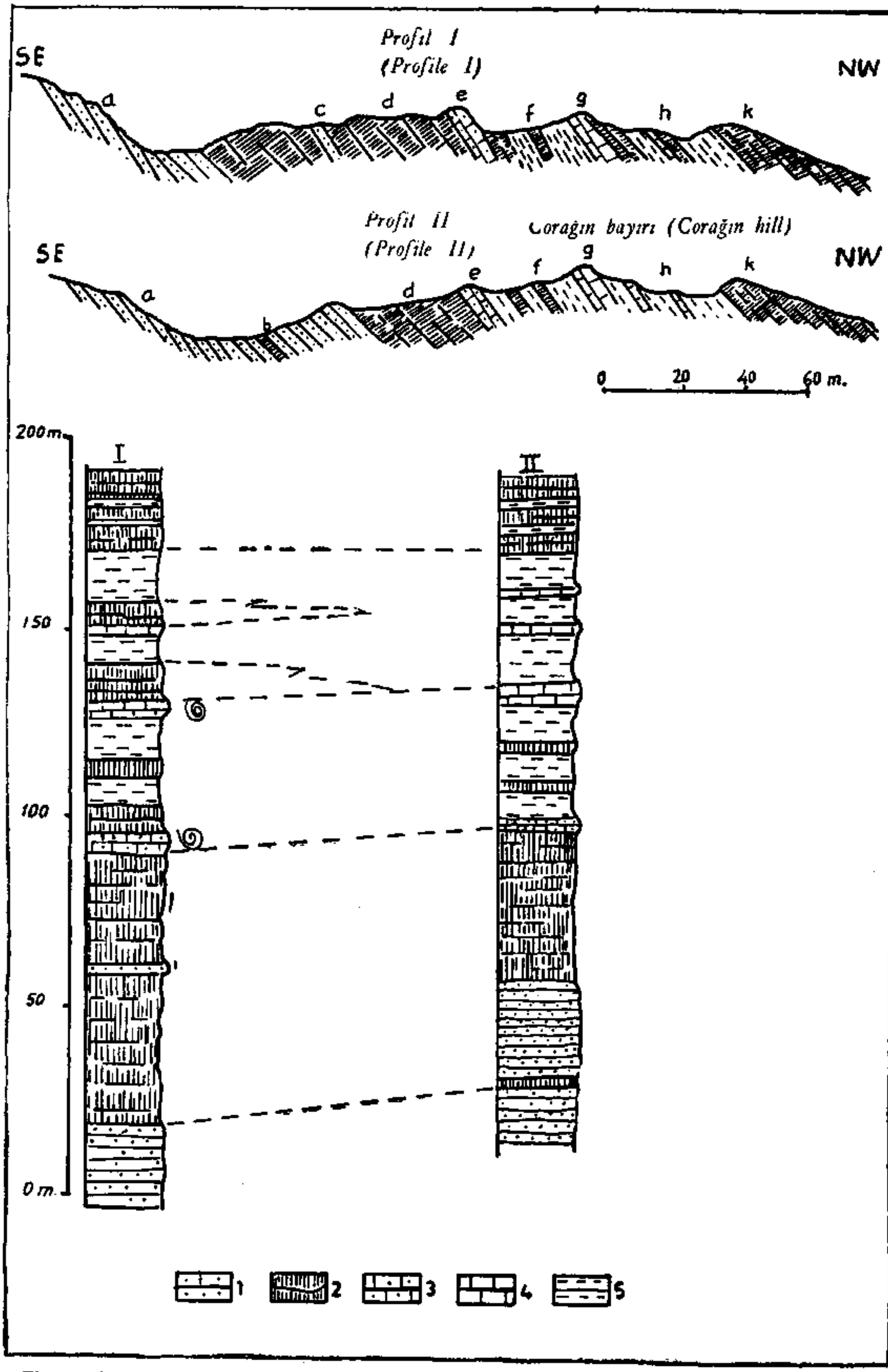


Fig. 5 - Sections showing alternations and lateral passage of marine limestone, marl and gypsum layers of Miocene age.

Locality : north of Boğazkesen village.

1 - Sandstone; 2 - Gypsum; 3 - Sandy limestone; 4 - Limestone; 5 - Marl.

Some of the studies that have been carried out in the vicinity of our area, also confirm our idea. E. Lahn (1950) pointed out that no marine Miocene had been deposited in the west of Sivas. R.F. Lebküchner (1957), who studied the Şarkışla and Gemerek area, mentions the gypseous series but does not write anything about the existence of marine Miocene in this region.

It is .understood however, that to the east of our area the marine Miocene has been developed more extensively. F. Kurtman (1967) noted the existence of fossiliferous marine Miocene made up of thick limestone and marl beds in the Kemah area.

From the above it may be assumed that the Miocene sea advanced from east or southeast and invaded the area up to Sivas.

b. Hafik formation

This formation has been developed in the central part of our region and in the less undulating area that extends nearly parallel to Kızılırmak River. It consists of prominent gypsum layers of white and light gray color and sandstone, siltstone and conglomerate layers mottled in color (red, wine-red, green and light blue).

Thick beds of gypseous layers that vary in thickness from 5-6 cm to 40-50 cm and show plicated folding were observed here. In some cases they are in alternation with gray and red-colored thin marl and claystone layers. Especially the upper levels of *Hafik formation* are completely made up of gypseous layers. However, in the lower levels they show alternations as well as lateral passage with the levels of variegated sandstone, siltstone and conglomerate. They are sometimes in the form of small and thin lenses.

As to the variegated sandstone, siltstone and conglomerate beds, they are formed by alternating layers of thicknesses varying from 1-2 cm to 5-6 m. However, sandstone layers generally predominate. No sorting is observed within the conglomerate and sandstone layers. Cross-bedding can be seen in places. Pebbles and sand grains are often made up of fragments of ophiolites, quartz, radiolarite and andesite. Stratigraphically, these variegated sandstone, siltstone and conglomerate layers predominate in the lower levels of Hafik formation. In places, thick or thin gypseous intercalations can also be observed. However, upwards these beds are completely replaced by gypseous layers. These variegated sandstone layers are mainly seen to dominate in the Beydağ, Celalli and Karayun regions.

The Hafik formation rests with an angular discordance on the Oligocene Selimiye formation. This can be clearly observed just north of Saklı village and south of Karayün. Here Hafik formation starts with conglomerate layers and passes upwards to gypseous layers.

No fossil traces have been discovered within the Hafik formation. However, this formation has been deposited together with the Karacaören formation. This is because both formations have lateral passage into each other. For instance, the passage of the fossiliferous limestone layers of Karacaören formation into Hafik formation in the form of lenses can be seen in a stream bank, 2 km east of Süleymaniye village.

As has been stated in the previous section, the Karacaören formation is of Lower and Middle Miocene age, as determined by fossils. Therefore, Hafik formation that has lateral connection with the Karacaören formation should also belong to Lower and Middle Miocene. The upper levels probably reach as far as Upper Miocene. This is because the uppermost levels of the Hafik formation are also above the Karacaören formation (Pl. II; Fig. 4, 5).

The gypseous series near Kızılırmak in the Sivas region has been first examined by W.J. Hamilton (1867). However, according to him, the age of this gypseous series might be Permian-Tertiary.

V. Stchepinsky (1939) considered that this gypseous series was of Oligocene age.

K. Nebert (1956) recorded that gypseous layers formed regressively over marine Burdigalian layers in Zara and İmranlı regions.

F. Kurtman (1961-1963) pointed out that gypseous series in Sivas region is of Oligocene and Miocene age.

The gypseous motley series, to which we have given the name of *Hafik formation,* has been developed outside our region, especially in the western areas. It is observed that towards west of Sivas region this formation gradually takes place of the marine Miocene layers.

7. PLIOCENE

This formation consists of conglomerate and sandstone layers. In places it includes also some chalk levels. It generally has a light-red and beige-colored appearance. The cementation is loose. Conglomerate layers are made up of pebbles of diameters changing from a few centimeters to 8-10 centimeters and generally consist of quartzite marble, radiolarite, ophiolite, limestone pebbles. They had been deposited in depressions at the southern outskirts of Sakardağ and Kösedağ, which lie in the northern part of our region. Moreover, in the west, these layers can be seen in the form of an outlier in a small area south of Mamuga village.

These beds rest discordantly over metamorphics, Upper Cretaceous limestones, Eocene flysch, Oligocene and Miocene layers. The bedding is generally horizontal or near horizontal. However, dips reaching some 20° have been measured in the east of İmranlı. These dips have been formed either by block movements caused by faulting or by original dipping instead of folding.

No fossils important for the age determination have been found within these layers. But these beds rest discordantly over gypseous, series of Miocene. In addition, limestone pebbles of Miocene age can also be seen among conglomerate pebbles. When this data is evaluated, it becomes clear that these layers are younger than Miocene. It is certain that they are older than alluviums and terraces seen at the present river beds. Therefore we think that it would be right to accept their age as Pliocene.

8. QUATERNARY

There are in our region alluviums, river terraces and travertine deposits of Quaternary age.

Terraces along the river sides and alluviums made up of pebbles and sand accumulations can be seen along wide beds of Kızılırmak River and of the streams that join this river.

Travertine layers, that spread over wide areas and crop out just at the southern outskirts of Sakardağ in the northwestern part of our region, have been deposited during Quaternary. Even today, in the same area, there are evidences of travertine growth near Orhun village.

II. MAGMATIC ROCKS

As magmatic rocks intrusive ultrabasics (ophiolites) and volcanics (andesite, tuffite, volcanic breccia) are present in our area.

1. ULTRABASICS

Ultrabasics are observed in areas situated in the southern part of our region, namely Tecer Mountains,- Gürlevik Mountain and Bozbel Mountains as well as in the wide areas that extend south of Fıdıl Mountain. Again in the form of relatively small exposures, ultrabasic rocks have been found around Bahçecik and Koşudere villages in the northern part of our region. Here and there these generally gray, dark green and even black-colored rocks have a morphology of scattered hills. It is interesting to note that, in places, Upper Cretaceous limestone and radiolarite lenses rest above the ultrabasics.

If ultrabasic rocks are examined closely, it can be seen that they generally have numerous cracks and fractures, scattered calcite veins and, in places, brecciated structures that were serpentinized.

As a result of mineralogical study of many samples carried cut by O. Baysal, it has been determined that they consist of wholly serpentinized peridotite and serpentinized bronzitic olivine-peridotite. They show cataclastic and partly fish-net texture. Within it, abundant serpentine, accessory opaque mineral, traces of chlorite, some calcite and accessory chromite have been observed. Serpentines have generally chrysotile and partly antigorite characteristics.

We accept the age of ultrabasic rocks in our region as Upper Cretaceous, because they are found together with the Upper Cretaceous limestone (Tecer limestone) and radiolarite lenses. Paleocene limestone (Gürlevik limestone) is observed above the ultrabasics. Ophiolite and radiolarite pebbles can be seen in great quantities in the Bahçecik conglomerate (Ypresian) that is found lying discordantly over Paleocene limestones.

2. VOLCANITES

Volcanites are represented in our area by andesites, tuffites and volcanic breccia. They all show widespread extension. They have been determined as Lutetian in age.

a. Andesites

Andesites outcropping in the northeastern part of our region had been discussed in the paragraph describing the Kösedağ formation (Lutetian). These andesites, alternating with marl, sandstone and shale layers, were considered as volcanic formation under the name of *Kösedağ formation.*

In places, light gray, sometimes pinkish-colored and thick-bedded andesites have been altered and gained a whitish color. The andesite levels generally create steep cornices. The rock itself is friable.

As a result of mineralogical studies on andesite rock samples carried out by K. Markus, it was determined that these rocks consist of augite-andesite, hornblende-andesite, analcitic trachy-andesite. Augite-andesites are porphyritic and contain plagioclase and accessory augite minerals. Calcite, sericite, prehnite and chlorite were observed as secondary minerals.

Hornblende andesites have also porphyritic texture. The phenocrysts are plagioclase and hornblende. The plagioclases sometimes show sericitization and choloritization.

Age of the andesites is Lutetian. This is because the Nummulites, which have been determined within marl and sandstone beds that have alternations with andesites, belong to Lutetian.

b. Tuffites and volcanic breccias

We have already mentioned the alternating tuffite and volcanic breccia layers that crop out at Bozbel Mountains, Karababa Mountains, Fıdıl Mountains and the mountain chains which form their continuation, while describing the Bozbel formation (Lutetian).

These dark gray and greenish-gray-colored rocks form a steep and generally high morphology around the area. They are well-bedded and frequently fractured. The bedding and fracture surfaces are smooth and of a lighter color. They have been developed as two thick levels within Bozbel formation of the Lutetian age and considered as a unit of the Bozbel formation. The age is Lutetian as Lutetian Nummulites have been determined in marl and sandstone layers of the Bozbel formation.

As a result of mineralogical studies done by K. Markus, the samples have been identified as tuffite and volcanic breccia. They have characteristics of spilites and consist of effusive and plagioclase mineral fragments. Effusive parts have been partly chloritized and this chlorite sometimes acts as a cementing material.

III. TECTONICS

1. GENERAL SITUATION

In order to clarify the tectonic structure of Anatolia many studies have been carried out up to now and some authors have tried to divide Anatolia into several tectonic units (P. Ami, 1939; N. Egeran, 1947; İ. Ketin, 1966).

Our area of study covers the region where tectonic units became closer and showed a tendencly of unification and has been evaluated as different tectonic units by different authors.

The latest subdivision of Anatolia into tectonic units has been done by İ. Ketin (1966). According to this classification the greater part of our area is considered as Anatolids and a smaller part in the south as Taurids.

The Anatolids, that essentially include Mid- and Western Anatolian crystalline massifs, Upper Cretaceous series with ophiolites, and Tertiary formations, seen discordantly above, become narrowed by being limited with Pontids along Kelkit valley in the north and with Taurids along Tecer Mountains in the south.

Tecer Mountains, situated in the southern part of our region, have been included into Taurids tectonic unit which show Alpine tectonic characteristics. In the south Taurids have been bordered by tectonic unit of border folds.

From the point of view of transversal tectonics of Anatolia, the Sivas region is situated in a depression. E. Parejas (1940) named this depression, which remains between Van uplift in the east and Kızılırmak uplift in the west, as *Malatya depression.*

From the point of view of general characteristics our region has been divided into three tectonic zones (Levha. IV).

a. Sakardağ-Kösedağ uplift

This zone, which falls north of İmranlı, Zara and Koşudere (Çaykürt) line, generally consists of areas that cover volcanic Eocene formations, ophiolitic series and crystalline series. In the south, a great fault 40-50 km long (İmranlı fault) makes a boundary between the uplift and the Hafik-Zara-imranh depression. In the north, the uplift extends probably as far as the great Kelkit fault. In comparison to the southern Hafik-Zara-İmranlı depression this zone shows a greater uplift.

b. Hafik-Zara-İmranlı depression

It extends between the İmranlı fault parallel to the İmranlı-Zara and Koşudere line in the north and the great Tecer thrust parallel to the Tecer Mountains in the south. This zone, which includes Eocene formations and gypseous series of Oligocene and Miocene, bears the characteristics of a typical depressional basin that had been created by thousands of meters of deposits. It has also been pointed out by I. Ketin (1968) that it is a Tertiary depression.

c. Tecer-Gürlevik uplift

It consists of ophiolites, Cretaceous, Paleocene limestone layers and gypseous Oligocene series that in the north are bordered by the great Tecer thrust. In relation to the northern Hafik-Zara-İmranlı depression it has created an important uplift. This uplift has been pushed over the Hafik-Zara-İmranlı depression with a great thrust from south to north. This zone belongs to the Taurids tectonic unit.

2. FOLDS

Almost all of the formations in our region show bedding. All bedded formations from metamorphic series that constitutes the base of the region, up to late Miocene, have been folded. Generally, folding tectonics predominates in our region. Although every formation that is exposed shows some different folding characteristics under the influence of different tectonic forces and within their own lithologic features, a general parallelism can be observed in the strike of the folds. The folding trends generally are E-W, NE-SW and ENE-WSW. However, when strikes and dips of the formation beds affected by different orogenic phases are evaluated by diagrams, the difference between the mean strike and the dip of the axis can be clearly seen (Fig. 6).

The oldest series in our region are metamorphic rocks of Sakardağ. This series, which consists of gneiss, quartzite, amphibolite-schist, sericite-schist, mica-schist and marble layers shows very clear folding. The whole metamorphic mass indicates an anticlinorium that shows plication of all sizes. The folds are generally symmetrical. They often have ENE-WSW strikes and ENE dips.

By evaluating the bedding strikes and dips by means of Schmidt diagram, the mean trend of the axis has been determined to be N 60°E and its mean dip to be 16°ENE (Fig. 7).

Cretaceous and Paleocene layers have been folded together. All of the folds have the same characteristics. Tecer anticline has been torn and the layers have gained rather a monoclinal structure, since the Cretaceous and Paleocene limestones that are exposed at Tecer Mountains were affected by the Tecer thrust. Here, formation dips are generally to the south.

As to Gürlevik Mountain, the Cretaceous and Paleocene limestones here reveal an anticline (Gürlevik anticline) of 10-12 km width. This anticline is generally asymmetrical.

The trend of the fold axis has been determined to be N 70°E and its plunge to be 4°WSW by evaluation of strike and dip measurements on Cretaceous and Paleocene layers (Fig. 8).

Especially Eocene layers show good folding. Particularly Kozluca and Bozbel flysch layers contain small plicate foldings beside big anticlines and synclines.

Disharmonic and creep folding has been observed in places due to plasticity difference within the flysch layers.

In spite of the folds being generally symmetrical, the northerly or southerly inclined folds, even recumbent folds, can be observed in places.

The most important fold that affected the Eocene layers in our region is the Bozbel anticline. This anticline with a width of 15 km and a length of 50 km is, as a whole, in a form of an anticlinorium.

The Eocene layers generally have E-W strikes. The trend of their fold axes is also E-W. By evaluation of the Eocene layers with diagrams the mean trend of the fold axis has been found to be N 90°W and its plunge to be 10°W (Fig. 9).

Folding is also present in the Oligocene layers. Strikes of the layers are generally NE-SW. Dips of the layers are generally steep. Small overturned anticlines and synclines and minor flexures at their flanks can be observed.

The mean trend of the fold axis of Oligocene beds has been determined by evaluating the strike and dip measurements with the Schmidt diagram. The trend of the axis obtained is N 45°E and the plunge is

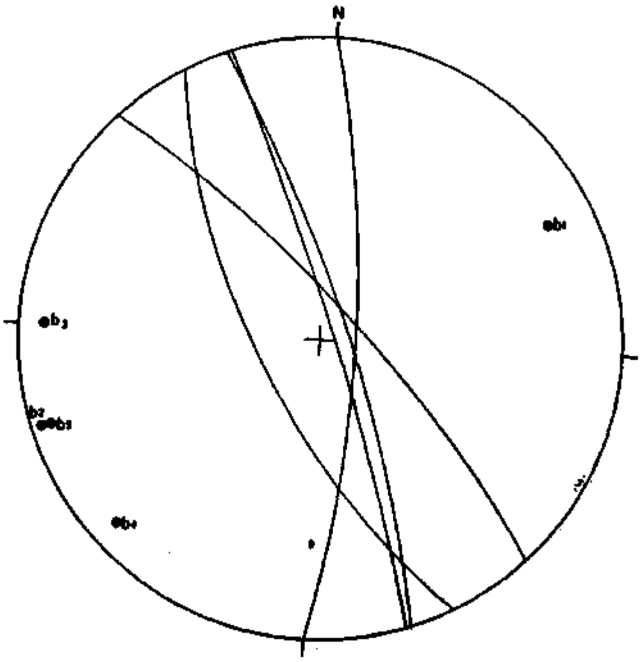


Fig. 6 - Determination of mean fold axis of various formations by Schmidt diagram. b_1 - in metamorphics; b_2 - in Cretaceous - Paleocene; b_3 - in Eocene; b_4 - in Oligocene; b_5 - in Miocene.

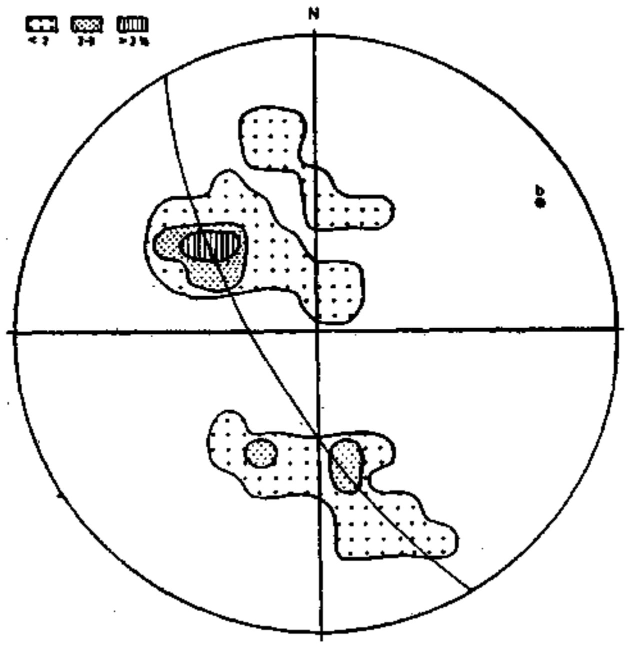


Fig. 7 - Schmidt diagram showing bedding and mean fold axis in metamorphics. b - fold axis, measurement: 17.

10°SW (Fig. 10). This value is considerably different from the trend of the fold axis obtained on Eocene beds. This is interesting because it indicates that the Oligocene layers have been affected by a different orogenic phase than were the Eocene layers.

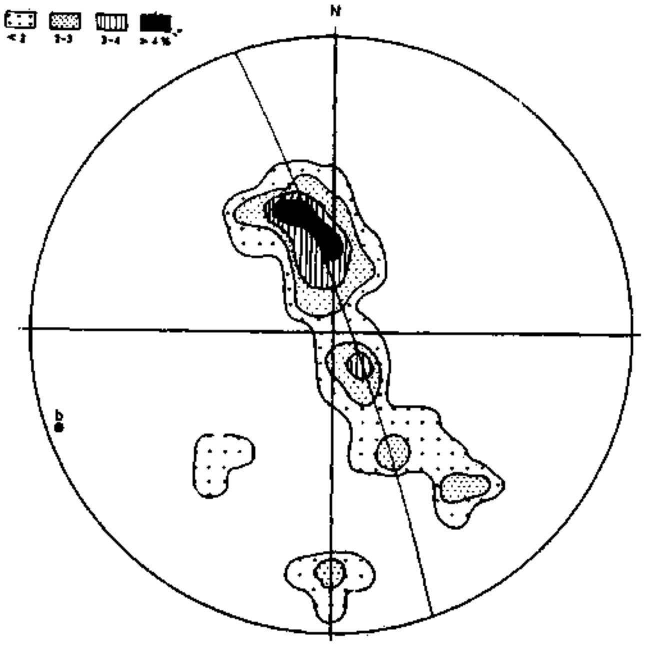


Fig. 8 - Schmidt diagram showing bedding and mean fold axis in Cretaceous-Paleocene. b - fold axis, measurement: 17.

The strikes and dips in Miocene layers are much more irregular. The folds are sometimes symmetrical, asymmetrical, inclined or overturned. The trends of the fold axes are also irregular. Frequent direction changes are observed. Here, of course, gypsum plays the most important role. Gypsum, as we know, has characteristics of diapiric folding.

The irregularity of strikes and dips on Miocene beds can be also clearly seen on the diagram. But still, it has been possible to determine the mean fold axis. The trend of the axis is N 70°E and its plunge is 4° (Fig. 11). This is a little different from the Oligocene fold axis. Therefore Miocene layers have also been folded differently from Oligocene layers.

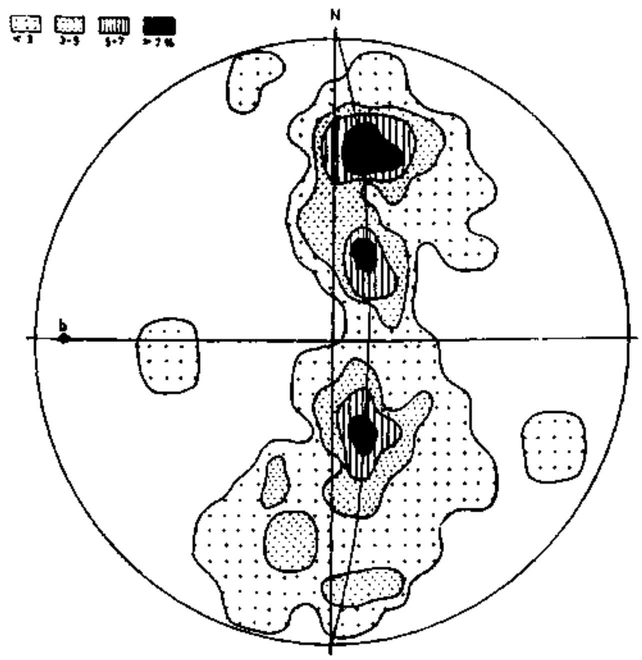


Fig. 9 - Schmidt diagram showing bedding and mean fold axis in Eocene. b - fold axis, measurement: 81.

Pliocene layers are generally horizontal. Although some dipping can be observed in some places (around İmranlı), no regular folding has been found. The dipping must generally be associated with faulting.

Alluviums and travertine deposits are wholly horizontal and show no traces of folding.

3. JOINTS

The rocks that crop out in our area show rare or frequent joints according to their lithologic and physical characteristics. Rigid and non-yielding rocks, such as marble, limestone, quartzite, sandstone, tuffite and andesite, have more joints in comparison with the soft rocks, such as marl, shale, sericite-schist and mica-schist, while widespread gypsum layers in our area show nearly no joints.

Joints show particularly two characteristics. Some of the joint surfaces are generally smooth and continuous. On the other hand, some of the joint surfaces are very rough, small and discontinuous.

The strikes and dips of the joints are also different.

When systematically measured joints of various formations are examined on diagrams, it becomes clear that these joints are not irregular, on the contrary, they develop maxima in certain directions and have been formed in a system. They are generally in symmetry with the fold axes (Fig. 12).

When the diagrams are examined, it can be seen that joints have been formed in parallel at right angle, and diagonal directions to the axes of folds. However, every kind of joint is not equally prominent in every formation. Almost every kind of joint has been represented in some formations (Fig. 12 D_5).

Longitudinal and transversal joints predominate in some formations (Fig. 12 D_2), while in some formations diagonal joints become most important (Fig. 12 D_4).

Jointing has close connection with folding as it can be understood from the symmetrical relations of joints with fold axes. Joints have also formed during folding. For this reason, joints also have close connection with characteristics of orogenesis that create folding; in other words, the formations that have been folded by different orogenesis have also been subjected to different folding and constitute different joint systems. So much so that a subsequent orogenic movement has affected the formation that had been previously folded and whose joint system had already developed.

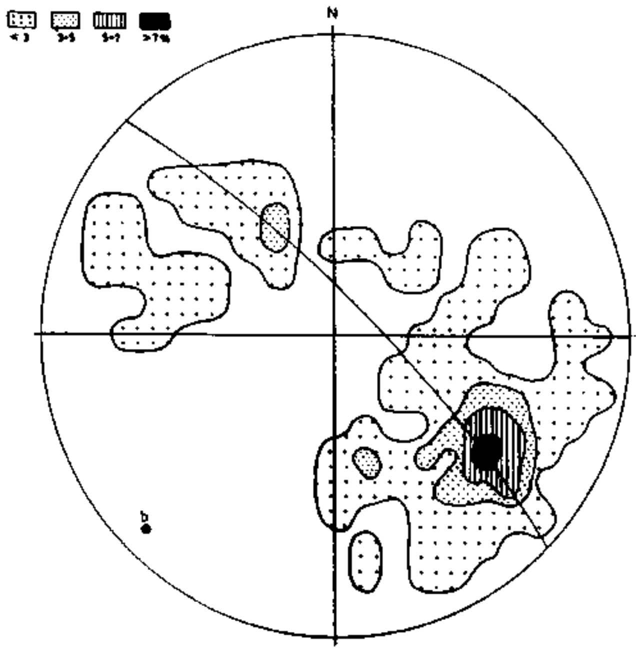


Fig. 10 - Schmidt diagram showing bedding and mean fold axis in Oligocene. b - fold axis, measurement: 50.

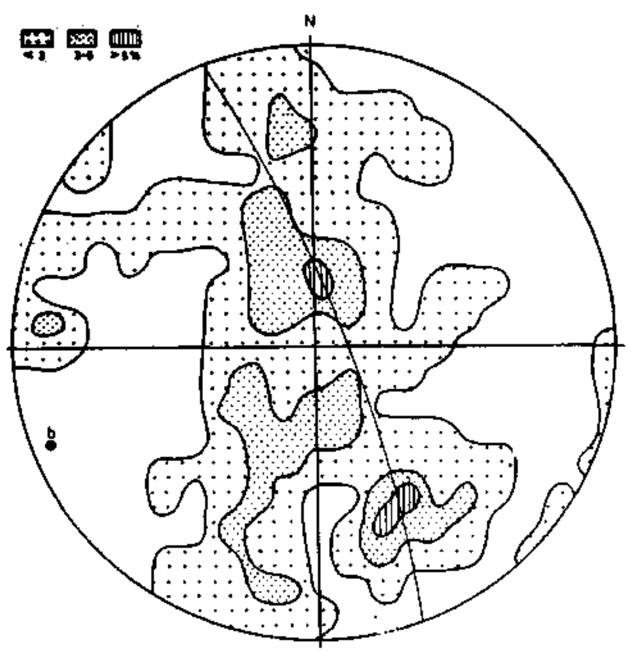
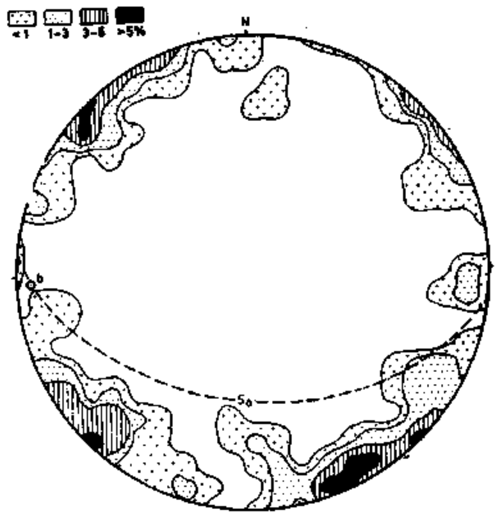


Fig. 11 - Schmidt diagram showing bedding and mean fold axis in Miocene. b - fold axis, measurement: 96.

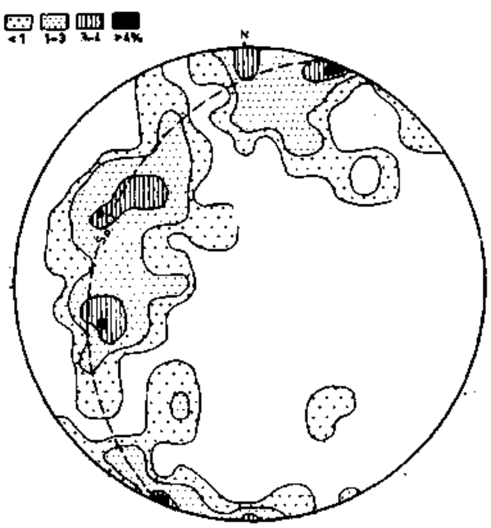
D_1 — Kristalinler
(Crystallines)

D_2 — Tecer kalkeri
(Tecer limestone)

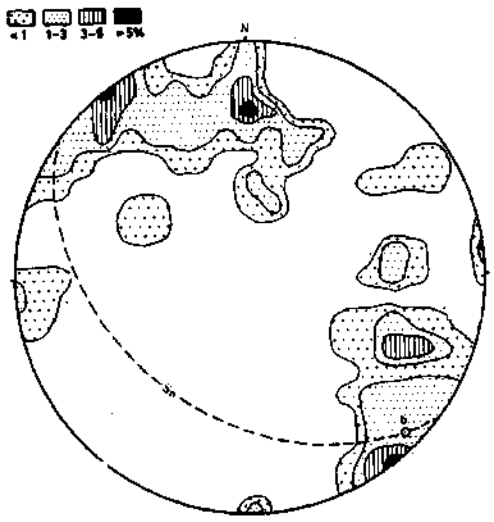
D_3 — Gürlevik kalkeri
(Gürlevik limestone)



D_4 — Bozbel formasyonu
(Bozbel formation)



D_5 — Selimiye formasyonu
(Selimiye formation)



D_6 — Hafik formasyonu
(Hafik formation)

S_0 = Tabaka (bed)

O_b = Kıvrım ekseni (fold axis)

Fig. 12 - Joint diagrams of various formations.

Divergencies of this nature observed in the existing symmetry and in the direction of fold axis have created some confusion within the joint system (Fig. 12 D_3). The joint systems that belong to metamorphic series (crystallines) have been developed in accordance with the same symmetry as that of the fold axis. Longitudinal and both of the diagonal joints have been developed almost to the same degree, while transversal joints constitute a little greater maximum (Fig. 12 D1).

Joints measured in the Tecer limestones of Upper Cretaceous age are symmetrical with the fold axis. Here, the longitudinal joints are less prominent, while transversal joints are strongly represented. Diagonal joints have been mostly developed in a single direction and have been probably under the influence of a second tectonic movement (Fig. 12 D_2).

The symmetry between the joint system and the fold axis is disturbed in the Paleocene-aged Gürlevik limestones. The joint system is also considerably complicated. The prominent maximum has been developed only in one direction. If this maximum belongs to the transversal joints—and this probability seems to be stronger when compared with D_2—it can be supposed that it has been influenced by subsequent tectonic movements (Fig. 12 D_3).

It is observed that particularly the double-directional diagonal joints constitute prominent maxima in the joint systems that have been measured in the Bozbel formation of Eocene age (Fig. 12 D_4). Longitudinal and transversal joints are almost not apparent. Diagonal joints have formed very clear symmetry with the fold axis.

The joint systems in the formation of Oligocene age have also been developed in a clear symmetry with the fold axis.

Longitudinal, transversal and diagonal joints are all well developed, almost to the same degree. However, the dips of the transversal and the NNW-SSE-oriented diagonal joints are less prominent (Fig. 12 D_5).

It is understood that the joints observed in the sandstone layers of the Miocene-aged Hafik formation have developed symmetrically to the fold axis. Here, particularly transversal and diagonal joints have been strongly developed, while longitudinal joints are almost absent. Dips in the diagonal joints are less prominent (Fig. 12 D_5).

4. FAULTS

A number of faults of different degrees of importance have been determined in our area. It is understood that some of them have played an important role in the tectonic constitution of our region. The faults generally consist of strike-slip faults, dip-slip faults, overthrusts and thrusts. They generally have been formed diagonally and parallelly to the fold axis of E-W, ENE-WSW, SE-NW directions.

a. Dip-slip faults

The most important one is the İmranlı fault. This has been formed in the E-W direction, parallel to the İmranlı-Zara and Koşudere (Çaykürt) line, a part of which stretches along Kızılırmak valley in the northern part of our region. This fault, with a minimum length of 40-50 km, generally constitutes the northern boundary of the gypseous Miocene series. Zones made up of fault breccias and cornices can be seen in places over the fault line distinguished by a special fault morphology of the continuous cornice type. In addition, correlation of Karacaören formation of Miocene age found on both sides of the fault line confirms this, fault.

The southern block in comparison with the northern had been considerably lowered by the İmranlı fault. The minimum downthrow has been measured as 600-700 meters.

It is understood that this fault has played an important role in the formation of the Hafik-Zara-İmranlı depression. The fault has been formed after Burdigalian, since it is observed that Burdigalian layers here have been affected by this fault.

Other important dip-slip faults are the Tavşanlı fault, the Ballıkbala fault and the Karababa fault. These faults have been formed approximately parallel to the İmranlı fault. Tavşanlı and Ballıkbala faults are observed within the Miocene layers, whereas Karababa fault is formed in the Eocene layers. In the Tavşanlı and Ballıkbala faults the southern blocks have collapsed, while in the Karababa fault it is the northern block that has been depressed.

b. Strike-slip faults

These faults are especially found in Miocene layers. They have generally been developed in the SE-NW and NE-SW directions, diagonally to the general trends of axes of the folds in this region. Some small and some big throws in these faults can be measured up to 2-3 km.

c. Thrusts and overthrusts

The Tecer thrust is the most important one in our region. It extends in the E-W direction along the entire southern part of our region (approximately 70-80 km). By this thrust the Tecer and Gürlevik limestones and ophiolite masses of Upper Cretaceous and Paleocene age at Tecer Mountains have been pushed over younger Eocene and Oligocene formations in the north. The movement has been from south to north. However, it is understood that this movement had been stronger in the west and the dip of the thrust approaches to 10-15°, even to horizontal, whereas to the east the dragging gradually diminishes but the dip of the thrust plane increases. Furthest east this thrust becomes a reverse fault.

Clippes have been developed between Ovacık and Kulyusuf villages. Here, Paleocene-aged Gürlevik limestones are seen as small islands above the gypseous and variegated Selimiye formation of Oligocene age. Here, dragging of the thrust has been measured to be 6 km at least.

Tecer thrust constitutes the southern border of the Hafik-Zara-İmranlı depression. This, in our opinion, is a very important tectonic line that divides Anatolids from Taurids. This line can be traced westwards outside of our region.

Another important fault in our region is *Gürlevik overthrust.* Gürlevik limestone and Bahçecik conglomerate have been pushed over Bozbel formation by this overthrust of 15-50 km length.

5. OROGENIC MOVEMENTS

The oldest orogenic movement in our region had played a dominant role in the folding of metamorphic layers of gneiss, quartzite, amphibolite-schist, sericite-schist and marble. Since it was not possible to find out the exact age of this metamorphic series, we could not determine the precise age of the orogenic movement. However, the Upper Cretaceous limestone layers have been found lying with an angular discordance over the metamorphic series. This indicates that folding movements within metamorphics had taken place before Upper Cretaceous. Obviously this could either be initial Alpine movement or Hercynian movement. The outcrops of the formations, that initially were affected by various orogenic phases, have been distinguished in an attached tectonic map (PI. IV). However, it should be kept in mind that younger phases can re-affect the previously folded formations. The formations outside the metamorphic series in our region have been affected by various Alpine movements.

The first Alpine movement detected in our region had taken place during late Paleocene. The Upper Cretaceous Tecer limestones and the Paleocene Gürlevik limestones, that are seen to be concordant, have been folded together. The Lower Eocene Bahçecik conglomerate layers rest discordantly over Paleocene Gürlevik limestones in the south of Gürlevik Mountain (Söğütlü village). It is apparent that Upper Cretaceous and Paleocene layers had been folded, uplifted, then severely eroded. The name *of Gürlevik phase* has been given to this interphase between Laramian and Pyrenean phases. This phase entirely corresponds to the *Van phase* which has been determined by E. Altınlı (1966) in East Anatolia. Another important orogenic movement in our region has taken place during late Eocene. Marine Eocene layers have been folded and uplifted by these movements, which correspond to the Pyrenean phase of the Alpine orogenic movements. Although no angular discordance between Eocene layers and Selimiye formation of Oligocene age overlying them has been found, it is deduced that an orogenic movement has taken place, since limestone pebbles with Nummulites within thin conglomerate layers are seen in places at the base of Selimiye formation (Oligocene). Great differences found in the trends of fold axes have also proved this theory (Fig. 9-10). Angular discordance between Oligocene and Miocene layers is very prominent. It is understood that a severe orogenic movement occurred at the end of Oligocene and the Oligocene layers that were folded and uplifted have been subjected to a severe erosion. This movement belongs to the Helvetic phase of Alpine orogenesis.

The latest orogenic movement in our area occurred during late Miocene. This movement belongs to the *Attic phase* of the Alpine orogenesis which caused the folding of Karacaören and Hafik formations of Miocene age and converted the entire region into a land.

No folding has been, observed in Pliocene layers and Quaternary alluviums. However, some slight dips in the Pliocene layers and river terraces seen in alluviums indicate a gradual development of general epirogenic movement in the region.

IV. PALEOGEOGRAPHY

Paleogeographic development of our region will be examined in this section.

If we look at the metamorphic series from bottom to top, we can see the development of alternating levels of gneiss, quartzite, amphibolite-schist, sericite-schist, mica-schist, with thick marble beds at the top. Therefore it is understandable that in the first phases of the period of deposition of metamorphic series the floor of the sea had been active, becoming alternatively deep and shallow, but during the period of deposition of limestones, fairly stable environment has been developed in our area.

The oldest formation seen today above metamorphics is Upper Cretaceous limestones. These limestones lie discordantly over metamorphics. Hence we can say that the region had remained as a land for a long time and had been consequently eroded.

The region remained under sea during periods of Upper Cretaceous and Paleocene. If we take into consideration that ophiolites and radielarites had been developed together with the Upper Cretaceous limestone layers, it can be understood that our region had complete geosynclinal characteristics which included initial magmatic activities. This region has been included within geosynclinal of Upper Mesozoic-Lower Tertiary of Middle Anatolia by R. Brinkmann (1968). However, it may be assumed that the Cretaceous sea became shallower in the south, but deeper towards northeast, because in the south were found such fossils as *Orbitoides media,* that live in the reef environment, and to the north, such deep-sea fossils as *Globotruncana lapparenti* have been determined. Since the sequence between Cretaceous and Paleocene is gradual we can say that the sea has also continued during Paleocene.

A severe erosion had occurred at the end of.Paleocene. This is inferred because thick Lower Eocene layers of conglomerate, in which pebbles of Cretaceous and Paleocene limestones and of radiolarite and ophiolite can be seen, had deposited discordantly over the Paleocene layers. Therefore, at the end of Paleocene, at least a part of the region became a land, while at the beginning of Eocene the region was gradually occupied again by Eocene sea. At this time, the area in the south, where Tecer and Gürlevik Mountains are present, constituted considerably higher grounds, as the sea approached these areas at the end of Ypresian.

In the beginning, Eocene sea had a rather calm and stable environment of deposition on the marginal areas, where especially thick conglomerate layers had the possibility of accumulation. But later, sea environment with vertical and rhythmic movements convenient for slow deposition of alternations of sandstone, marl, shale, limestone layers had been developed. We understand that there had been submarine volcanic activity, especially in the northeast part of the region, from the accompanied accumulations of tuffites and volcanic breccia with andesite lavas.

The presence of small Foraminifers within the Eocene layers, such as *Acarinina rotundimarginata* and *Hantkenina alabamensis,* indicates that the sea was rather deep.

From Eocene pebbles within the Oligocene basement we understand that in late Eocene the sea floor emerged and erosion affected some regions.

During Oligocene an entirely lagoon environment prevailed. A saline inner sea, which had almost no connection with open sea and which was not suitable for life, had covered our region as well.

This inner sea, in which initially only evaporites had been deposited, gradually had gained the characteristics of an environment suitable for deposition of elastics of fine sandstone and siltstone. From the accumulation of gypsum and variegated sandstone and siltstone we deduce that a very hot and rather dry climate predominated.

At the end of Oligocene the region again became a land and a severe erosion prevailed.

At the beginning of Miocene our region was again invaded by an open sea that developed from east to west. The invasion of sea had been very rapid and limestone layers had been deposited with almost no conglomerate deposition at the base. As the Lamellibranch shells in limestone layers at the base are all broken, we deduce that the sea had been shallow or moderately deep and agitated. However, formation of later-deposited marl and sandstone layers with reef lenses indicates that the sea had gained a shallow but calm environment and the climate was hot. For a short period the sea had a tendency of withdrawal, but then again invaded the region and in Late Miocene it had completely withdrawn from the area.

It is understood that outside the Miocene sea there had been developed a lagoon environment of gypseous deposits that was not suitable for life.

By the end of Miocene the region completely became a land and after a severe erosion phase the present surface features had been developed.

The presence of thick Pliocene conglomerates suggests that some depression hollows have been filled by unsorted pebbles of floods and rivers.

Manuscript received February 24, 1972

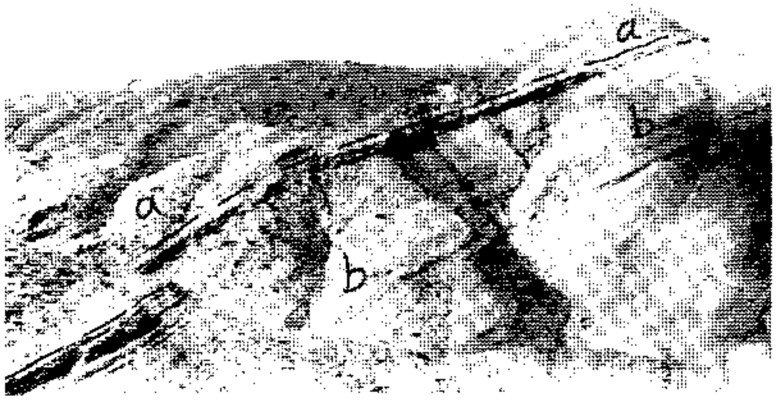


Photo 1 - Relation between Selimiye (Oligocene) and Bozbel (Lutetian) formations. Locality: West of Karaşar village. a - Selimiye formation, b - Bozbel formation.

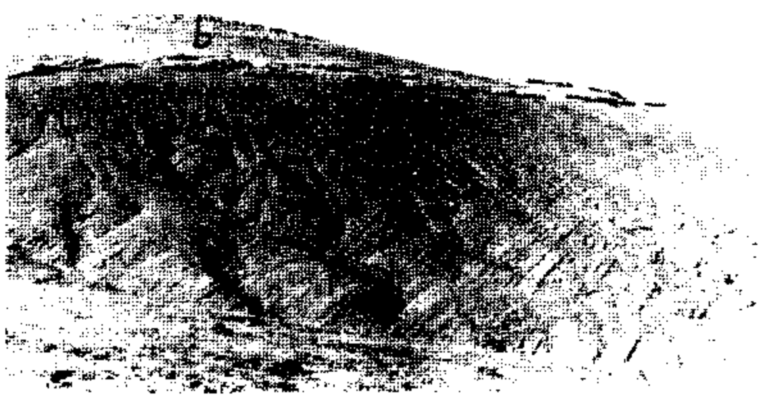


Photo 2 - Relation between Selimiye (Oligocene) and Karacaören (Miocene) formations. Locality: West of Celâlli village. a - Selimiye formation, b - Karacaören formation.

Photo 3 - A discordance seen between Oligocene-Miocene beds. Locality: East of Süleymaniye village. a - Oligocene (Selimiye formation), b - Miocene (Karacaören formation).

BIBLIOGRAPHY

AKARTUNA, M. (1962): Çaycuma-Devrek-Yenice-Kozcağız bölgesinin jeolojisi. *İst. Üniv. Fen Fak. Monografisi,* s. 17, Istanbul.

AKKUŞ, M.F. (1964): 1:25 000 ölçekli Divriği İ39-d_2 paftasının detay petrol etüdü. *M.T.A. Rep.* no. 4039 (unpublished), Ankara.

ALAGÖZ, C. (1967): Sivas çevresi ve doğusunda jips karstı olayları. *Ankara Üniv. Dil ve Tarih Coğ. Fak. Publ.* no. 175, Ankara.

ALTINLI, E. (1966): Geology of Eastern and Southeastern Anatolia. *M.T.A. Bull.* no. 66, Ankara.

ARNI, P. (1939): Tektonische Grundzüge Ostanatoliens und benachbarter. *M.T.A. Publ.* ser. B, no. 4, Ankara.

ARPAT, E. (1964): Gürlevik dağı bölgesinin genel jeolojisi ve petrol imkanları. 1:25 000 ölçekli İ39-d1 paftaları. *M.T.A. Rep.* no. 4180 (unpublished), Ankara.

BAYKAL, F. (1945): Darende ile Kayseri arasındaki Toroslar'ın jeolojik yapısı. *İst. Üniv. Fen Fak. Bull.,* s. B, vol. 10, no. 2, İstanbul.

———(1946): Zile-Tokat-Yıldızeli bölgesinin jeolojik etüdü. *M.T.A. Rep.* no. 1709 (unpublished), Ankara.

BLUMENTHAL, M. (1937): Les traits principaux de la geologie de la region entre Kangal et Divrik (Vilayet Sivas). *M.T.A. Rep.* no. 568 (unpublished), Ankara.

———(1938): Recherches geologiques dans le Taurus oriental a la hauteur de Hekimhan-Hasançelebi-Kangal (Vilayet Sivas-Malatya). *M.T.A. Rep.* no. 570, Ankara.

———(1945): Die Kelkit-Dislokation südlich Niksar und ihre tektonische Rolle. *M.T.A. Mecm.* no. 2/34, Ankara.

BRINKMANN, R. (1966): Geotektonische Gliederung von Westanatolien. *N.fb. Geol. Pal. Mh.* 10, Stuttgart.

———(1968): Einige geologische Leitlinien von Anatolien. *Geol. et palaeontolog.* 2, Marburg.

DEMİRMEN, F. (1965): Sincan bölgesi (Zara-Divriği) genel jeolojisi. 1:25 000 ölçekli Divriği İ39-c4 paftası. *M.T.A. Rep.* no. 4127 (unpublished), Ankara.

DİZER, A. (1962): Foraminifer of the Miocene of the Sivas Basin (Turkey). *İst. Üniv. Fen Fak. Bull.,* ser. B, vol. XXVII, no. 1-2, Istanbul.

EGERAN, N. (1947): Tectonique de la Turquie et relation entre les unites tectoniques et les gites metalliferes de la Turquie. *These,* Nancy.

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

ERENTÖZ, L. & ÖZTEMÜR, C. (1964): Aperçu generale sur la stratigraphie du Neogeene de la Turquie et observations sur ses limites inferieure et superieure. *Instituto «Lucas Mallada» C.S.I.C.* (Espana) Cursillos Y Conferencias, IX.

İZDAR, E. (1963): Geologischer Bau, Magmatismus and Lagerstatten der ostlichen Hekimhan-Hasançelebi Zone (Ostanatolien). *M.T.A. Publ.* no. 112, Ankara.

KETİN, İ. (1955): On the geology of Yozgat region and the tectonic features of the Central-Anatolian massif (Kırşehir crystalline). *T.J.K. Bull.* vol. VI, s. 1, Ankara.

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

———(1968): Relations between general tectonic features and the main earthquake regions of Turkey. *M.T.A. Bull.* no. 71, Ankara.

KURTMAN, F. (19610): Stratigraphie der Gipsablagerurigen im Bereiche von Sivas (Zentral-Anatolien). *M.T.A. Bull.* no. 56, Ankara.

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

———(1967): Geologie des Munzur dağ-Gebietes. *Geelogische Rundschau,* Band 56, Stuttgart.

LAHN, E. (1950): Les formations gypsiferes en Anatolie (Asie Mineure). *Bull.. Soc, CM. Fr.* (5), t. XX, Paris.

LEBKÜCHNER, R.F. (1957): Zur Geologie der Umgebung von Kayseri-Avanos-Ürgüp und Boğazlıyan bis in die Uzunyayla. *M.T.A. Rep.* no. 2656 (unveröffentlicht), Ankara.

LEUCHS, K. (1943): Der Bauplan von Anatolien. *N.Jb. Min. Min. etc.* Jahr. B, Heft 2/3.

NEBERT, K. (1955): Zur Geologie des Akdağ. *M.T.A. Rep.* no. 2512 (unveroffentlicht), Ankara.

———(1956): Zur stratigraphischen Stellung der Gipsserie im Raum Zara-İmranlı (Vilayet Sivas), *M.T.A. Bull.* no. 48, Ankara.

NORMAN, T. (1964): 1:25 000 ölçekli Sivas-İ38-c2 paftası Celalli (Hafik) bölgesinin genel jeolojisi. *M.T.A. Rep.* no. 4774 (unpublished), Ankara.

OKAY, A.C. (1952): Sivas 62/2 paftası lövesi raporu. *M.T.A. Rep.* no. 1996 (unpublished), Ankara.

———(1953): Sivas ile Tokat arasındaki bölgenin (Reşadiye 44/3 paftasının) jeolojisi hakkında not. *M.T.A. Rep.* no. 2242 (unpublished), Ankara.

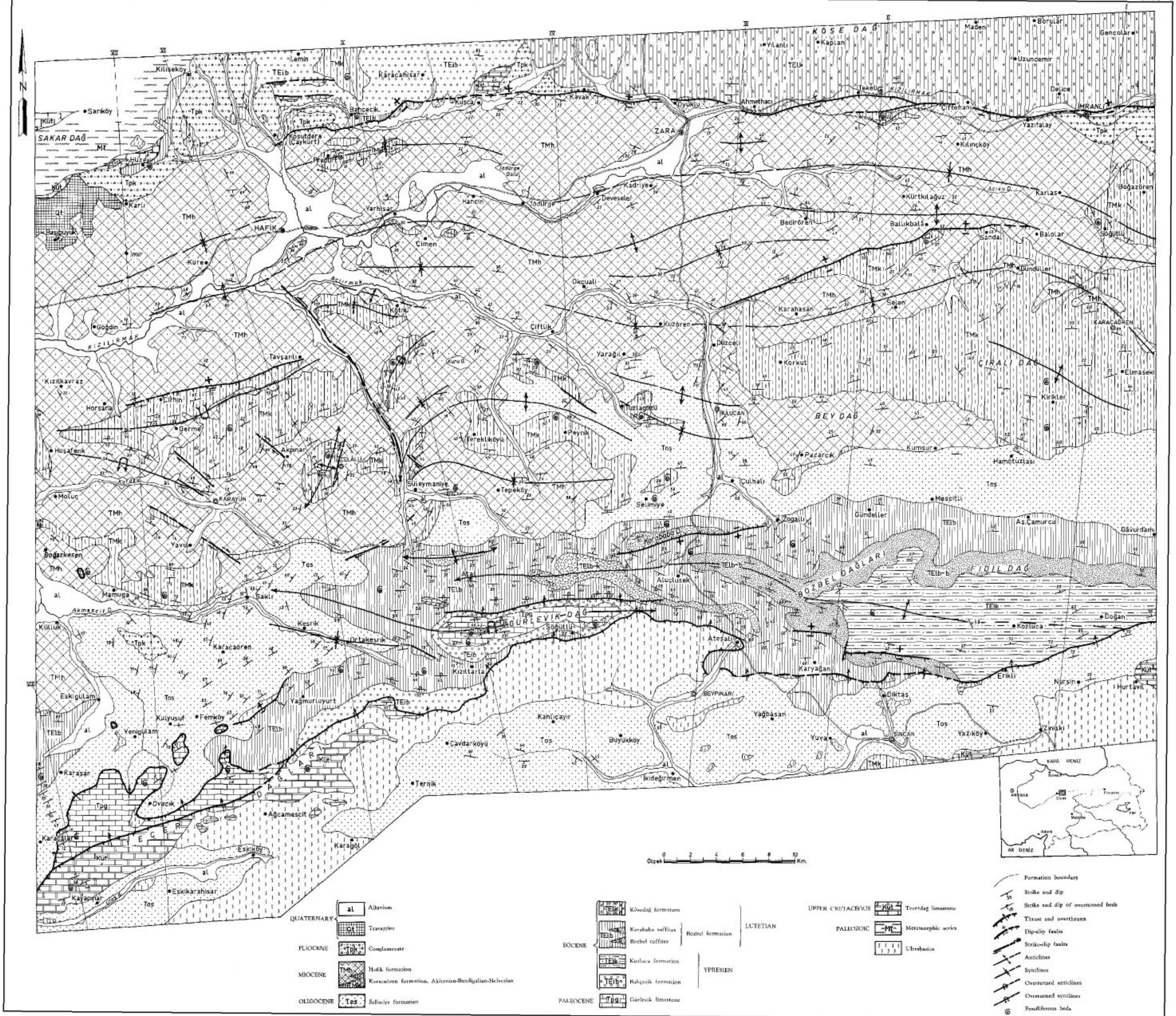
PAREJAS, E. (1940): La tectonique transversale de la Turquie. *Rev. Fac. Sci. Univ. İst.,* seri 2 B, t. V. 3-4.

RATHUR, A.Q_. (1965): Divriği İ39-d3 paftasına (Beypınar sahası) ve bu sahadaki petrol olanaklarına ait genel rapor. *M.T.A. Rep.* no. 4257 (unpublished), Ankara.

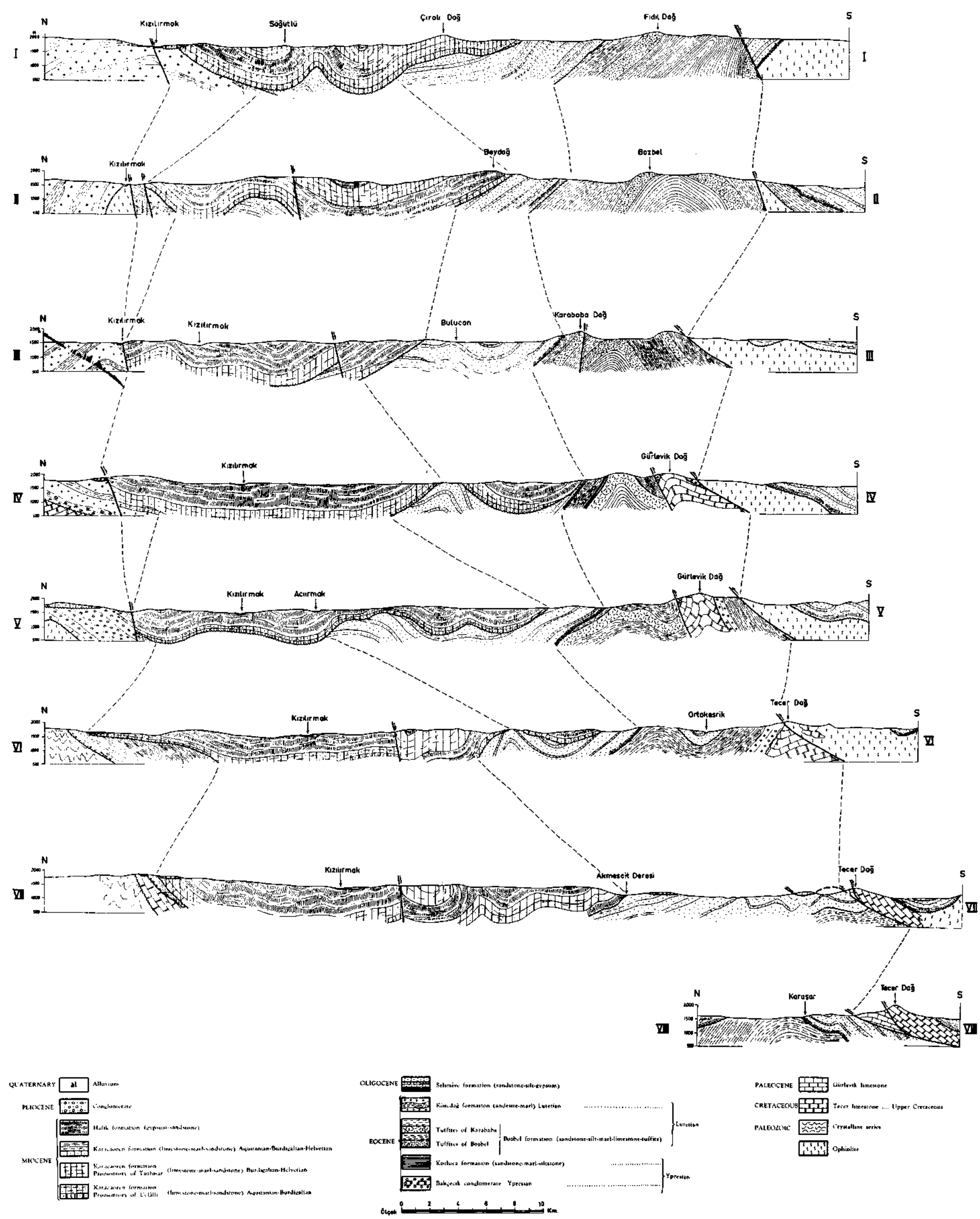
STCHEPINSKY, V. (1939a): Rapport sur la geologie generate de la partie centrale du vilayet de Sivas. *M.T.A. Rep.* no. 868 (unpublished), Ankara.

———(1939b): Faune miocene du vilayet de Sivas (Turquie). *M.T.A. Publ.,* serie C, no. 1, Ankara.

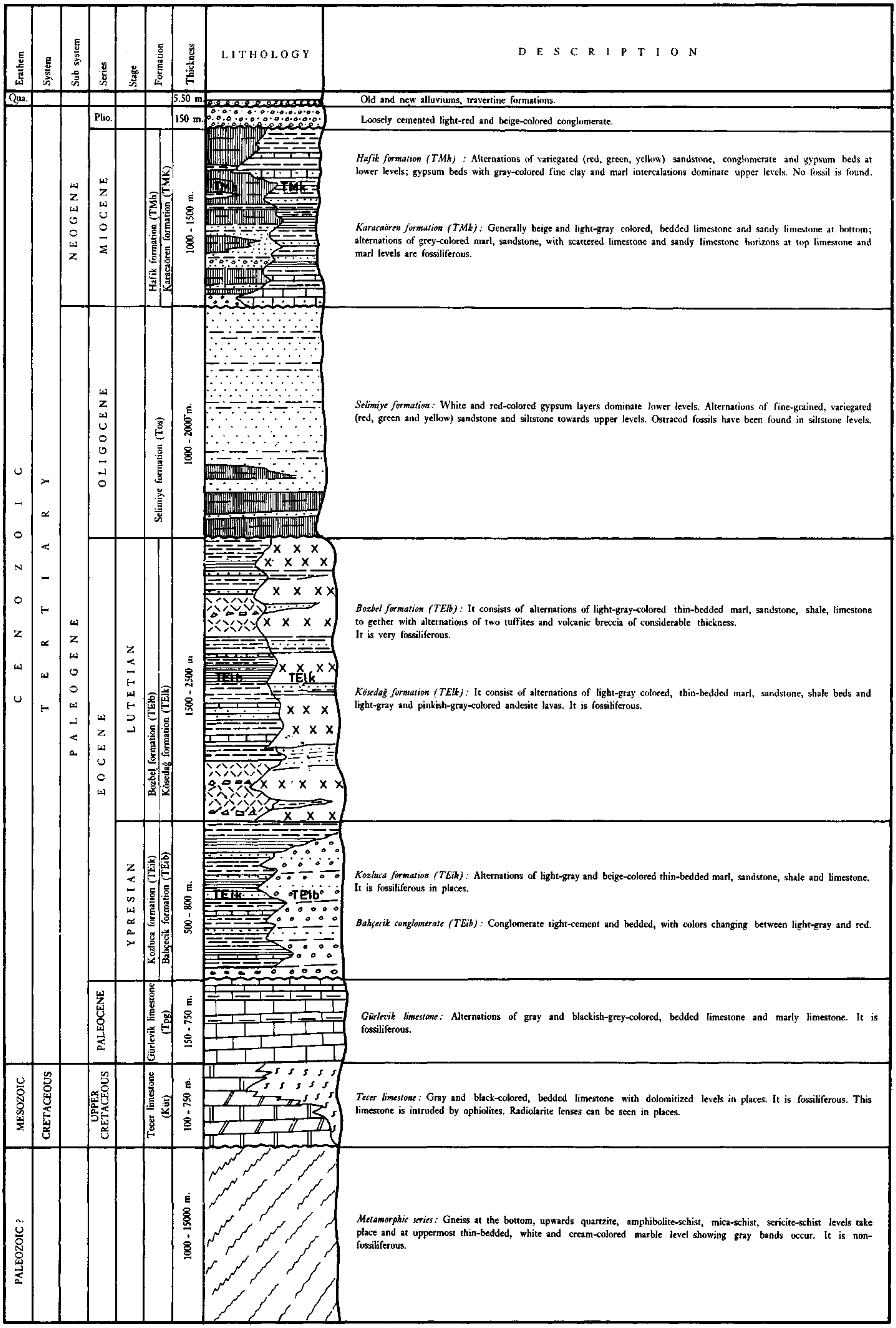
TCHIHATCHEFF, P.de (1867): Asie Mineure. *Geologie,* vol. I, Paris.



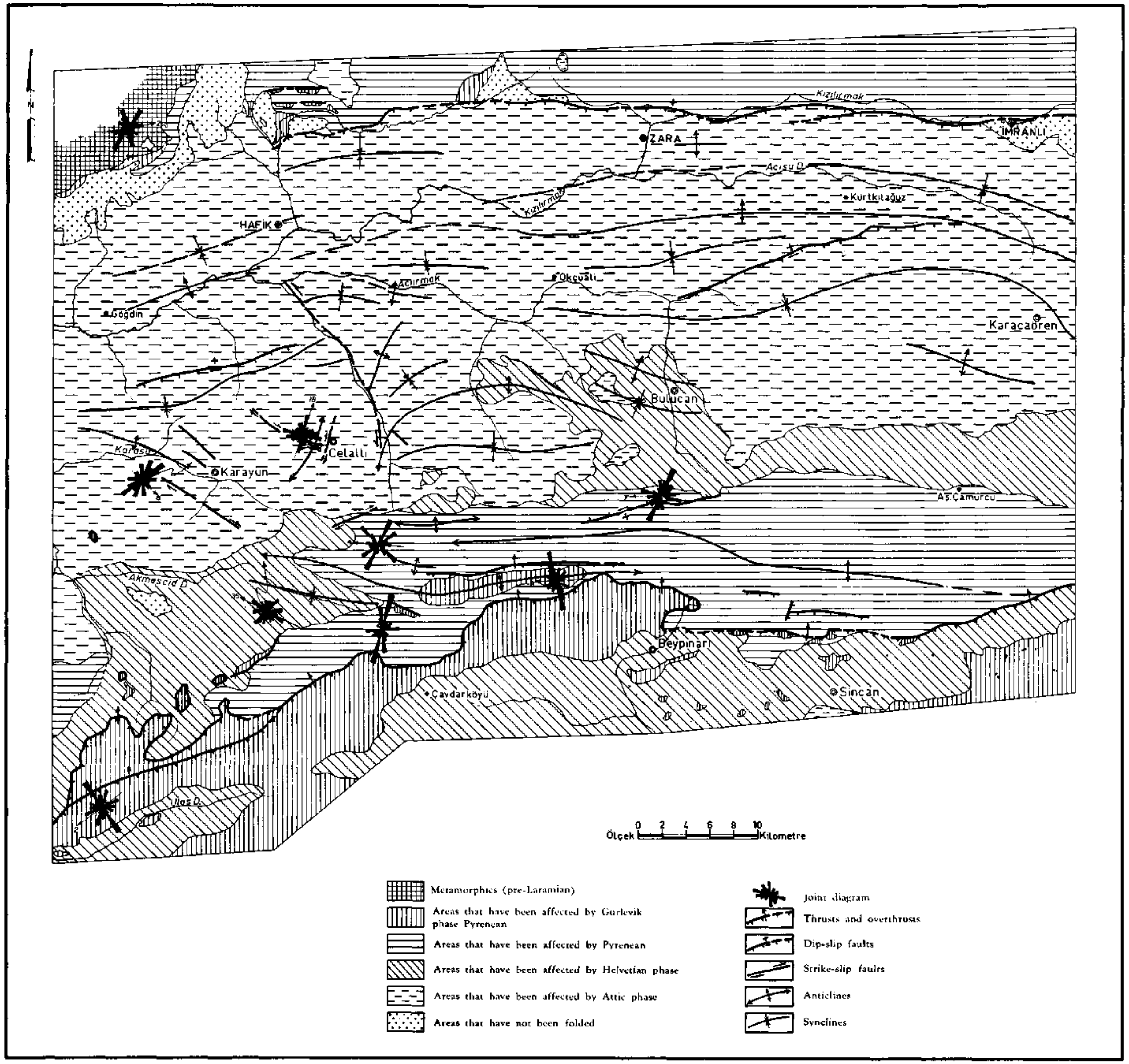
GEOLOGIC MAP OF THE SİVAS-HAFİK-ZARA AND İMRANLI REGION



GEOLOGIC CROSS-SECTIONS OF THE SİVAS-HAFİK-ZARA-İMRANLI REGION



COMPOSITE STRATIGRAPHIC SECTION OF THE INVESTIGATED



TECTONIC MAP OF THE SİVAS-HAFİK-ZARA-İMRANLI REGION