THE LOWER MIOCENE (BURDIGALIAN) FORMATIONS OF THE ADANA BASIN, THEIR RELATIONS WITH OTHER FORMATIONS, AND OIL POSSIBILITIES

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ABSTRACT - The purpose of this study is to discuss the general geology of the Adana Basin and especially to make a detailed description of the Lower Miocene formations, situated to the northwest of the Mersin - Tarsus region, and to review in a general way the oil possibilities of the basin, with a particular stress on the importance of the Lower Miocene formations in this connection.

The Adana Basin is divided into three regions : The Hatay (=Antakya), İskenderun, and Adana regions; the latter is subdivided in its turn into two secondary regions, namely the Adana and Mersin (= İçel) regions. The direction of the tectonic ridges dividing these regions is NE-SW. The general features of sedimentation in these regions are more or less alike; however, some differences have been observed.

Although transgressions are predominant in the Miocene, regressive movements have also taken place. At places, the Lower Miocene overlies discordantly the Paleozoic, Mesozoic, Paleocene, Lutetian and Oligocene formations. The Lower Miocene consists of conglomerates, limestones, sandy limestones, marly limestones, and marls; lateral and vertical facies changes can be observed here. The calcareous parts are, in some places, reef-complex or biohermal in character. The reefs are transgressive and they more or less follow the direction of the buried ridges and hills, which are older in age. Despite the fact that the Lower Miocene is more calcareous at the periphery of the basin, towards the center, it turns into fine-grained sediments. In the middle of the basin shales are predominant.

The thickness of the Lower Miocene calcareous formations in the Adana Basin is 80 m. near Kozan and some 500-700 m. in the proximity of Mersin. It may be said that in the vicinity of Misis it is practically missing.

It is most probable that the Alpine tectonic forces came from the NW and the SE, the direction of folds is NE-SW on the western and northwestern borders of the basin, and partly E-W in the center. These folds are monoclinal. The southern parts of many of the anticlines have steeper slopes. In general, the Miocene presents folds with slopes gradually decreasing towards the upper layers. Certain structures are in the form of terraces. Faulting in the Tertiary is rare. The folding and faulting movements in the İçel section of the Adana region, as compared with other regions, have been more frequent, violent, and irregular.

The Lower Miocene formations are overlain discordantly by the Helvetian or, in some places, by Tortonian. There are many places where the Lower Miocene is directly covered by river terraces, caliches or alluvium.

Petroleum indications are observed in the Paleozoic and Miocene formations. The Lower Miocene formations display the characteristics of source-rock and reservoir-rock. The Middle Helvetian sandstones and limestones and the Tortonian sandstones are of the reservoir-rock type, whereas the Lower Helvetian or the Upper Helvetian marls and the Tortonian marly series are of the cover-rock type. There are many anticlines in the basin.

A search for petroleum in the Adana Basin should be concentrated in reef-complex formations, in terrace structures, in the vicinity of buried ridges and hills, and in the stratigraphic and tectonic

traps. In our opinion, it should be advisable to have the exploratory drillings conducted on reefs, within the areas of some 15-25 km. further to the south of the southern boundaries of the Lower Miocene, exposed on the surface, or in the proximity of the buried ridges and hills and where facies changes of the Lower Miocene are observed. Furthermore, we believe that the drilling operations should be executed not in the center of the basin, but further to the periphery; or, to be more exact, some distance from the periphery, avoiding, however, the central parts of the basin. There is a great chance that such drillings should prove very productive, and in our opinion bearing in mind of the above-stated recommendations should be very useful and efficient and the safest way to find petroleum.

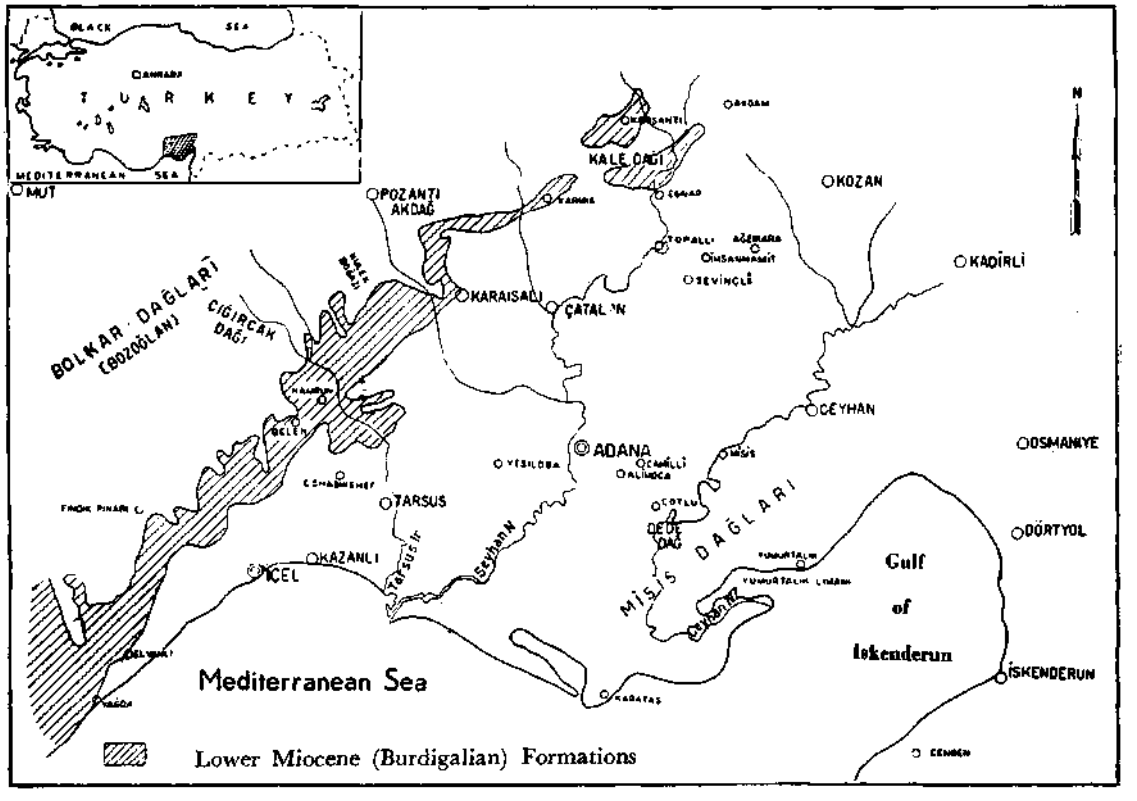


Plate 1 - Map of the Adana Basin showing areas where Lower Miocene (Burdigalian) Formations are outcropping

INTRODUCTION

By the Adana Basin we mean the area which is limited by Osmaniye, Kadirli, Kozan, Karsantı, Pozantı, Namrun, Fındıkpınarı, and Elvanlı (pl. I). This basin, roughly speaking, consists of three main parts: The Adana, İskenderun, and Hatay (= Antakya) regions; this division of the basin into three distinct regions has taken place during the Eocene epoch.

After discussing here, in a general way, the Adana region, [1] which is a part of the Adana Basin, we shall study the Lower Miocene formations at several different places in this region, laying particular stress on the Mersin (= İçel) part where detailed surveys have been conducted, and we shall try to explain the main characteristics of these formations.

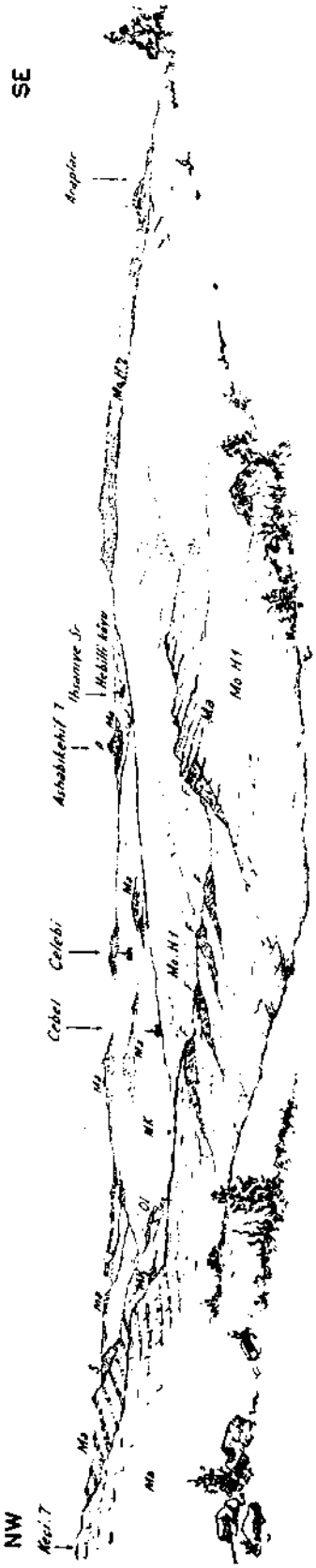


Fig. 1 - View of the area between Araplar and Keçitepe, looking from the hill, which is located on the eastern flank of Kızıldere

P) Limestones and crystalline limestones (Paleozoic)
S) Serpentines
Ol) Oligocene formation
Ma) Lower Miocene (Burdig.) limestones
MK) Marly limestones - Lower Miocene
F) Fault escarpment
Mo.H1) Middle Miocene (L. Helvetian) marls - Marls with Pteropoda = lower marls
Mo.H2) Limestones and sandy limestones of Middle Miocene (M. Helvetian) age

PHYSIOGRAPHIC OUTLINE

I —-Orography ofthe Adana Region

The Adana Basin (in the narrow sense of the word) is encircled from Kozan to Mersin by such mountains as Andıl Dağ (750m.), Kale Dağ (1835 m.), Akdağ (2471 m.), and Çığırcak Dağ (2500 m.), which are known as the Taurus Mountains. This Taurus Range extends ,in the NE - SW direction. In the southeast the basin is bordered by Misis Mountains (pl. I).

As we go from the north towards the south of the basin, we descend from the mountainous region towards the hills and finally down to the Adana plain, which covers practically half of the basin.

II — Hydrography of the Adana Region

The largest principal running waters of the Adana Basin are the Seyhan River, the Ceyhan River and the Tarsus River, all of which flow from the east to the west (pi. I). The Ceyhan River takes its tributaries in the proximity of Maraş and the neighbouring areas. The tributaries of the Seyhan River flow as far as the environs of Kayseri; the Tarsus River begins in the Taurus Mountains (Bolkar Dağları) and flows into the sea near the mouth of the Seyhan River. All these rivers flow into the Mediterranean; they cut deep canyons in the limestone area of the Taurus Range. These rivers are fed by spring waters and rainfalls, but mainly by melting snow.

STRATIGRAPHY

I - OUTLINE OF THE STRATIGRAPHY OF THE ADANA BASIN

a - Paleozoic

The Paleozoic formation is observed at Dede Dag in the Misis Mountains; at

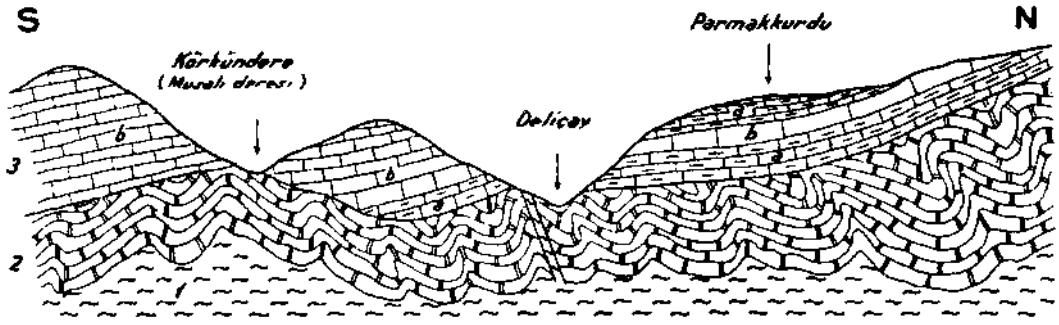


Fig. 1 a - Schematic section passing through Parmakkurdu and Körkün (= Musalı) Dere

1) Serpentines
2) Mesozoic (Cret.?) limestones
3) Miocene limestones
a) Marly limestones
b) Slightly porous, cream-colored limestones

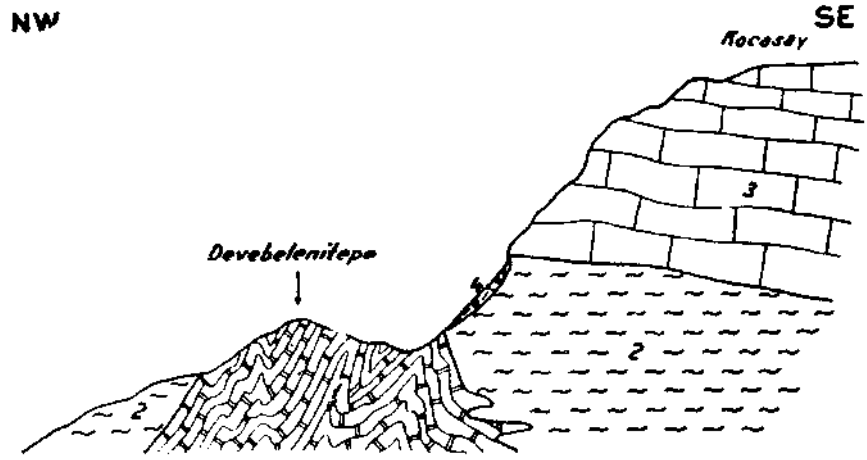


Fig. 1 b - Section passing through Devebeleni Tepe located near Erçelköy

1) Limestones and Radiolarites - Mesozoic (Cret.?)
2) Serpentines
3) Cream-colored, fossiliferous limestones (Burdigalian)
4) Scattered gravels

the Ashabı Kehif Hill (fig. 1) and its vicinity, northwest of Taurus; at the Bolkar Dağları mountains, north of Namrun; and to the north of Kozan.

The Paleozoic formation consists generally of black, sometimes white,- gray-colored, fine - grained, recrystallized, fetid limestones; gray sandstones; bluish-colored schists; and chlorine- schists. The limestones are sometimes completely recrystallized and sometimes porous in texture. Among fossils collected in this formation some *Fusulinidae,* found in the vicinity of Fındık Pınarı to the northwest of Mersin, can be mentioned.

The direction of the folds of the Paleozoic rocks is, in general, NNE-SSW or NE - SW. The Paleozoic limestones are overlain by schists and sometimes by sandstones. The folding movement has been strong, the dips varying between 45° and 60°.

b - Mesozoic

There are some areas covered by dioritic intrusions, partly schistous, radiolaritic or cherty, which occur mainly to the north and northwest of Mersin (pl. II, III; fig. la, lb). Generally they are Mesozoic in age.

According to the Paleontologists, certain fossils, observed in the dark - red colored limestones of the Misis Mountains, resemble the Liassic fossils found in the vicinity of Gümüşhane and the Triassic fossils of the Kocaeli Peninsula. In the vicinity of Belemedik, near the northern boundary of the region, Triassic and Jurassic deposits have been found in the lower levels of the border limestones.

c - Cretaceous

The Cretaceous formations are found in two bands: one starting at the Gülek Boğazı and extendig, at intervals, in the NE-SW direction (photo 1), and another one in the south, extending again in the NE - SW direction, along the Misis Mountain Range.

The Cretaceous band in the Misis Range -branches out into another band, in the neighbourhood of Ceyhan (between Kozan and Ceyhan); this band has a N - S direction.

The Cretaceous, formations show two facies: 1) limestones and 2) flysches. The Cretaceous limestones are white, gray, buff or pink in color; sometimes recrystallized or hard, with fine-grained and sublithographic texture. They contain such fossils as *Globigerina* sp. and *Globotruncana linnei*.

In the Adana Basin the Tertiary is represented by the Nummulitic (Paleocene, Oligocene) and Neogene (Miocene, Pliocene) formations.

d - Paleocene

The Paleocene is limited to a small area, south of the Gülek (= Külek) Boğazı; it consists of basal conglomerates and gray, pink, sandy limestone beds containing *Rotalia* sp., *Miliolidae, Asterigerina* sp., *Amphistegina* sp., *Miscellanea miscella, Alveolinellidae, Chlamys,* Coral fragments and Bryozoa.

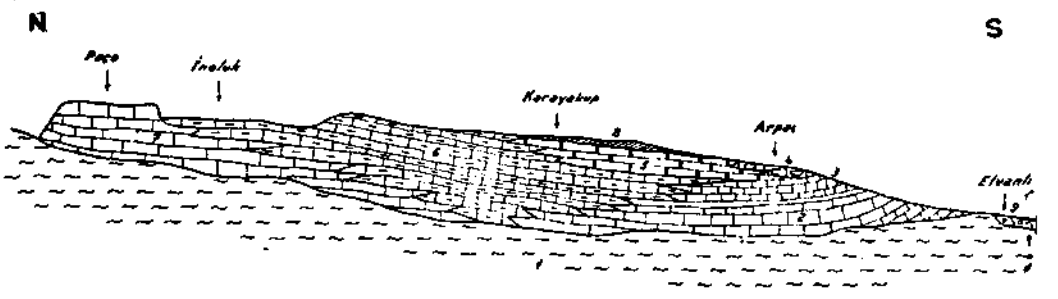


Fig. 2 - Section through Elvanlı and Paça

1) Serpentine
2) Hard, yellow limestones
3) Buff-colored limestones
4) Nodular, algal limestones
5) Coarse crystalline, yellow, soft limestones with some marls
6) White and gray, highly fossiliferous (Echinoid, Lamellibranch, Gastropod), soft and concretionary limestones
7) Coarse crystalline, porous, highly fossiliferous limestones. Whit - ecolored inside and gray or yellow - colored outside
8) Caliche
9) Alluvium

e - Eocene

Sandy limestones have been found in the Misis Mountain Range and in the neighbourhood of Namrun. Due to the presence of Nummulites, the Eocene formations in the vicinity of Namrun were attributed to the Lutetian age.

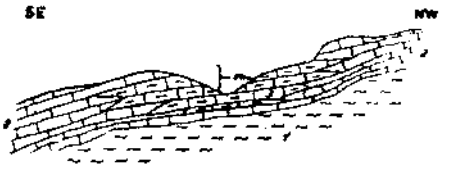


Fig. 2 a - The left side of the gully extending from Akarca to Fındıkpınar Valley

1) Serpentine
2) Hard, white-colored on the inside, fossiliferous (Algae, Corals, Miliolidae) limestones
3) Grayish-white, soft, Echinoid-bearing, marly limestones

f - Oligocene

The Oligocene deposits in the vicinity of Gülek and north of Mersin are lacustrine, terrestrial and estuarine in character. They, consist of gray, red marls, sandy marls, sandstones, limestones and conglomerates and contain such fossils as *Meretrix incrassata* SOWERBY, *Pecten, Pirula, Amphistegina,* solitary Corals, and plant fossils. Apart from these, there exist Oligocene deposits of marly and sandy-like flysches in the Misis area.

g - Lower Miocene

The Lower Miocene is transgressive and consists of conglomerates (basal conglomerates), marly limestones, sandy limestones, marls and limestones; between these beds there are horizontal as well as vertical transitions (fig. 2, 2a, 2b, 2c, 2d).

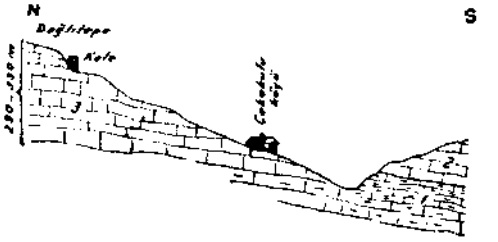


Fig. 2 c - Geologic section between Dağlıtepe and Çekokulu Köyü

1) White - colored, somewhat marly limestones
2) Hard, little fossiliferous, poorly bedded limestones
3) Hard, fine-grained and fossiliferous limestones (thickness: 290 - 330 m.)

The following are the principal fossils found in the Lower Miocene formations : *Globigerina, Heterostegina assillinoides* BLANCKENHORN, *Heterostegina prae-*

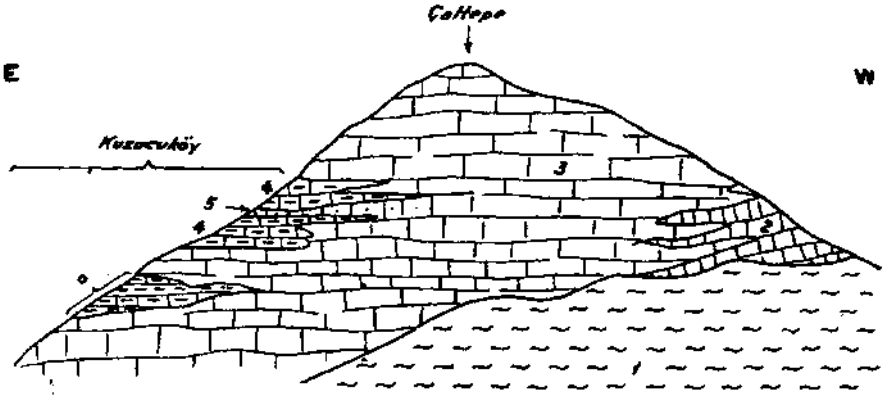


Fig. 2 b - Section through the west of Kuzucuköy and Çaltepe

1) Serpentine
2) Hard and dense limestones
3) Algae and Coral-baering limestones
4) White, marly limestones
5) Sandy, white limestones
6) Alternating thin-bedded marls and marly limestones

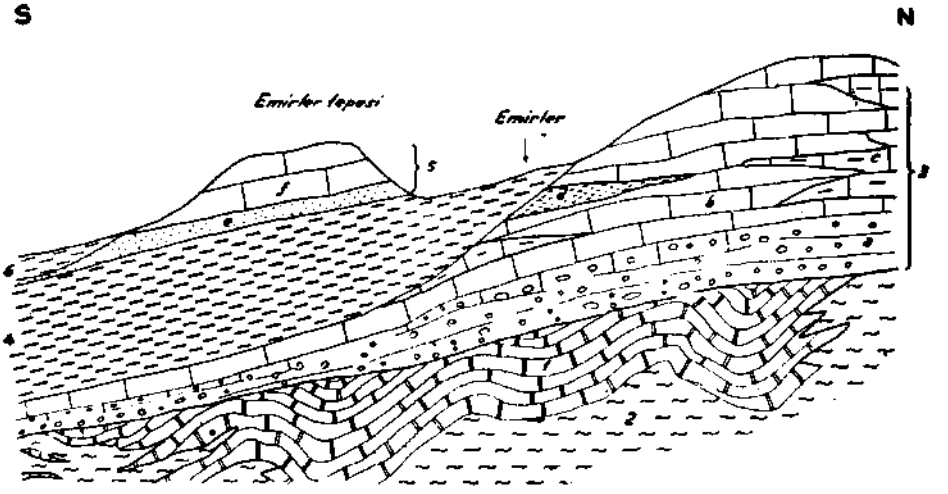


Fig. 2 d - Cross - section through Emirler

1) White, light-gray, buff-colored, fine crystalline, jointed, sublithographic limestones (Cretaceous)
2) Eruptive rocks and serpentines
3) Conglomerates (a), limestones (b), shaly limestones (c), and shales (d), (Lower Miocene= Burdigalian)
4) Pteropod - bearing shales = lower shales = (Lower Helvetian)
5) Coarse sandstones(e), and limestones (f), (Middle Helvetian)
6) Gray shales containing Heterostegina and Turritella - upper shales = (Upper Helvetian)

cursor TAN, *Heterostegina costata* d'ORB., *Heterostegina* sp., *Operculina complanata* (DEFRANCE), *Operculina complanata* DEFRANCE var. *heterostegina* SILVESTRI, *Cydoclypeus, Quinqueloculina, Rotalia viennoti* GREIG, *Textularia, Meandropsina, Alveolinellidae, Archaias, Lithothamnium bourcarti* (LEMOINE), *Lithophyllum* cf. *prelichenoides* (LEMOINE), *Lithophyllum* cf. *giraudi* (LEMOINE), *Tarbellastraea reulini* M. EDW. and J. HAIME, *Tarbellastraea reussiana* M. EDW. and J. HAIME, *Favites neglecta* d'ARCHIAC, *Heliastraea considea* REUSS, *Thegiostrae* cf. *lyensi* GREGORY sp., *Thegiostraea miocenica* ZUFF, *Solenastraea* sp., *Hypsoclypeus doma* POMEL, *Echinolampas scutiformis* LESKE var. *angulatus* MERIAN, *Echinolampas* aff. *tagliafenoi* COTTEAU, *Schizaster* sp. du gr. de S. *eurynotus* AGASSIZ, *Schizaster* sp. *Schizaster lovisatoi* COTTEAU, *Clypeaster latirostris* AGASSIZ, *Clypeaster (Bunactis)* aff. *scillae* DESM., *Clypeaster scillae* DESM. var. *geneffensis* GAUTHIER, *Clypeaster* aff. *geneffensis* GAUTHIER, *Clypeaster (Oxyclypeina) obtusus* POMEL, *Clypeaster pentadactylus* GAUTHIER, *Pectunculus, Flabellipecten, Amussium* aff. *duodecimlamellatum* (BRONN), *Chlamys holgeri* GEINITZ, *Ostrea gryphoides* SCHLOTHEIM, *Alectrionia aquitanica* MAYER, *Pitaria (Callista)* aff. *erycinoides* (LAMARCK), *Panopea faujasi* MENARD, *Turbo, Xenophora.*

The Burdigalian formations begin at Karsantı, in the northern part of the basin, and continue as a band gradually widening to the north of Mersin. This band is interrupted west of Karsantı. The narrowest and the widest parts of this band are 3 km. and some 20-25 km.., respectively (pl. I).

h - Middle Miocene

The Middle Miocene in this area is represented by Helvetian and Tortonian formations.

Helvetian Deposits :

The Helvetian deposits can be divided into three layers : the lower, the

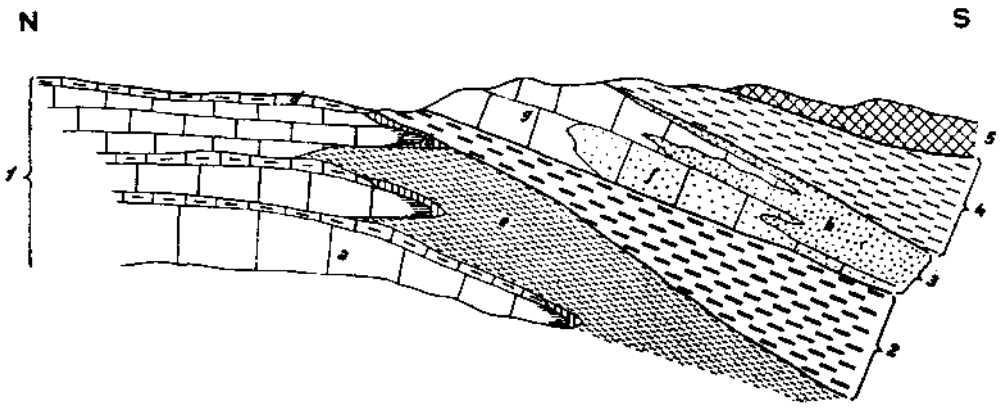


Fig. 3 - Section showing facies changes of the Lower and Middle Miocene in the Mersin - Tarsus Region

1) Lower Miocene (= Burdigalian) formation
a - Hard, white or yellow-colored, partly porous, fossiliferous limestones
b - Algal limestones
c - Coral, reef-like limestones
d - White or grayish-white colored, fossiliferous (Echinoid) and shaly limestones
e - Light-gray colored marls
2) Gray or bluish-gray colored, Pteropod - bearing marls - lower marls = Lower Helvetian
3) Middle Helvetian formation
f - Buff, yellowish or whitish-colored, rough-surfaced, sandy limestones
g - Buff or yellowish - colored, nodular, rough-surfaced, fossiliferous limestones
h - White or light gray - colored, coarse sandstones
4) Heterostegina and Turritella-bearing gray marls = upper marls - Upper Helvetian
5) Caliche

middle and the upper, which, are in the order of sequence : 1 - *Pteropod* - bearing marls (a - Flaggy marls, b - bluish marls = soft marls = lower marls = Lower Helvetian (1000-1400 m. thick); 2 - coarse sandstones and limestones = Middle Helvetian (400-700 m. thick); and 3 - gray marls with *Helero.stegina* = upper marls = Upper Helvetian (400 - 600 m. thick) (fig. 3, 4 - photo 2, 3, 4).

The following fossils have been found in the flaggy marls : *Cavolinia audeninoi* VINASSA, Vaginella, Cuspidaria, *Lunulites, Amussium* sp. and in the soft marls : *Hyalea, Cavolinia audeninoi* VINASSA, *Balantium pedemontanum* MAYER-EYMAR and *Amussium duodecimlamellatum* BRONN.

In the foliated («cartonne») marls of the Lower Helvetian, we found : *Lithocarpus, Bryozoa;* in the Middle Helvetian: *Heterostegina, Globigerina, Amussium cristatum* BRONN mut. *badense* FONTANNES, *Pecten* aff. *subarcuatus* TOURNOUER, *Chlamys solarium* LAMARCK, *Clypeaster* aff. *depressus* VADASZ, *Lunulites.*

In the Upper Helvetian marls the following fossils were found : *Astraea (Bolma) rugosa* (LINNE), *Turrittella (Archimediella) bicarinata* EICHWALD var. *percingulata* ERENTOz, *Turritella turris* BASTEROT var. *taurocrassula* SAGCO, *Aponhais uttingerianus* (RISSO), *Charonia (Sassia) tarbellianum* (GRATELOUP), *Murex (Alipurpura) delbosianus* GRATELOUP, *Eutria (Eutria) cornea* (LINNE) mut. *curvirostris* GRATELOUP, *Ancilla (Baryspira) glandiformis* LAMARCK, *Volutilithes (Athleta) ficulina* (LAMARCK) var. *rarispina* LAMARCK, *Drillia (Crassispira)* cf. *scillae*

BELLARDI, *Clavatula (Clavatula} calcarata* (GRATELOUP) var. *francisci* TOULA, *Clavatula (Clavatula)* aff. *granulato - cincta* MUNSTER, *Clavatula (Perrona) taurinensis* (MAYER), *Tunis(Tunis) rotata* (BROCCHI) , *Tunis (Tunis)'contigua* (BROCCHI), *Moniliopsis (Bathytoma) cataphracta* (BROCCHI), *Conus (Dendroconus} betulionides* LAMARCK, *Conus (Chelyconus)* aff. *pyruloides* BROCCHI, *Conus (Conospirus) dujardini* DESHAYES, *Conus (Conospirus) antediluvianus* (BRUGUIERE) var. *taurocatenatoides* SACCO, *Conus (Lithoconus) antiquus* LAMARCK, *Dentalium inaequale* BRONN, *Dentalium* sp.

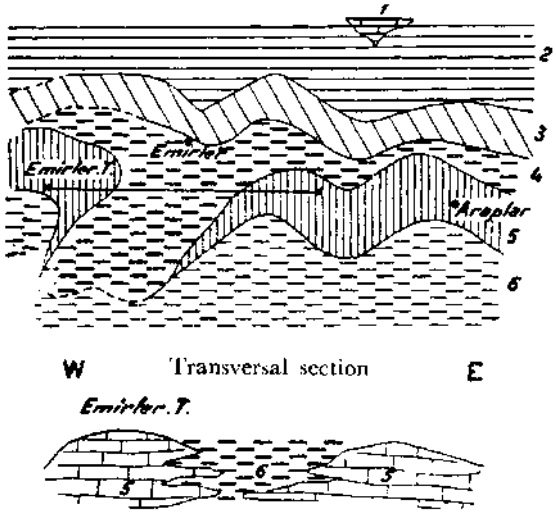


Fig. 4 - Preliminary sketch of Emirler area

1) White, light-gray, buff - colored, fine crystalline, jointed, sublithographic limestones (Cretaceous)
2) Eruptive rocks and serpentines
3) Conglomerates, limestones, shaly limestones and shales (Lower Miocene = Burdigalian)
4) Pteropod - bearing shales - lower shales = (Lower Helvetian)
5) Coarse sandstones and limestones (Middle Helvetian)
6) Gray shales containing Heterostegina and Turritella — upper shales = (Upper Helvetian)

There is a slight discordance between the Helvetian and Burdigalian formations.

Tortonian Deposits :

The Tortonian deposits can be divided as follows :

a) Ostrea-bearing sandstones (500-700 m. thick).

b) Formations where calcareous layered marls and ' sandstones alternate.

c) Gray-colored marls, sandstones, and sandy marl alternation.

The Ostrea level of (a) is known as the «Second Ostrea Zone».

In these sandstones the following fossils were found : *Ostrea crassissima* LAMARCK, *Ostrea edulis* var. *lamellosa* BROCCHI, *Lutraria (Psammophila) oblonga* CHEMNITZ, *Turritella (Haustator) triplicata* BROCCHI aff. var. *depressiplicata* SACCO, *Pleurotoma* cf. *calcarata* LAMARCK, *Terebralia bidentata* var. *cingulatior* SACCO, *Terebralia lignitamm* EICHWALD, *Conus (Dendroconus) berghausi* MICHELOTTI.

In the formations' with calcareous layered marls and sandstones we have found these fossils : *Pecten aduncus* EICHWALD, *Pecten praebenedictus* TOURNOUER, *Linga columbella* LAMARCK, *Codakia* aff. *lennina* BASTEROT, *Cardium* aff. *turonicum* MAYER, *Thracia* cf. *pubescens* PULTEXEY, *Turritella (Archimediella)* cf. *bicarinata* EICHWALD.

The Middle Miocene formations cover mostly the area of the Taurus Mountain Range, where it is gradually sloping towards the Adana plain in a series of hills. These formations are seldom encountered in the Misis Mountain Range.

i - Pliocene

This formation begins with conglomerate beds. Further up come anhydrites, sandstones with pink or brown surfaces, and layers of limestones, pebbles and marls. The total thickness is 700-800 meters.

j - Quaternary

The Quaternary consists of caliches and alluvium.

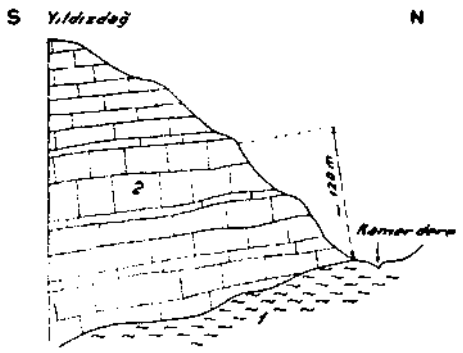


Fig. 4 a - Section passing through Yıldızdağ

1) Serpentine
2) Lower Miocene (Burdigalian) limestone beds; each 8 - 20 m. thick

II - OLDER FORMATIONS IN CONTACT WITH THE LOWER MIOCENE

The older formations are the Paleozoic limestone and schist formations, the Cretaceous limestone and flysch formations, the calcareous, conglomeratic and marly formations of the Paleocene and Eocene, and, finally, the marly, sandstone, calcareous and mostly conglomeratic formations of the Oligocene. Sometimes the Lower Miocene formations are also in contact with serpentines (fig. 4a; photo 5).

Some of the above formations, especially the Paleozoic, Cretaceous and partly the Paleocene- Eocene formations, have been eroded and appear on the surface (photo 1), but generally they follow the buried hills and ridges covered by the recent Tertiary. These older formations present a discordance both at the contacts between themselves and at their contacts with the Lower Miocene (fig. 5).

Besides the dicordance of the Lower Miocene formations with the older formations, the Lower Miocene, in certain localities, begins with thick basal conglomerates, which may be — as for instance in the vicinity of the Gülek Boğazı — some 350 meters thick. On the other hand, the contact may be direct, as observed in several parts of the Cretaceous limestones.

Ill - EXTENSION OF THE LOWER MIOCENE DEPOSITS IN THE ADANA BASIN

The formations, occupying the border-line of the basin, extend along the Taurus Mountain Range from Karsantı to the north of Mersin and from there towards Silifke. These formations are generally forming rather gentle folds which plunge towards the plain; they cannot be clearly seen from the Misis Mountains. These formations are apparent, however, towards southwest where they reach the Göksu-Mut Basin. These

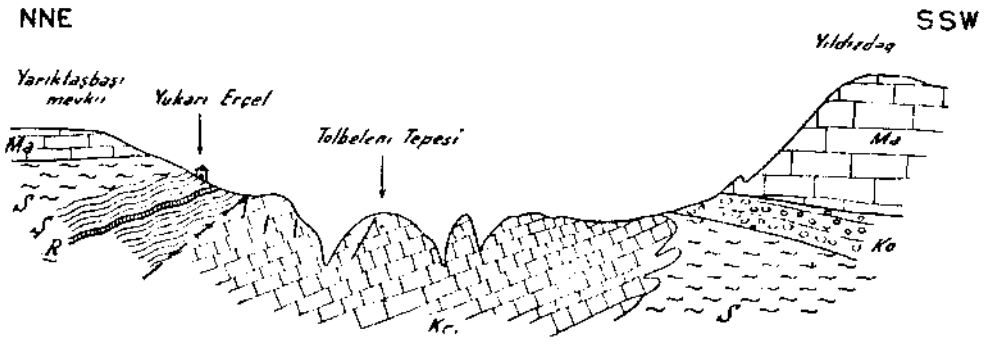


Fig. 5 - Section passing through Yarıktaşbaşı and Yıldızdağ

Kr) Cretaceous limestones
S) Serpentines
R) Radiolarites
Ş) Metamorphic schists
Ko) Conglomerates
Ma) Lower Miocene (Burdigalian) limestones

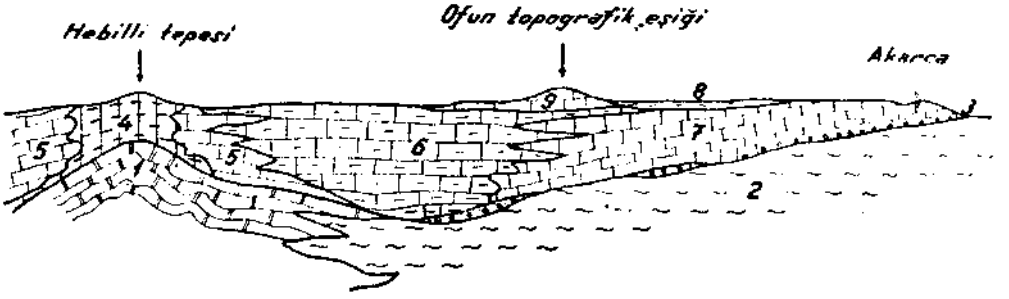


Fig. 6 - Section between Akarca and Hebilli Tepe

1) *Hard, grayish-white, dense, partly recrystallized limestones (Cret.?]*
2) *Serpentine*
3) *Conglomerate*
4) *On the surface dark - red or brown - colored, hard, dense, partly massive, algal and reef - like limestones*
5) *Hard, loose, fine crystalline limestones with Lithothamnium*
6) *White or grayish-white colored marly limestones*
7) *Greenish, bluish-colored, hard limestones in the lower part, yellow and fossiliferous limestones toward the top*
8) *Light - gray, partly conchoidal marls*
9) *Yellowish-white, hard, partly porous, seldom fossiliferous limestones*

two basins are connected by the greenstones and serpentines of the Mersin - Silifke regions (pl. I, II).

IV - CHARACTERISTICS OF THE LOWER MIOCENE FORMATIONS

The Lower Miocene is transgressive and consists of conglomerates, marly limestones, sandy limestones, marls and limestones. Between the various layers of the Lower Miocene there are lateral transitions from one layer to another (fig. 3, 6). In some places the limestones are of the reef-complex character (pl. III) and it can be said that practically all of the layers contain fossils.

Despite the fact that the conglomerates of the Lower Miocene are basal conglomerates, they are not observed everywhere in this basin. Their maximum thickness is 350 meters; however, in many places, between the Lower Miocene and the older formations, they are lenticular. In some places they are missing.

The hard limestones are white, creamy or yellowish in color and usually constitute thick beds. Sometimes these limestones are in the form of banks. Their structure is often cavernous and porous; sandy parts are also observed. These hard limestones display lateral facies transitions (fig. 7) in the form of marls and marly limestones; sometimes a vertical change is also observed (fig. 7a, 7b; photo 6).

Let us study the Lower Miocene of the Adana Basin in various places, starting from the northeast to the southwest (i. e. from Karsantı towards Mersin) (pl. I).

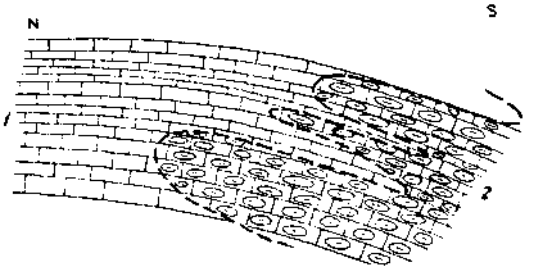


Fig. 7 - Lateral facies changes in the Lower Miocene limestones located on the western flank of Deliçay, west of Parmakkurdu

- - - *Line of lateral facies changes*
1) *Cream-colored, hard limestones; white-colored when broken*
2) *Whitish-gray colored, hard, nodular and marly limestones*

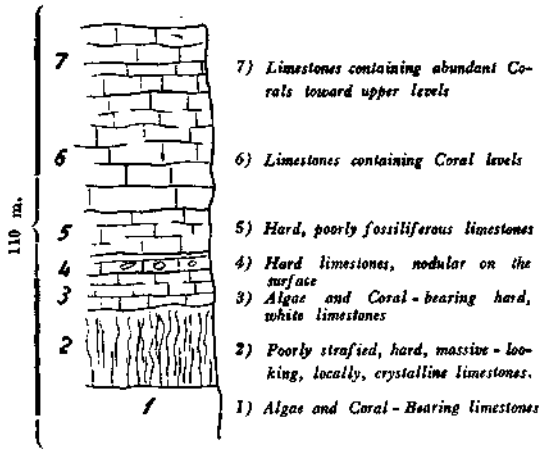


Fig. 7 a - Columnar section showing Lower Miocene limestones near Çevlik

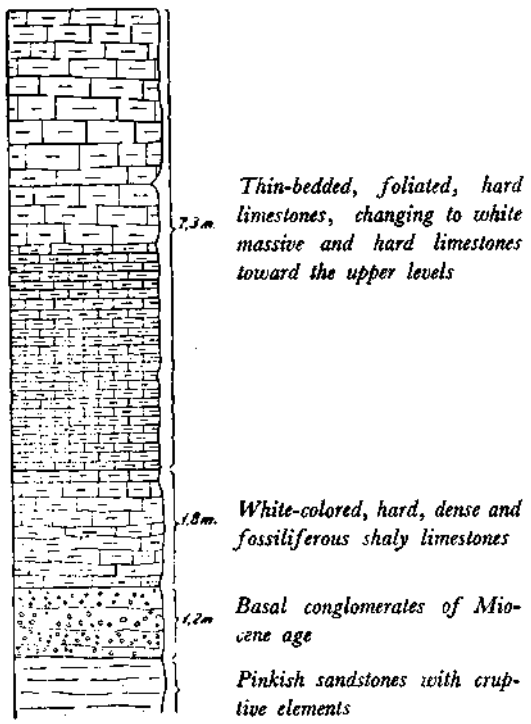


Fig. 7 b - Geologic column between Inoluk and Karayakup

a - Lower Miocene in the vicinity of Akdam, NW of Kozan

Here, the Lower Miocene, resting on the basal conglomerates, overlies discordantly the Paleozoic formations. Above these conglomerates, from bottom upward, follow marls and limestones of Lower Miocene age. Further upward, also discordantly, come Helvetian conglomerates and sandstones.

b - Lower Miocene in the vicinity of Egnar

The Lower Miocene formations in this locality, situated some 20 km. SW of Akdam, consist (from bottom to the top) of gray - colored marls overlain by algal and marly limestones; above these lie discordantly the bluish - gray, hard shales (Lower Helvetian). The latter are covered by sandstones (Middle Helvetian) alternating with thin-bedded marls. Here the Lower Miocene is greatly faulted and fragmented (pl. IV, IVa).

c - Lower Miocene Formations north of the Hacıkırı Station

In this region the Lower Miocene overlies discordantly in some places the Paleozoic formations and in other

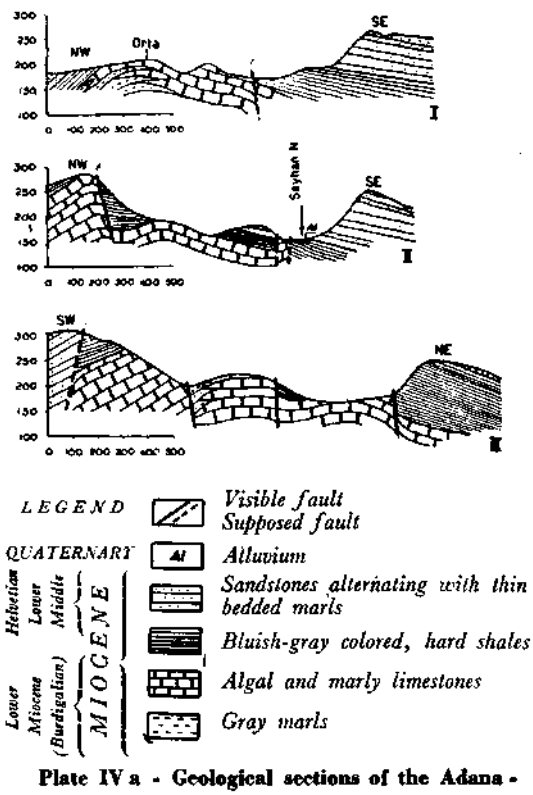


Plate IV a - Geological sections of the Adana - Egnar region (Tahtacı, Orta, Avhyah)

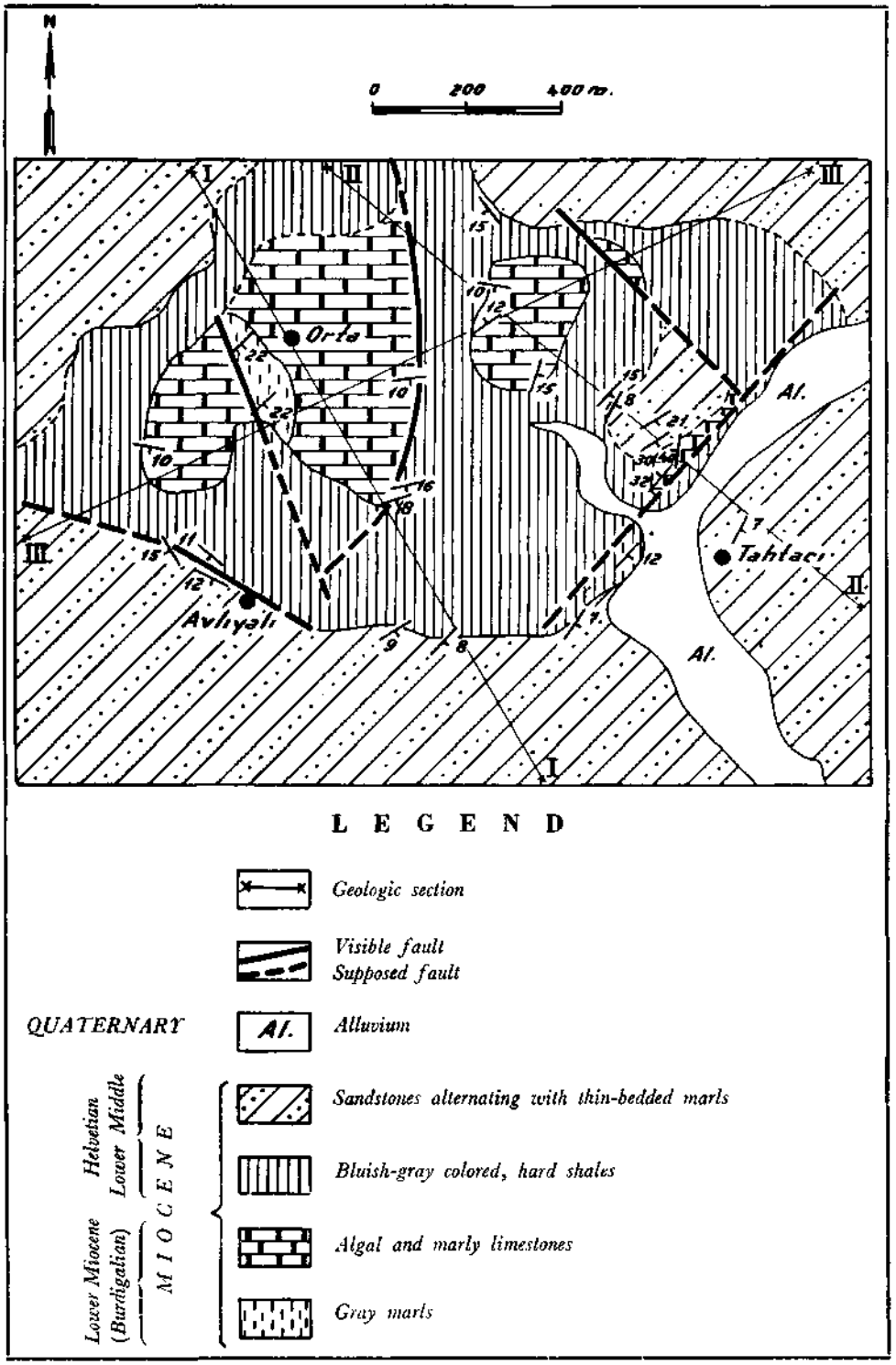


Plate IV - Geological Map of the Adana - Egnar Region (Tahtacı, Orta, Avlıyalı)

places the Upper Cretaceous limestones. The succession of the layers is as follows: Burdigalian, basal conglomerates, and— overlying these conglomerates — Burdigalian marls and limestones. Here and there can be seen marly limestones.

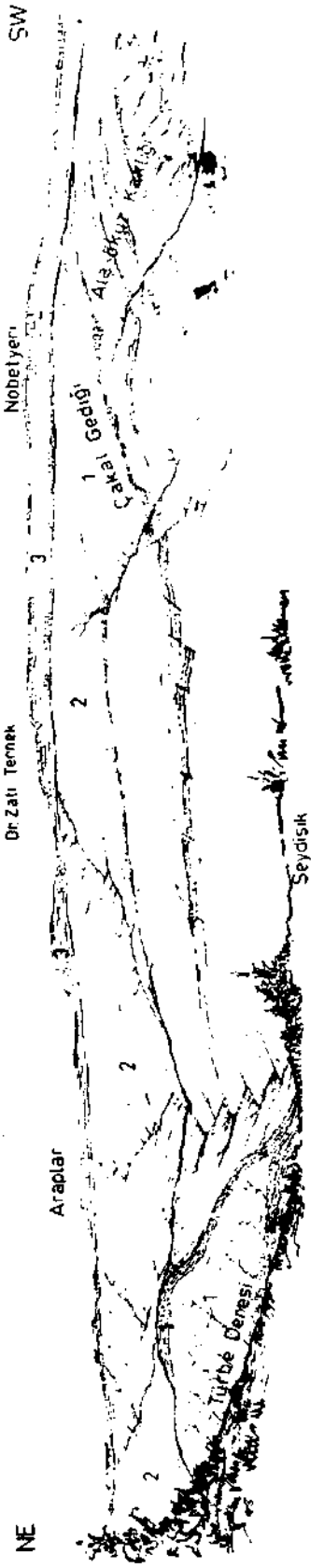


Fig. 8 - View of the area between Araplar and Nöbetyeri looking from Seydişik

1) White or gray-colored, hard, in some places marly, fossiliferous limestones - Lower Miocene (Burdig.)
2) Gray marls - Araplar marls - marls with Pteropoda - lower marls - Lower Helvetian
3) Limestones and sandy limestones - Middle Helvetian

d - Lower Miocene in the neighbourhood of the Gülek Boğazı

Here the Lower Miocene beds overlie discordantly the Oligocene limestones containing marly and sandy layers. These layers vary between 1 m. to 40 m. in thickness; they are fossil-bearing layers and can be shortly described as follows (from bottom to the top) : buff-colored limestones, brown limestones, whitish limestones, conglomeratic sandstones, hard, nodular limestones, gray, sandy limestones, sandy marls, greyish, yellowish, hard marly limestones, algal and coral - bearing limestones, marly limestones and hard, white limestones.

e - Lower Miocene Formations in the norhtwest of Mersin - Tarsus

Here also the Lower Miocene formations lie discordantly either on the Mesozoic rocks or on the serpentines (pl. III; photos 1, 5). However, it cannot be said that there are Miocene basal conglomerates everywhere in the neighbourhood. Overlying the conglomerates are hard, porous, light-gray, buff-colored, yellowish, sandy or cavernous limestones; sometimes these are also overlain by marly limestones or marls. Between these hard limestones, sandy limestones, marly limestones, and marls there are characteristic lateral transitions and vertical facies changes.

However, in some places of this region —between Seydişık and Çopurlu villages, at Turunçlu— practically none of the above formations of the Lower Miocene can be found (pl. II, fig. 8).

These formations show some other typical characteristics : in some places the limestones do not display any apparent stratification, or they are entirely

massive and are of reef cores or bioherm character, by their color, faunal association, hardness and texture. In these reef-cores, the coral colonies and abundant algae are present. It has been observed., in tliese reef- cores, that some large or small hills are entirely formed by masses of ball-shaped algal nodules of various sizes. These reef- cores have been mostly seen near the Lower Miocene, Middle Miocene boundaries (pl. III).

V - YOUNGER FORMATIONS IN CONTACT WITH THE LOWER MIOCENE

There are Pterepoda-bearing marls and the Lower Helvetian marls overlying the Lower Miocene deposits almost everywhere in the Adana Basin (fig. 2, 9): However, at certain places — although rarely — some Tortonian sandstones overlying directly these deposits have been observed.

Of the younger formations, with which the Lower Miocene formations are in contact in the western parts of the basin, we may mention the Quaternary caliches.

Besides these, in certain parts of the Seyhan and Ceyhan river-beds, we can see, as younger formations, the Quaternary terraces, which overlie the Lower Miocene.

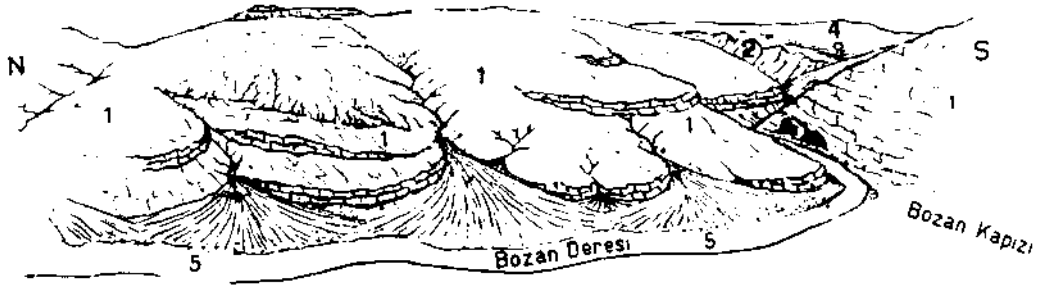


Fig. 9 - View of the area from the NW edge of the Bozan canyon towards east

1) *Middle Miocene (Vindobonian) M. Helvetian limestones*
2) *Gray marls with Heterostegina - upper marls = Vindobonian (U. Helvetian)*
3) *Fossiliferous sandstones = Vindobonian, Tortonian*
4) *Caliche* } *Quaternary*
5) *Dejection cones* }

From the geologic evidence observed by us, it can be assumed that towards the south of the basin, in the area covered by the Lower Miocene and the Middle Miocene formations, there exists a reef- line, transgressive in character, and consisting of a succession of reef-cores connected to one another as in a string of beads. Furthermore, based on the data made available from the wells drilled in the Adana Basin, it is understood that the Lower Miocene limestones, which show vertical and horizontal facies changes, turn into sandy marls or entirely into shales, towards the middle of the basin.

VOLCANISM

There is little evidence of volcanic activity in the Adana Basin. The formation of serpentines, observed in the northwest and in the southeast of the basin (Misis Mountain Range), has ta-

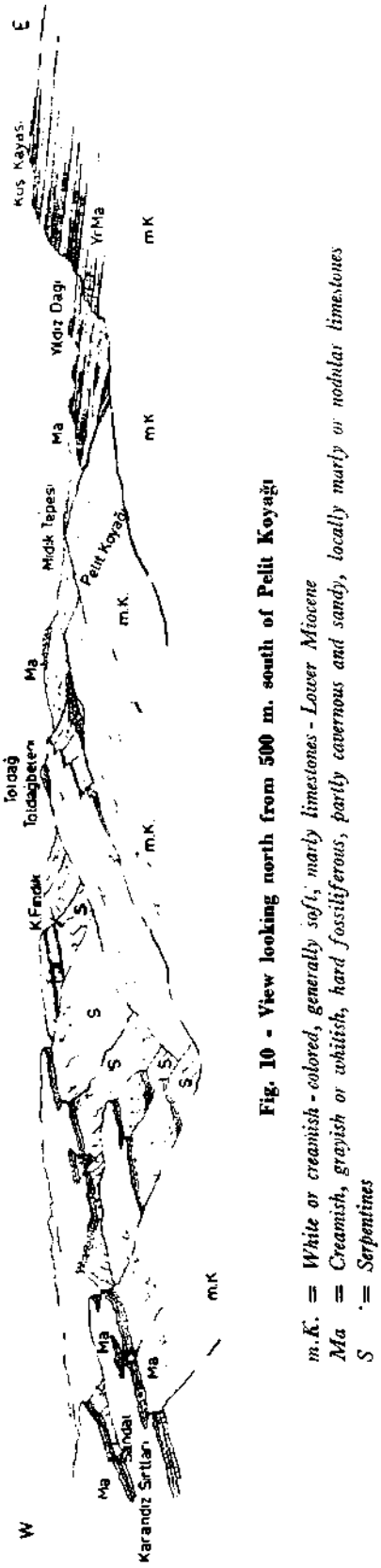


Fig. 10 - View looking north from 500 m. south of Pelit Koyağı

m.K. = *White or creamish - colored, generally soft, marly limestones - Lower Miocene*
Ma = *Creamish, grayish or whitish, hard fossiliferous, partly cavernous and sandy, locally marly or nodular limestones*
S = *Serpentines*

ken place during the Mesozoic and particularly during the Cretaceous (fig. 10). These serpentines are sometimes found associated with diorites and radiolarites.

There has been a period of volcanic tranquility between the Paleocene and Middle Miocene. A white-colored, thick tuff bed series, containing very few diatomites, is observed between the Tortonian beds. After the Tortonian no volcanic activity has taken place in this area.

PALEOGEOGRAPHY AND TECTONICS

The Adana Basin was covered by a rather deep sea during the Paleozoic. The deposits of this sea, in which some *Fusulinidae* have been found, have been subjected to folding by the Hercynian movements (probably «Pfalzian» phase). Thus the core of the Ashabi-Kehif — with the related Paleozoic hill chains — and of the Misis Mountains has been formed.

The Triassic and Jurassic seas in the Adana Basin have left deposits, a major part of which has been eroded. Later on, the basin was covered by the sub-continental Cretaceous sea. Starting from the Middle Cretaceous until the end of this epoch, volcanic activities have taken place; towards the end of the Cretaceous the sea became deeper and very favorable for organic life. The oscillatory movements of the sea formed series of flysch-like deposits; finally these deposits were folded during the Laramian folding period. The transgressive Paleocene sea left deposits which lie in discordance with the Cretaceous. Following this, the Eocene deposits have taken place, which were folded during the Pyrenean folding period, but have been eroded later on.

The culmination which has divided the basin into small areas, the core of

which was originated by the Hersinian folding, became a well-formed cordillera during the Eocene. Thus, the Paleozoic Ashabı - Kehif hills have made another division in the west of the Mersin district. During the Oligocene, lacustrine, lagunary and estuarine conditions mostly prevailed. During the Oligocene important erosion processes have taken place.

At the beginning of the Burdigalian there happened a major transgression, at the end of which folding — corresponding to the Styrian folding —took place and the sea regressed. The Burdigalian sea was favorable for the living of organisms, particularly of Corals, Algae and Bryozoa, and for the formation of reefs.

At the beginning of the Helvetian, the sea" made a sudden transgression: later on there were oscillatory movements at the bottom of the sea. In the middle of the Helvetian, the depth of this sea decreased, and towards the end of the Helvetian it increased once more.

The Tortonian sediments too are the deposits of a transgressive sea. The sea underwent also oscillatory movements and towards the end it regressed, as a result of which brackish and lagunary formations have been deposited.

At the beginning of the Pliocene, lacustrine and lagunary conditions prevailed, whereas during the Quaternary conditions started to prevail,

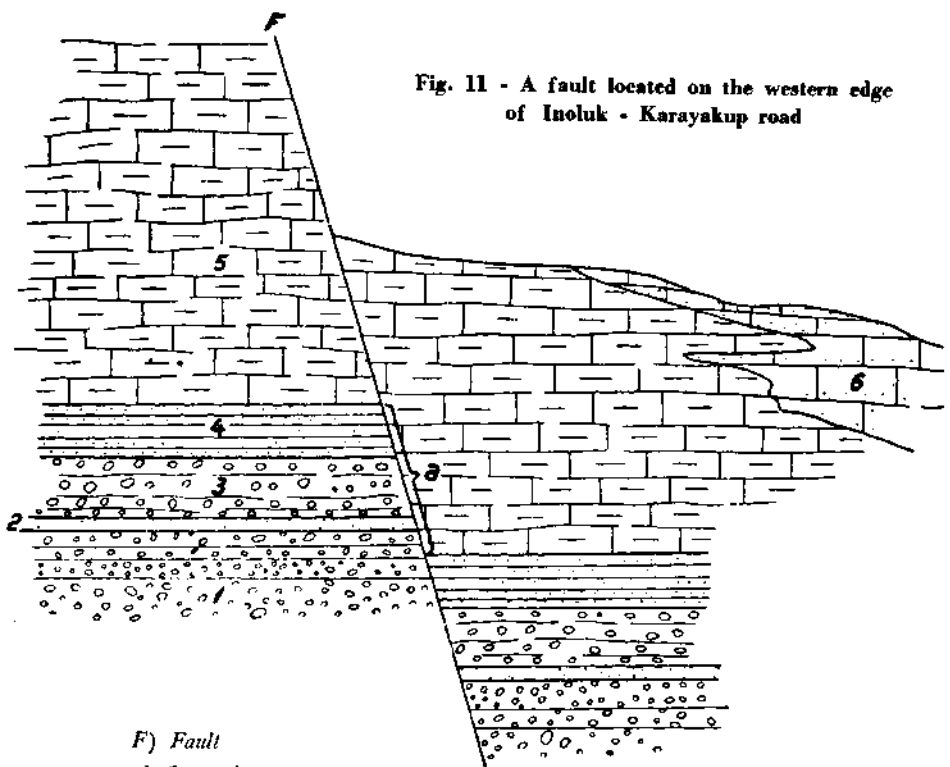


Fig. 11 - A fault located on the western edge of Inoluk - Karayakup road

F) Fault
a) 5 m. throw
1) 5 m. red - colored, loose cemented conglomerates with serpentine pebbles
2) 0.7 m. sandstones
3) 3 m. conglomerates
4) 2 - 3 m. gray - colored, highly fossiliferous sandstones
5) Grayish - white colored, marly limestones
6) White - colored, hard, somewhat sandy limestones

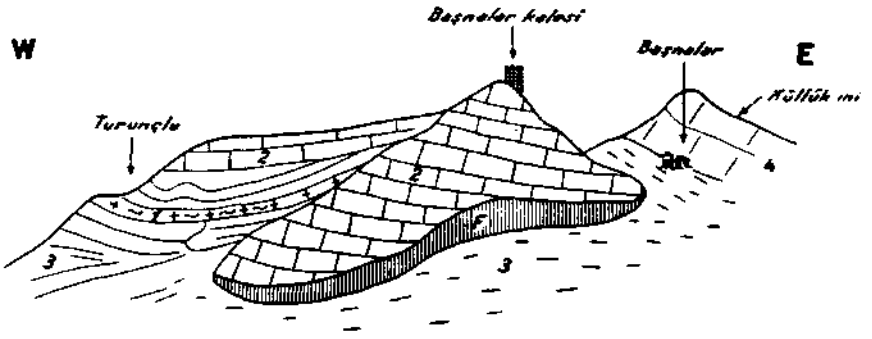


Fig. 12 - View of the area between Turunçlu and Başnalar from the Emirler - Turunçlu road

1) Eruptive rocks and serpentines
2) Lower Miocene limestones
3) Lower marls - Lower Helvetian
4) Nodular, sandy, cavernous limestones - Middle Helvetian
F) Fault escarpment

and the epirogenic movements continued.

In the region, the direction of the Paleozoic beds is most frequently N - S and the general direction is NE-SW. The Mesozoic strata have practically the same direction. Later on, the Alpine movements have affected more or less, these directions. The direction of the folding of the Tertiary .strata is NE-SW, in general; however, the ENE - WSW and rarely the E-W directions also occur. The movements, which took place during the Tertiary, in particular during the end of the Burdigalian, have raised the basin, and especially the Taurus Mountains raised as a.block.

The Miocene strata are uniform in folding; there are continuous or discontinuous anticlines and synclines, but they are not very typical. The Miocene strata descend from the Taurus Mountains to the Mediterranean Sea topographically and tectonically in a series of steps, by forming wide and mostly asymmetrical anticlines and synclines. These are generally homoclinal folds; there are also many anticlines which form terraces. The anticlines and synclines are plunging from the north to the south; however, a NE-SW plunge, or from the east to the west, is often observed. The lengths of these anticlines and synclines vary between 2 and 28 km. (mostly 8-10 km.) and their width is 2-5 km. The southern flanks of many of the anticlines are steep.

The pressure from the SE and NW has resulted in folds, generally SW-NE in direction. The crevices, joints and faults, which originated during the folding, are rather large and numerous in the formations older than the Lower Miocene (as, for instance, the Gülek Boğazı fault) (fig. 11, 12).

The lateral pressure greatly affected the area west of the line, passing through Mersin in a NE-SW direction, and the forces were rejuvenated. The folding movements, west of this line, have been stronger; going towards the center of the basin, from this line and from the Misis Mountain Range, we can expect to see milder and wider folds, with fewer joints and faults (in the Miocene strata). In the Miocene formation the thickness of the faults varies between 10 to 15 m. and sometimes it attains some 100-150 m.

OIL POSSIBILITIES OF THE ADANA BASIN AND THE IMPORTANCE OF THE LOWER MIOCENE FORMATIONS

In the first place let us see the oil seepages of the basin.

At Fındıkpınarı, Mersin, there exists in the Permo - Carboniferous limestones some distilled liquid oil in the form of bubbles; when broken, these limestones emit bituminous odor.

There exist also asphalt traces in the Paleozoic formations, in the vicinity of Kozan. An asphalt seepage is also observed in the Burdigalian limestones in the Miocene series, at the Çukur Çömlek village. There is a bituminous impregnation, coming from a fault, in the flyschy Helvetian series, near Topallı, and a gas seepage in the Helvetian shales, near a fault, at the AH Hocalı.

Source-rocks

The parts of the Permo - Carboniferous limestones, which have not undergone much metamorphism, have not lost their characteristics of source-rock. The importance of the Paleozoic is somewhat lessened by the presence of a hiatus which occurred in many places after the Paleozoic. The Cretaceous and especially the Upper Cretaceous formations with abundant fossil-horizons display only in a feeble way the features of a source-rock.

Burdigalian Limestones

These limestones possess the most characteristic features of source-rock. The fact that many horizons of these formations are rich in fossils, the transgressive reef- complex characteristics observed in places, and particularly the existence of some reef- cores and bioherms, are strong arguments for the resemblance between these limestones and the Asmari limestones of Iran.

Some of the horizons of the Burdigalian formation — especially in places where lateral transition from limestones to finer-textured sediments are observed— contain abundant accumulations of fossils, Algae and Corals. During the formation of these limestones, fossil accumulations, bioherms and reefs originated at the levels with a favorable basement. The cores of these bioherms and reefs follow, more or less, the direction of the buried hills and ridges. It is in the vicinity of these bioherms and reefs that the most favorable conditions for the formation of oil prevail.

Because of these reasons the importance of the Burdigalian limestones as a source-rock is very great.

Reservoir Rocks

The Burdigalian limestones, being in places of reef-complex type and having porous and sandy parts, display excellent characteristics of reservoir rock. In addition, Helvetian sandstones and limestones, as well as Tortonian sandstones, may also represent perfect reservoir rocks.

Cover-Rocks

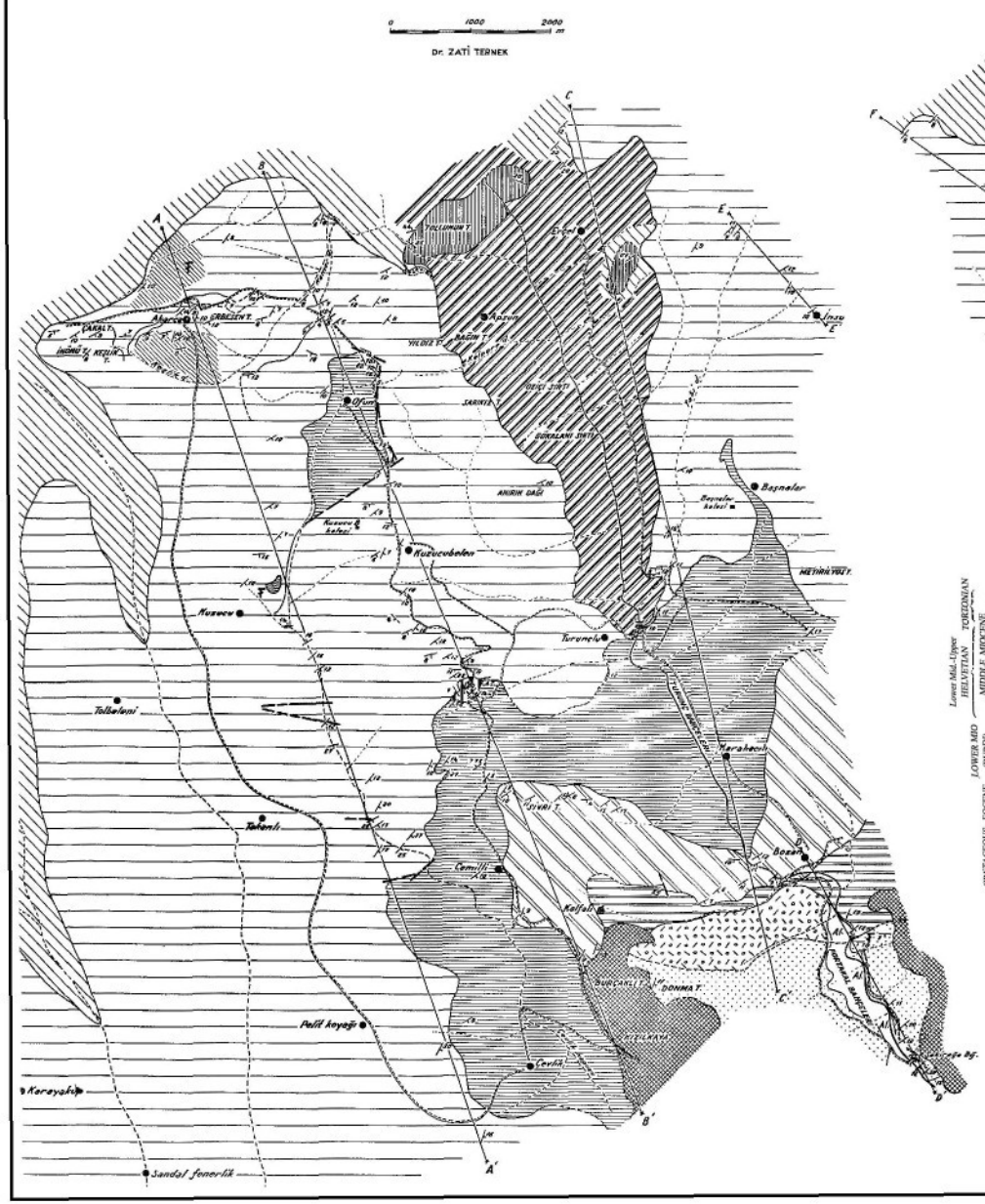
The marls of the Lower Helvetian and Upper Helvetian possess excellent characteristics of cover - rock.

Structures

Among the structures present in the Adana Basin the following can be mentioned: the Ali Hocalı-Dağcı, Çotlu-Misis, Dikili, (Çatalan, Sevinçli,

and Adana structures and some ten structures of secondary importance in the vicinity of Mersin.

DETAILED GEOLOGICAL MAP OF THE NORTHWESTERN PART OF MERSIN - TARSUS

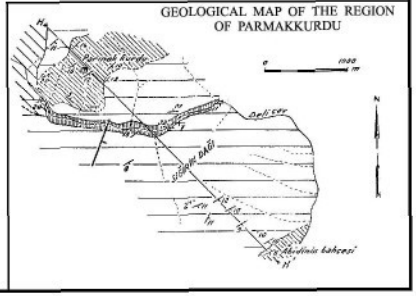


LEGEN

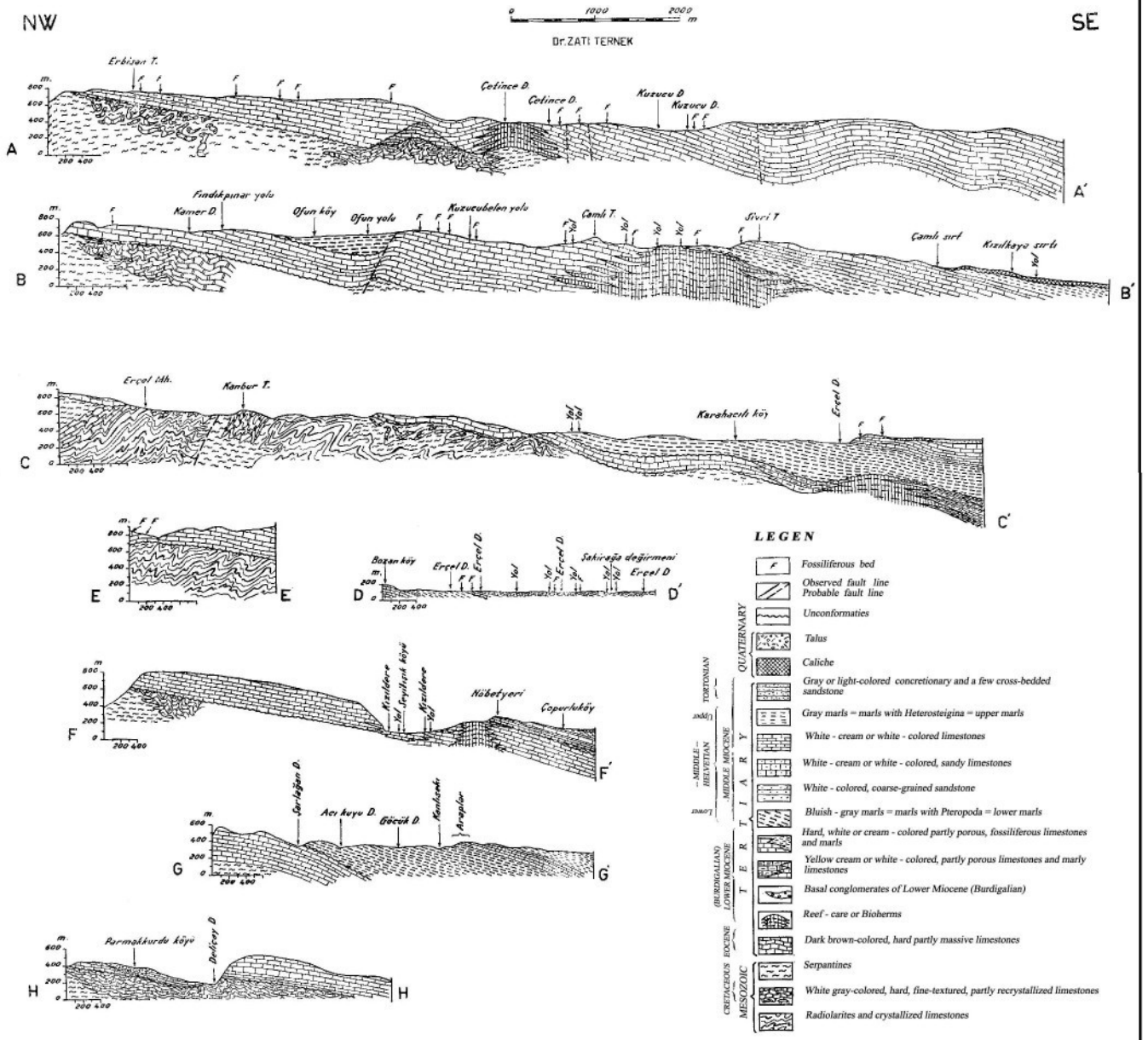
- Fossiliferous bed
- Observed fault line
- Probable fault line
- Alluvium
- Talus
- Caliche
- Gray or light-colored concretionary and a few cross-bedded sandstone
- Gray marls = marls with Heterosteigina = upper marls
- White - colored, coarse - grained sandstones - white, cream and yellowish- colored sandy limestones and limestones
- Bluish - gray marls = marls with Pteropoda = lower marls
- Foliated marls
- Grayish - white colored marly limestones
- Yellow cream or white - colored, partly porous limestones
- Basal conglomerates of L. Miocene
- Dark brown-colored, hard partly massive limestones
- Serpantines
- White gray-colored, hard, fine-textured, partly recrystallized limestones
- Radiolarites and crystallized limestones

QUATERNARY; TERTIARY: Lower Mid.-Upper HELVETIAN / TORTONIAN / MIDDLE MIOCENE; LOWER MID (BURDI); EOCENE; CRETACEOUS; MESOZOIC

GEOLOGICAL MAP OF THE REGION OF PARMAKKURDU



DETAILED GEOLOGICAL SECRIONS AT THE NORTHWESTERN PART OF MERSIN - TARSUS



LEGEN

- Fossiliferous bed
- Observed fault line / Probable fault line
- Unconformaties
- QUATERNARY — Talus
- Caliche
- TERTIARY — TORTONIAN — Gray or light-colored concretionary and a few cross-bedded sandstone
- Upper — Gray marls = marls with Heterosteigina = upper marls
- MIDDLE MIOCENE — MIDDLE – HELVETIAN — White - cream or white - colored limestones
- White - cream or white - colored, sandy limestones
- White - colored, coarse-grained sandstone
- Lower — Bluish - gray marls = marls with Pteropoda = lower marls
- Hard, white or cream - colored partly porous, fossiliferous limestones and marls
- LOWER MIOCENE (BURDIGALIAN) — Yellow cream or white - colored, partly porous limestones and marly limestones
- Basal conglomerates of Lower Miocene (Burdigalian)
- EOCENE — Reef - care or Bioherms
- Dark brown-colored, hard partly massive limestones
- CRETACEOUS — MESOZOIC — Serpantines
- White gray-colored, hard, fine-textured, partly recrystallized limestones
- Radiolarites and crystallized limestones

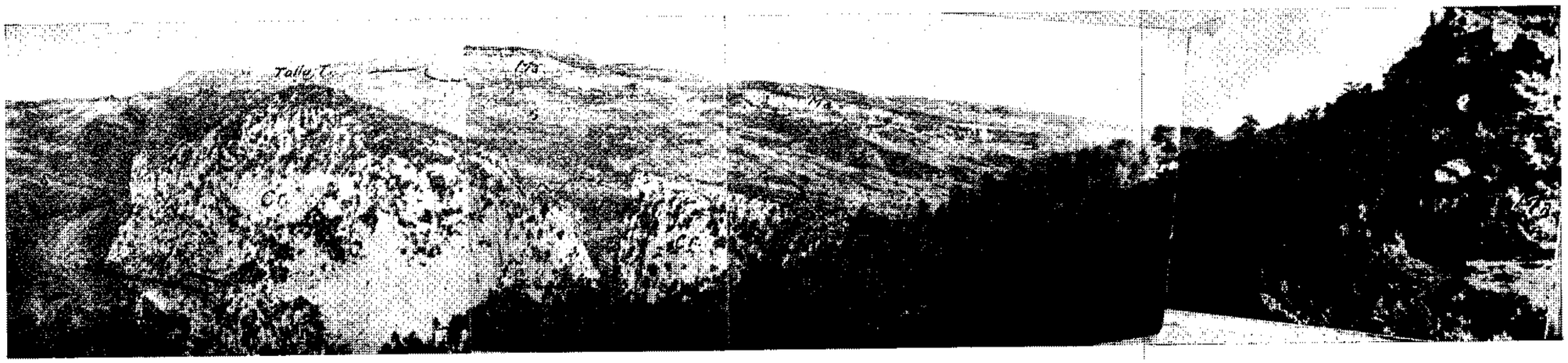


Photo 1 - View of Tella Tepe and its vicinity from the northern edge of Yildiz Dag

S. - Serpentines Cr. - Cretaceous limestones Ma. - Yellowish, hard limestones - Lower Miocene (Burdig.)

Photo 2 - View of the Karatepe, Teshihdağ, Çamdağ, Seydişuk and their vicinity, from the point of Nöbetyeri, located S 20 W of Araplar

S. - Serpentines Ma. - Yellow or cream-colored, hard limestones - Lower Miocene (Burdig.)
MK. - White or light-cream colored, soft marly limestones - Lower Miocene (Burdig.)
Mo.H1. - Marls with Pteropoda = lower marls-Middle Miocene = Vindobonian (Lower Helvetian)
Mo.H2. - Limestones and sandy limestones - Middle Miocene = Vindobonian (Middle Helvetian)

Photo 3 - View of the area between Çevlikköy and Metrilyos Tepe, from the North of Çanak Tepe

Ma. - Yellowish - colored, hard limestones - Lower Miocene (Burdig.)
Mo.H1 - Marls with Pteropoda = lower marls = Middle Miocene = Vindobonian (Lower Helvetian)
Mo.H2. - Limestones, sandy limestones and coarse - grained sandstones - Middle Miocene = Vindobonian (Middle Helvetian)
Mo.H3. - Gray - colored marls with Hsterostegina - Middle Miocene = Vindobonian (Upper Helvetian)

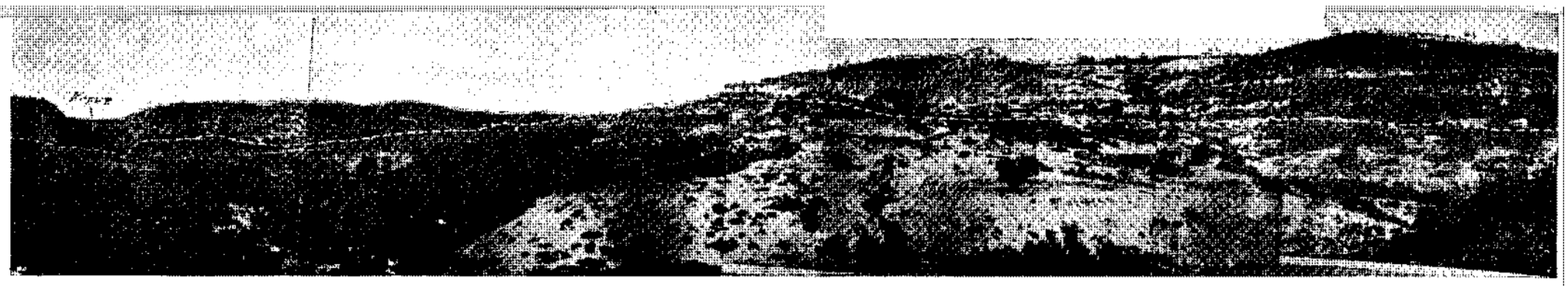


Photo 4

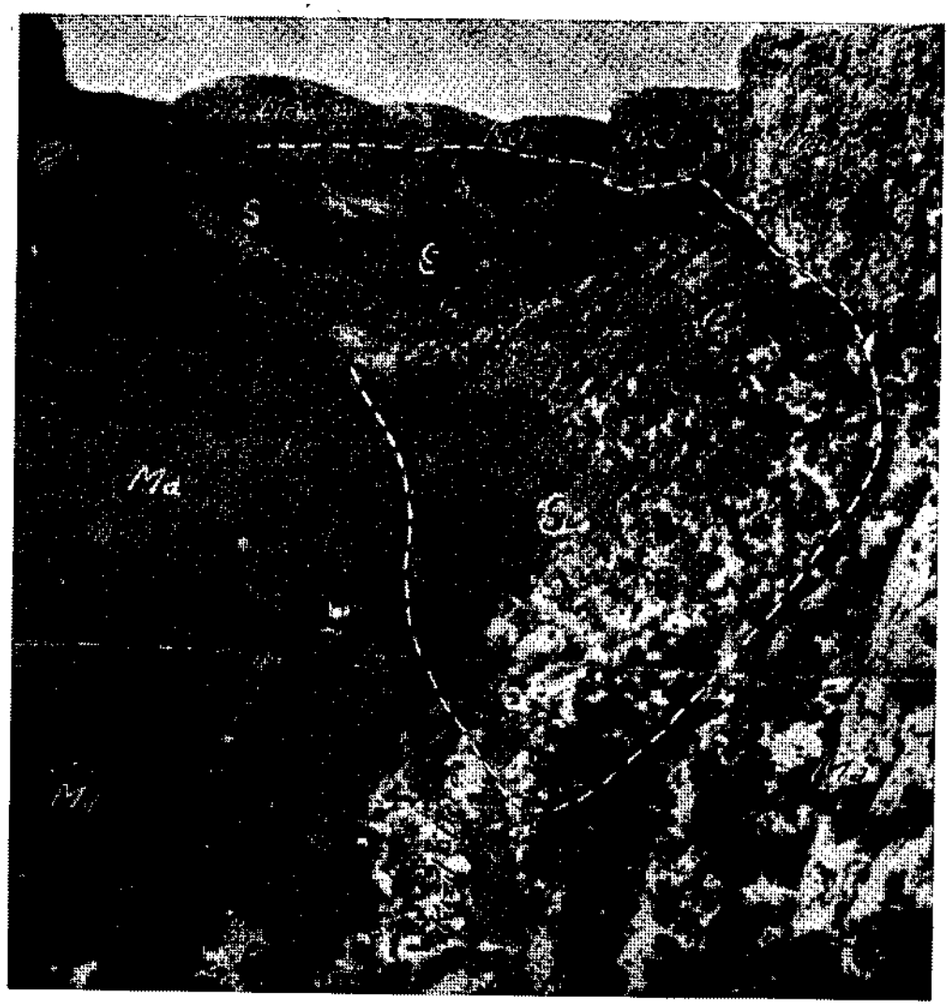


Photo 4 - View of the Cemilli and its vicinity from the south of Cemilli

Ma. - Yellowish, hard limestones - Lower Miocene (Burdig.)
Mo.H1. - Marls with Pteropoda - lower marls - Middle Miocene (Vindobonian) (Lower Helvetian)
Mo.H2. - Limestones and sandy limestones - Middle Miocene (Vindobonian) (Middle Helvetian)

Photo 5 - View of the Kızıldere valley from SSE towards NNW (the picture was taken from the point at 245 m. elevation on the left flank of the valley)

S. - Serpentines
Ma. - Yellowish hard limestones - Lower Miocene (Burdig.)

Photo 6 - Picture taken from Inoluk towards Karayakup, showing Karayakup and its vicinity

S. - Serpentines
MK. - White or light - cream colored, soft, marly limestones - Lower Miocene (Burdig.)
Ma. - Yellow or cream - colored, hard limestones - Lower Miocene (Burdig.)

Photo 6

Some formations in the Adana Basin favorable for oil accumulation

The following formations are favorable for oil accumulation :

1 — Reef-complex formations,

2 — Terrace formations,

3 — Vicinity of the buried hills and ridges,

4 — Places, where Burdigaliari limestones have been faulted and traps have been formed by the marls overlying these faults,

5 — Facies changes: - At the places where -Burdigalian formations have formed lateral passages. The possibility finding oil at the lateral passages in the of Middle Miocene is also very strong.

CONCLUSIONS

We have tried in this article to point out the main characteristics of the Burdigalian formations.

The important points to bear in mind in connection with the oil research in the Adana Basin are as follows :

1 — A search for reef-complex in the entire basin must be conducted,

2 — The subsurface positions of the reefs should be studied,

3 — Drilling for oil must be conducted on the reefs, some 10-15 km. south of the existing southern boundaries of the Lower Miocene,

4 — Drilling operations must be conducted not far from the probable sites of buried hills and ridges,

5 — Drilling operations must be carried out not in the center, but near the periphery of the basin.

REFERENCES

ARNI. P. : Relations entre la structure regionale et les gisements mineraux et petroliferes de l'Anatolie. *Bull, of the M. T. A. No. 4/2,* 1939.

LEVORSEN, A. I. : Geology of Petroleum. *San Francisco,* 1954.

EGERAN, N. : Geological characteristics and oil possibilities of the Adana Basin. *Bull, of the M. T. A. M. 39, Ankara,* 1949.

ERENTÖZ, C. : Geologie detaillee de la structure petrolifere de Kışla Köy (İskenderun - Hatay). *Bull, of the M. T. 'A. No. 46/47, Ankara,* 1954-1955.

LEROY, J. W. : Subsurface Geologic Methods (As symposium). *Colorado School of Mines Department of Publication, Golden, Colorado,* 1950.

BLUMENTHAL, M. M. : Esquisse de la geologie du Taurus dans la region de Namrun et le gisement de bauxite decouvert dans ces parages. *Bull, of the At. T. A. No. 4/21,* 1940.

BLUMENTHAL, M, M. : Un apergu de la geologie du Taurus dans les Vilayet de Niğde et d'Adana. *«Metea», Serie B: Memoires, No. 6, Ankara,* 1941.

BLUMENTHAL, M. M. : Les discordances de plissement dans la grande gorge du Çakıt Çayı. *Turk Cogr. Derg. 2/5-6, Ankara,* 1944.

BLUMENTHAL, M. M. : Das Palaeozoische Fenster von Belemedik und sein Mesozoischer Kalkrahmen (Cilicischer Taurus). *Beitrage zur geqlogischen Karte der Türkei. Ser. D, No. 3, Ankara,* 1947.

TOLUN, N. ve TERNEK, Z. : Notes geologiques sur la region de Mardin. *Bull, of the Geologica Society of Turkey. Vol. III, No. 2, Ankara,* 1952.

NEWELL, N. D. - RIGBY, J. K. - FISCHER, A. G. - WHITEMAN, A. J. - HICKOX, J. E. - BRADLEY, J. S. : The Permian Reef Complex of the Guadalupe Mountains Region, Texas and New Mexico. A Study in Paleocology. *San Francisco,* 1953.

PAREJAS, Ed. : Tectonique transversale et les gisements de petrole. *Arch. Sc. Phs. el Nat. (Vol. 27) Geneve,* 1945.

TERNEK, Z. : Geological Study of the Region of Keşan - Korudağ. *Bull, of the M. T. A. No. 39, Ankara,* 1949.

TERNEK, Z. : Geological study of the southeastern region of lake Van. *Bull, of the Geological Society of Turkey. Vol. IV, No. 2, Ankara,* 1953.

TERNEK, Z. : Regional geology north of Mersin-Tarsus. *Bull, of the M. T. A. No. 44/45, Ankara,* 1953.

TEN DAM, A. : Sedimentation, facies and stratigraphy in the southern part of the Neogene Basin of İskenderun. *Bull, of the Geological Society of Turkey. Vol. HI, No. 2 Ankara,* 1952.