THE GEOLOGY AND PETROLEUM PROSPECTS OF THE TUZ GÖLÜ BASIN

Yener ARIKAN

N.V. Turkse Shell, Ankara

SUMMARY. — The Tuz Gölü basin is a NW-SE trending intramontane basin situated in a transverse structural depression bordered to the north by the Ankara High, to the east by the Kırşehir Massif, to the south by the Taurus Mountains and to the west by the Sivrihisar-Bozdağ Massif (PI. II).

The oil geological basement is generally formed by ophiolites, or, where these are eroded, by Mesozoic limestones or Paleozoic metamorphics.

The Tuz Gölü basin developed during the Upper Senonian - Oligocene. Over 10,000 meters of sediments, representing a complete sedimentary cycle, accumulated in the deepest part of the basin. Subsidence occurred during the Upper Senonian - Lower Middle Eocene, followed by regression which started in the Upper Middle Eocene and lasted until the end of the Oligocene.

During the Upper Senonian - Lower Middle Eocene, the Tuz Gölü basin formed one continuous depression with the Haymana area to the northwest. After the deposition of the Middle Eocene Nummulitic limestone, the Tuz Gölü basin was separated from the uplifted Haymana basin by a fault zone along the eastern side of the Karacadağ uplift.

The connection with the Çankırı basin further to the north-northeast came into existence during the Paleocene and continued throughout the Middle Eocene-Oligocene, at which time the Tuz Gölü area became a graben bounded by major NW-SE trending fault zones.

After the main deformation in late Oligocene or Miocene times, local basins which formed during the Neogene accumulated varying thicknesses of volcanic and continental sediments, including lacustrine limestones.

The Tuz Gölü basin was only slightly affected by the late Alpine compressional movements during the Pliocene.

Tensional movements took place during the Neogene and continued into the Pleistocene, leading to volcanic activity which extended into historical times.

I. STRATIGRAPHY

1. INTRODUCTION

Our knowledge of the stratigraphy of the Tuz Gölü basin is based on outcrops along the fault zones bordering the Tuz Gölü basin (Aksaray fault zone and Karacadağ uplift), on the Esso well Ko9hisar-l, and on the stratigraphy of the Haymana and Bala areas. Nothing is known in detail about the stratigraphic development in the basin center, but the very thick sedimentary sequence shown by the seismic line TG-7 (10,000 m) suggests that the facies may be more marine there than on the flanks (PI. XI).

2. OIL GEOLOGICAL BASEMENT

a. Paleozoic

Paleozoic rocks are mainly found in the crystalline massifs.

Metamorphic and highly folded rocks occur in the Taurus Mountains and the Sivrihisar-Bozdağ Massif. The most common types are mica schists, graphitic schists, phyllites, quartzites and

marbles. In the Taurus Mountains these are overlain by graptolite shales and schists indicating a Silurian age. The metamorphics are considered to be of Cambrian age.

Rocks of the Kırşehir Massif are distinctly more metamorphic, consisting mainly of granitic gneiss and marble with quartzites and mica schists. Acid intrusions (granites, syenites, granodiorites) are associated with these metamorphic rocks.

Near Ankara, strongly tectonized graywackes occur («Dikmen graywacke» of Erol, 1956), in which quartzites and carbonaceous shales have been observed. Some authors mention plant remains from shales of the graywacke south of Ankara which have been determined as Upper Devonian.

The Upper Carboniferous - Middle Permian is represented in the Taurus Mountains by limestones, apparently transgressive on the folded older rocks. A Permo-Carboniferous limestone unit consisting of blue or brown-gray crystalline limestones with abundant calcite veins is also present in the central Anatolian Massifs. All authors who have studied these massifs, especially the Ankara High, agree that an important stratigraphic break occurs at the base of the Permo-Carboniferous limestones.

The only Triassic rocks known on the central Anatolian Massifs are described by Bilgütay (1960), who mentions some formations between the Jurassic basal conglomerates and the Permian limestones in the Hasanoğlan area, about 40 km NE of Ankara. These consist of brachiopod-bearing conglomerates, and marls containing lamellibranchs, crinoidae and brachiopods. These formations are dated as Triassic by the presence of *Spirifera* cf. *oxycolpos* Emmerich. It is possible that Triassic sediments have been deposited over wider areas, and subsequently were eroded before the Jurassic transgression.

b. Mesozoic Limestone

Mesozoic limestones have been described from several localities in the vicinity of Ankara. The boundary between Jurassic and Lower Cretaceuos is in general very difficult to establish in the field. However, in some places, for instance in the Hasanoğlan area, near Ankara (Bilgütay, 1960), subdivisions are based on accurate geological age determinations.

The Jurassic is transgressive with a basal conglomerate upon the Permo-Carboniferous limestones or Triassic in the Hasanoğlan area, but the contact is not always easy to detect. For this reason the Permian and Mesozoic have been mapped together, as in the İkizce area between Ankara and Haymana (Pl. I and V).

Mesozoic limestones unconformably overlie the Sivrihisar-Bozdağ Paleozoic formations, with a thin clastic interval at the base (Mobil reports, Schmidt, 1960). The top is an angular and erosional unconformity in all cases. A period of erosion preceded the Upper Cretaceous marine transgression.

A composite stratigraphic column can be given as representative of the Mesozoic limestone sequence (see Table 1).

In the Hasanoğlan area, a complete section through the Jurassic - Lower Cretaceous sequence was studied by Bilgütay (1960). It is locally transgressive, with conglomerates consisting mainly of granite pebbles with chert and large orthoclase crystals. The overlying predominantly limestone members are deposited with an onlap sequence upon the Paleozoic paleohighs. The upper part is represented by platy limestones with chert.

Southwest of Ayaş near Ankara, Middle and Upper Jurassic limestones overlie metamorphic schists.

Table - 1

Formations	*Localities*	*Age (basis of dating)*
5. Thinly bedded limestones rich in chert with frequent marl intercalations at the top or Platy white purple or yellow Aptychus limestones	Nallıhan and Çeğiköy Hasanoğlan and Haymana	Cenomanian (Pelagics)
Unconformity or disconformity		
4. Alternation of medium to thick-bedded yellow brown limestones	Nallıhan, Çeğiköy and Haymana	L. Cretaceous (Berriasian-Barremian) partly U. Jurassic (*Lamellaptychus* sp. and algae)
3. Hard, thick-bedded to massive, yellow to dark brown limestones. Red marls with limestone beds	SW of Ayaş and Hasanoğlan	Dogger-Malm (Ammonites and benthonic foraminifera)
2. Pelletoid limestones, marl and sandstones with red limestones	Hasanoğlan	Lias (Ammonites and Crinoidea)
1. Conglomerates	Hasanoğlan	Lias

At Küçük Çaltepe, 1.5 km east of Haymana, Lower Cretaceous sediments occur in the core of the Haymana anticline. The formation consists of a massive white fractured limestone with a limestone breccia at ,the top. This might indicate an unconformity or disconformity with the overlying Cenomanian platy limestones (Erk, 1957).

c. Ophiolite suite

Age: Santonian - ?Campanian.

The Ophiolite suite is a complex of serpentinites, exotic blocks and red cherts and radiolarites. The exotic blocks are fragments of Mesozoic and Permo-Carboniferous limestones. In the Elmadağ and Dereköy areas, they sometimes form discontinuous horizons parallel to each other.

The contact with the underlying formations is tectonic. The base has been seen only near Deveci (north of Haymana), where ophiolites overlie the platy limestones of the uppermost part of the Jurassic - Lower Cretaceous limestone group.

The contact with overlying formations, where it is not tectonic, is unconformable. The Upper Senonian elastics overlie the ophiolites and contain ophiolite detritus.

Between Dereköy and İkizce on the Haymana-Ankara road, as well as on the Ankara High near Elmadağ, the Mesozoic limestone group seems to be overlain by the ophiolites.

In the Haymana area no ophiolites occur. Here they were probably eroded prior to deposition of the Upper Senonian elastics.

In the Tuz Gölü area, on the Kirsehir and Sivrihisar-Bozdağ Massifs ophiolites overlie the Mesozoic and Paleozoic formations. On the Karacadağ uplift a sequence of yellow and greenish limestones and red radiolarian limestones of Upper Cretaceous age (probably Santonian - ?Campanian) seems to be part of the Ophiolite suite.

3. HAYMANA FORMATION (UPPER SENONIAN CLASTICS)
(Plate VI)

Age: Campanian-Maestrichtian.

Deposition of this unit took place in a NW-SE trending trough between the Kırşehir and Sivrihisar-Bozdağ Massifs, and in a SW-NE trending narrow trough in the Bala area (Pl. VI). This formation marks the transgression at the base of the Upper Cretaceous - Tertiary cycle in the intramontane basins.

a. Tuz Gölü - Haymana trough

In Upper Senonian times, the Tuz Gölü and Haymana areas formed one continuous trough. Upper Senonian elastics are found in outcrops in the Haymana area, on the Karacadağ uplift and along the Aksaray fault zone.

i. *Haymana area.* — The Haymana formation is well exposed in the Haymana anticline. The Upper Senonian sequence (1500-2000 m) starts with conglomerates at the base, followed by an alternation of gray sandstones and sandy marls or olive-gray calcareous claystones/shales. The middle part of the succession starts with a conglomeratic rudist limestone, containing Orbitoides, overlain by very calcareous claystones, and blue-gray marls. The upper part is represented by black shales and sandstones increasing in thickness upwards. Asphalt impregnations have been observed in sandstones of the uppermost Senonian. These Upper Cretaceous elastics are overlain by the Paleocene Algal Limestone.

The middle and upper parts of the Haymana formation are well dated, but fossils are very scarce in the lower part which has been attributed to the Lower Senonian (including the Campanian) by Erk (1957). However, the fact that these elastics contain ophiolitic debris and overlie the Mesozoic platy limestones is a clear indication that they belong to the post-ophiolitic Upper Cretaceous sequence and have a Campanian-Maestrichtian age.

ii. *Karacadağ uplift.* — At Hatip Yaylası, near Samsam Gölü, the Haymana formation unconformably overlies the ophiolites and their associated sediments (radiolarian wackestones). At the base are coarse elastics composed of ophiolite detritus and quartz grains. Channelling and cross-bedding are common features. In the lower part of the sequence, predominant sandstones are intercalated with some dm-bedded sandy lime packstones containing gastropods, rudists and big oysters. Fossils and debris of the underlying Ophiolite suite clearly show that the sedimentation took place in the Campanian-Maestrichtian, after the emplacement of the ophiolitic nappe. The upper part of the sequence consists of an alternation of fine sandstones and claystones of Maestrichtian age. The sequence apparently grades conformably into the overlying Paleocene Algal Limestone. The thickness of the Haymana formation is estimated to be around 700 meters.

The same succession has been observed near Sinanlı on the western flank of the Karacadağ uplift.

iii. Aksaray fault zone. — The oldest formations encountered along the Aksaray fault zone are of Upper Senonian age. The base is not exposed. The lowest horizons seen are continental red conglomerates (300-400m) composed almost exclusively of ophiolitic detritus, and very occasional granite and granite gneiss pebbles of the Kırşehir Massif. Along the road to Mezgit (Pl. I) these red conglomerates are overlain by massive gypsum (averaging 50 m thick) which wedges out eastwards. In other places (Kocayokuş Tepe) continental reddish silty and sandy claystones are overlain by Maestrichtian intertidal sandstones which contain Orbitoides, gastropods, lamellibranchs and rudists.

The boundary between the sediments of Upper Cretaceous and Paleocene age is mostly gradual near Asma Yaylası and Çardak (Pl. I). Here large nodules of algal limestones intercalated in a sandy matrix mark a gradual transition from the reddish conglomerates of the Haymana formation to the overlying Tetriary Algal Limestone.

At Kocayokuş Tepe the paleontological boundary between the Upper Cretaceous (Maestrichtian) and Tertiary (Paleocene) coincides with the lithological boundary. The dusky yellow lime mudstones of the Haymana formation are dated as Maestrichtian by Orbitoides, whereas the Algal Limestone (10-30 m) contains typical Paleocene larger foraminifera and algae.

The Upper Cretaceous/Tertiary boundary, however, is not always marked by a lithological break. Where the characteristic Algal Limestone is absent, the Upper Cretaceous and Tertiary formations are developed in a uniform coarse clastic facies. This occurs mainly along the edge of the basin. Along the road to Mezgit fluviatile conglomerates and sandstones of Lower Tertiary age directly overlie Upper Cretaceous gypsiferous beds.

b. Bala area

During recent field surveys by the author for N.V. Turkse Shell, Upper Cretaceous (uppermost Maestrichtian) sediments were encountered for the first time in the Bala area. The base is not seen, the contacts being tectonic (Pl. XII).

West of Üçem, near Bala, only the upper part of the sequence crops out near a fault within the Paleocene sediments. It consists of shallow marine-lagoonal claystones and coastal sandstones containing rudists and orbitoids which possibly represent the southwestern edge of the Bala trough.

Further to the northeast, at Küredağ, the Haymana formation is overthrust by the Ophiolite suite and is itself thrust on the Paleocene sediments which unconformably overlie the Paleozoic basement (Pl. XII). The Haymana formation is here mainly made up of deeper marine olive-gray claystones with thin cm-bedded, graded, very fine, greenish gray-olive gray sandstones in which slumping is very common.

More to the northeast, in the Kırıkkale area, the Ophiolite suite is thrust over deeper marine claystones of uppermost Maestrichtian age which in turn are thrust onto the Paleocene sediments. These, again, are unconformable on the Paleozoic basement.

Paleogeographic reconstruction (Pl. VI) suggest that the Haymana formation was deposited in a narrow intramontane trough between the Ankara High and the Kırşehir Massif both of which were land areas at that time. These sediments were probably separated form the Tuz Gölü basin by a saddle in the Paşadağ area, as indicated by the existence of uppermost Maestrichtian coastal sediments near Üçem, believed to represent the southwestern edge of the Bala trough. A connection between the two basins was subsequently established in the Paleocene.

c. Massifs

No Upper Senonian rocks have been observed on the Kırşehir and Sivrihisar-Bozdağ massifs.

4. ALGAL LIMESTONE

Age: Paleocene.

As mentioned above, the Upper Cretaceous-Tertiary boundary is often marked by an Algal Limestone of Paleocene age. In the Haymana area this unit is reported to extend down into the upper part of the Upper Maestrichtian.

In the Haymana area, the Upper Cretaceous marls with thin intercalations of sandy limestones or calcareous sandstones, rich in algae, are included in the Algal Limestone unit. The Algal Limestone consists of thick-bedded, hard, yellow or light reddish limestones with only minor sandy or marly intercalations. These in turn are overlain by conglomerates, sandstones and marls of Paleocene-Lower Eocene age. The lower part of the Paleocene-Lower Eocene section also locally contains thin algal limestone intercalations.

In the Haymana anticline the Algal Limestone can be seen to form reef nuclei (bioherms) or biostromes consisting of reef detritus (Erk, 1957). Eight beds of algal limestone have been observed, consisting of biostromes of 30-40 cm thickness.

At Kadıköy Boğazı, about 10 km northwest of Haymana, the Algal Limestone unit thickens and begins to coalesce to the east, with a corresponding thinning of the intervening black shales. More to the east, on the north flank of the Haymana anticline, the limestones form a single biohermal unit. Here, asphaltic hydrocarbons are found impregnated in the fine structures of algae and foraminifera (Erk, 1957).

The extent and distribution of these reefoidal formations in the whole central Anatolian basin is not yet clearly known. Algal limestones, sometimes up to 30 meters thick, have been observed at the Upper Cretaceous-Tertiary boundary on both sides of the Tuz Gölü basin, on the Karacadağ uplift and in the Aksaray fault zone. Thus it can be assumed that the Algal Limestone may also be present beneath the Tuz Gölü area, at least near the basin margins.

5. KÜREDAĞ FORMATION

(Plate VII)

Age: Paleocene-Lower Eocene.

Near the margins of the basin, the sequence starts with coarse sediments, conglomerates and sandstones, passing laterally and upwards into coastal and shallow marine claystones and sandstones (PI. VII).

The Küredağ formation conformably overlies the Algal Limestone or where this has not been developed, the equivalent elastics. The top of this rock unit is well defined in the areas where it is overlain by the transgressive Middle Eocene Nummulitic Limestone (Çayraz formation). Elsewhere, e.g. in the basin center where the Çayraz formation is represented by its clastic equivalent, the upper boundary of the Küredağ formation is transitional with the overlying layers.

The Paleocene-Lower Eocene sedimentary sequence has been subdivided by several geologists into small rock-units, which, however, have no regional extension. This is caused by pronounced lateral facies changes in the otherwise undisturbed Lower Tertiary basin.

a. Bala area

On the Kırşehir Massif, around Kırıkkale and Keskin, Lower Tertiary red conglomerates and arkoses with some reddish sandy claystone intercalations unconformably overlie the Paleozoic. The conglomerates contain granite-syenite-diorite pebbles and boulders with some phyllites, basalts and andesites. Boulders up to 1.5 m in diameter have been observed; they are sub-angular and sub-rounded. Arkoses and arkosic sandstones in the sequence are composed of detrital feldspars, quartz and biotites, indicating that the detrital material (pebbles, boulders and components of arkoses) has been derived from nearby sources with little transport.

Near Kırıkkale, some Paleocene algal lime wackestones (with vertical burrows) and nummulitic lime packstones are intercalated towards the top of these red beds. This sequence is followed by an alternation of fluvio-marine claystones and sandstones, partly turbiditic.

To the southwest, at Küredağ, the lower part of the Küredağ formation is represented by red beds with nummulitic lime packstone and yellowish gray arkosic sandstone intercalations. As in the Kırıkkale area, conglomerates and sandstones are present, and contain granite-syenite-diorite debris, although in this area the boulders are very scarce. These red beds are followed by an alternation of fluvio-marine claystones and sandstones. The upper part of the sequence consists of coastal conglomerates and sandstones in which big masses of Paleocene lime packstones are scattered. These masses are up to 20 m in length and 4-5 m in height and the limestones are believed to be contemporaneous with the surrounding elastics.

More to the southwest, near Üçem, only the lower part of the Küredağ formation occurs, being represented by red beds with limestone intercalations towards the top. In the red bed sequence reddish claystones are predominant. Conglomerates and sandstones are also present but show a decrease in grain size compared with the previous section. Intercalations of nummulitic, algal and miliolid lime packstone become more important. Some small coral reefs also occur (tens of meters across, 2-3 m thick). West of Üçem, the lower part of the Küredağ formation is again present and is represented by coastal sediments in which conglomerates and sandstones are predominant.

Thus, from Kırıkkale to Bala, the following observations were made:

— decrease of grain size of the basal Küredağ red beds;

— increase of limestone intercalations with an environmental change from tidal flats to more marine environments;

— the upper part of the Küredağ is fluvio-marine throughout.

Generally the Küredağ formation is overlain with apparent conformity by red beds of the Bald formation of Upper Middle Eocene - Oligocene age.

b. Tuz Gölü area

In the Aksaray fault zone which follows roughly the eastern margin of the Tuz Gölü basin the Küredağ formation conformably overlies the Algal Limestone or the Upper Senonian elastics (Haymana formation). Near the basin edge coarse sandstones and conglomerates were deposited passing laterally and upwards into lagoonal, coastal and shallow marine claystones and sandstones.

Basinwards, near Karamollauşağı, the sequence starts with coastal sandstones grading into fluvio-marine sediments.

In the Paşadağ area, between Tuz Gölü and Bala the base is not exposed and the outcropping part of the Küredağ formation is represented by fluvio-marine sediments with turbidites. These are conformably overlain by the Bala formation.

On the Karacadağ uplift, near Kütükuşağı in the Yeniceoba area, ophiolites are overlain by red beds followed by alveolinid lime wacke/packstones of Paleocene age. The red beds contain a great amount of ophiolite detritus. The detrital materials are derived from the nearby ophiolitic source area.

c. Haymana area

Nearly 800 meters of Küredağ elastics conformably overlie the Upper Senonian Haymana formation with or without an intercalation of Algal Limestone at the Upper Cretaceous - Tertiary boundary. The Tertiary starts with a clastic unit at the base, consisting mainly of conglomerates, coarse and fine sandstones, siltstones and marl intercalations This sequence, almost 200 m thick, characteristically contains small Nummulites. The section overlying the highly fossiliferous Lower Paleocene becomes less fossiliferous and contains an undiagnostic fauna within the Paleocene-Eocene transition zone.

The Küredağ formation is conformably overlain by the Middle Eocene Nummulitic Limestone. Locally the Nummulitic Limestone is missing and clastic sediments extend without interruption into the Middle Eocene. In this case the formation boundary becomes indistinct.

d. Ereğli-Ulukışla area

In the southern part of the Tuz Gölü basin, at Kayasaray southeast of Ereğli, ophiolites are unconformably overlain by thin Tertiary conglomerates and crystalline limestones. At Dedeliköy they are overlain by lime wackestones of Paleocene age, followed by volcanic tuffs interbedded with claystones and sandstones.

Near Çiftehan, in the Ulukışla area, ophiolites are overlain by Paleocene limestones followed by tuffaceous sandstones, fluviatile sandstones and claystqnes/shales with some andesite intercalations.

The Paleocene-Eocene sequence in this area is overlain by gypsum and gypsiferous formations attributed to the Bala formation.

6. ÇAYRAZ FORMATION (NUMMULITIC LIMESTONE UNIT)

(Plate VIII)

Age: Lower part of the Middle Eocene.

The name «Çayraz formation» has been given to the nummulitic limestone facies of the Lower Middle Eocene sediments. Its clastic equivalents are included on the map in the Küredağ formation (Pl. I).

In the basin center this Nummulitic Limestone unit conformably overlies the Paleocene-Lower Eocene Küredağ elastics. On the basin edges it has been found unconformable on the Ophiolite suite on the Ankara-Bala road SE of Ankara, on granites near Savcılı and on ophiolites on the west shore of the Hirfanlı Lake, east of Bıyıkkebir in the Kırşehir Massif. The area of deposition of the Middle Eocene thus extended beyond that of the Paleocene-Lower Eocene Küredağ elastics.

a. Haymana area

To the west of Çayraz, the Lower Middle Eocene is represented by nummulitic limestones with marly intercalations, containing abundant large Nummulites and Assilinas. Towards the top sandstones and marls occur. To the north and east of Çayraz the Nummulitic limestone passes laterally into elastics. The Middle Eocene sediments can attain a thickness of 600 m.

b. Tuz Gölü area

The Lower Middle Eocene is represented, here, by elastics which can hardly be separated from the underlying Küredağ formation (mapped together on Pl. I). In the Karamollauşağı area, southwest of Şereflikoçhisar, the lateral equivalent of the Nummulitic Limestone unit consists of an alternation of claystones and sandstones, partly turbiditic.

c. Bala area

On the basin edges, near Karaali on the Ankara High and near Savcılı and Bıyıkkebir on the Kırşehir Massif, the Çayraz formation is represented by the transgressive nummulitic limestone facies. It seems to have been eroded, since only some remnants have been observed in the Savcılı and Bıyıkkebir areas.

In the central part of the Bala area, the age equivalent of the (Çayraz formation is represented by elastics. Dating of the formations is rather doubtful since only a general Lower Tertiary age can be given to the equivalent strata above the well dated Paleocene sediments.

7. BALA FORMATION

(Plate IX)

Age: Upper part of Middle Eocene-Oligocene.

In Upper Middle Eocene-Oligocene times, the Haymana area was uplifted and the trend of the northern end of the Tuz Gölü basin, which became a fault-bound graben feature, turned sharply to the north. At that time the Tuz Gölü basin was well connected with the Çankırı basin, another intramontane basin to the NE of Ankara.

The Bala formation overlies either the Paleocene - L. Eocene (Küredağ) elastics or the Nummulitic Limestone unit without a distinct angular unconformity in the Tuz Gölü and Bala areas. On seismic line TG-7 a distinct erosional surface can, however, be seen at this approximate level in the eastern part of the Tuz Gölü area.

a. Bala area

In the Bala area, the lower part of the section is represented by red beds, starting with continental reddish conglomerates sandstones and sandy claystones, and passing into yellowish gray sandstones and thin gypsum intercalations towards the top. The conglomerates consist mainly of ophiolitic detritus. The red beds are overlain by olive gray silty claystones/shales with massive gypsum intercalations. This shaly and gypsiferous interval is overlain by conglomerates, sandstones and claystones. The massive gypsiferous interval has been accurately dated as the upper part of Middle Eocene, based on paleontological determinations of the underlying and overlying horizons. The upper part of the sequence, which has not been measured in the field, consists of conglomerates containing detritus from older stratigraphic units, tuffs, tuffaceous sandstones and basalt layers. The total thickness of the Bala formation is estimated to be more than 1000 meters.

Further to the north, in the Elmadağ range, this unit unconformably overlies ophiolites, thus indicating an absence of the Nummulitic Limestone, due either to non-deposition or erosion. At the base of the Bala formation there are red beds in which conglomerates and coarse sandstones predominate. The conglomerates contain a great amount of ophiolitic detritus. These are overlain by grayish coarse sandstones with conglomerate layers containing Paleocene-Middle Eocene limestone pebbles. The middle part of the sequence is represented by greenish gray shales and siltstones. In the west these contain thin carbonaceous shales, while in the east thin gygsum intercalations are present. Pollen determination of a sample collected near Ağaçalı gave an Oligocene age for this shaly interval. The upper part is represented by volcanics, which are mainly developed in the Ankara area (Pl. IX).

b. Tuz Gölü area

In the escarpment on the eastern margin of the Tuz Gölü basin, the Lower Eocene seems to be overlain by the continental beds of the Upper Middle Eocene-Oligocene Bala Formation without any hiatus, but the contact could not be observed in the field due to poor exposures. Near Karandere, the sequence starts with light to medium brown sandy claystones with conglomerate intercalations containing alveolinid lime wacke/packstone pebbles of Paleocene age. The middle part consists of olive black and olive gray silty claystones with thick massive gypsum and sandstone intercalations. The upper part is represented by conglomerates and channel sandstones followed by an alternation of fine sandstones and claystones/shales. Palynology suggests an Upper Eocene-Oligocene age for the gypsiferous interval. The claystones overlying this gypsiferous interval contain a fauna indicating a Lower Tertiary age. Moreover the underlying and overlying intervals contain limestone pebbles of Paleocene age. Based on the above facts and by comparison with the Bala section, an Upper Middle Eocene age is assumed for the gypsiferous interval of the Bala formation m the Tuz Gölü area.

Near Şereflikoçhisar, on the left bank of the Peçenek River, the Bala formation starts with olive gray silty claystones in which no fauna has been found. These are overlain by a thick sequence of grayish orange-yellowish gray coarse arkosic sandstones and conglomerates containing almost exclusively debris of granites, syenites, diorites and, at the base, some boulders and pebbles of Paleocene limestones. On the right bank of the river these sandstones are overlain by gypsiferous claystones (palynologically dated as Oligocene), in which lignites are mined. These are overlain by lacustrine white limestones.

Between 2 and 3 km north of Şereflikoçhisar there are outcrops of a thick sequence of nearly 700 meters of thick-bedded coarse arkosic sandstones. These seem to be tectonically overlain by the gypsiferous interval, and are considered to be the equivalent of the thick sandstone sequence of the Peçenek River.

Based on the above observations the following composite stratigraphic succession is considered to be representative for the Bala formation in the Elmadağ, Bala and Şereflikoçhisar areas. From the base to the top:

1. Red beds, present at all localities. Middle Eocene?
2. Silty claystones with thick gypsum intercalation; missing in the Elmadağ area. Dated accurately as Middle Eocene, in the Bala area.
3. Conglomerates and sandstones, containing pebbles of Paleocene-Middle Eocene limestones. Assumed age: Middle-Upper Eocene.
4. Sandstones, silty claystones and carbonaceous-gypsiferous claystones. Lignites are present in the Şereflikoçhisar area, but absent at Bala. Dated palynologically as Upper Eocene-Oligocene.
5. Volcanics in the Bala and Elmadağ areas, lacustrine limestones near Şereflikoçhisar. Assumed age: Oligocene.

c. Ulukışla-Ereğli area

In the Ulukışla-Ereğli area, the Paleocene-Eocene elastics are overlain by the gypsiferous fades of the Bala formation.

8. NEOGENE SEDIMENTS

(Plate X)

Age: Mio-Pliocene to Pleistocene.

The Neogene continental basin occupied large areas, especially in the southern part of the map area, where large-scale volcanism gave rise to frequent tuff intercalations.

In some places sedimentation is continuous from Miocene to Pleistocene. In other localities, only the top part of the Neogene sequence occurs. Therefore, both the upper and lower parts are locally found unconformable on all older stratigraphical units.

The *lower part of the Neogene* sequence shows a variety of facies, as outlined below:

Around Aksaray in the Tuz Gölü area, yellow, white and red tuffs and tuff breccias occur, with subordinate calcareous sandstones and conglomerates. These are named «Aksaray volcanics». Chaput (1930), quoted by Erol (1956), discovered an important vertebrate bed of Pontian age in the tuffs near Karaindere village between Ürgüp and İncesu, to the east of the mapped area. Pontian vertebrates have also been found by Yalçınlar and İzbırak (1950-1951) north and northeast of Kayseri (not on maps), and by Tschachtli (1942) east of Karacahasan in the Elmadağ area.

Lacustrine limestones are well developed in the Cihanbeyli area, west of Tuz Gölü, and extend south-eastwards through Sultanhanı towards Aksaray. To the south of Tuz Gölü, white lacustrine limestones and marls contain numerous Pliocene fresh-water fossils (Druitt, 1959; Lahn, 1946).

East of Tuz Gölü, variegated conglomerates and sandstones predominate. In the Kesikköprü-Karakeçili area, the lower part of the sequence consists of sandstones and marls containing thin gypsum layers. Near Karaman (to the southwest of the map area), littoral Helvetian deposits are overlain by tuffaceous-lacustrine beds similar to those of Aksaray. Moreover by the presence of fish remains a Helvetian-Tortonian age is indicated for the basal part of the sequence in the Ayaş area. The situation is similar to that found in the Aksaray and Karaman areas. Thus, the age of the lower part of the Neogene sequence is probably mainly Miocene, but also including Pliocene.

The *upper part of the Neogene* is characterized over the whole area by fluviatile and lacustrine sediments consisting of gravels or conglomerates, sands or sandstones, argillaceous sediments and caliches. Volcanics occur towards the top (Karacadağ and Hasandağ volcanics).

In the Taurus Mountains, to the south of the Tuz Gölü basin, the Neogene consists of clastic sediments. At the base are conglomerates up to 500-600 m thick. These are overlain by sandstones alternating with marls. Although no characteristic fossils are found in these clastic layers, they have been presumed to be of the same age as the calcareous and fossiliferous Miocene sediments cropping out around the Taurus Mountains (Blumenthal, 1941).

9. IGNEOUS ROCKS

(Plate I)

The igneous rocks forming the Kırşehir Massif are phanerocrystalline granites, syenites and granodiorites.

The acid and basic plutonics are believed by Lahn (1949) to be of Hercynian origin, and by some authors to be of Late Paleozoic age. However, Burchardt (1957) observed that acid plu-

tonics intersect metamorphics which were already folded, and concludes their age to be Paleocene. Ketin (1955) observed near Çiçekdağ (outside of the map area) that acid intrusions penetrate and thermally metamorphose the limestones and marls of the Upper Cretaceous.

According to recent observations, four groups of igneous rocks have been differentiated in the area studied. These include two distinct groups of acid intrusions, the ophiolites, and extrusive volcanics of various ages.

1. An earlier phase of acid intrusions is associated with the highly metamorphic rocks of the Kırşehir Massif and their metamorphism. These are probably of Caledonian origin. Rocks of this group consist of granites and granite-gneiss and are strongly weathered and form smooth surfaces and areas of low topographic relief. The debris of this unit were found by Bilgütay (1960) at the base of the Mesozoic limestone group and in the red bed sequence of the Haymana formation along the Aksaray fault zone.

2. A second phase occurred after the emplacement of the ophiolitic nappe. Rocks of this group have been intruded into previously folded metamorphics, as well as into rocks of the first acid intrusion phase. Near Kesikköprü, ophiolites are cut by pegmatites of the second intrusion. Moreover, rocks of this second phase contain xenoliths of the earlier intrusive rocks and they form pronounced topographic highs. Pebbles and boulders of these rocks are found in the Paleocene. It is believed that these intrusions took place during the Laramide phase at the end of the Cretaceous.

3. Ophiolite suite. Sediments associated with the ophiolites, radiolarian wackestones, indicate an Upper Cretaceous age (Santonian-Campanian?), and the ophiolite emplacement probably took place in the early Campanian.

4. Extrusive volcanics:

a) Agglomerates, tuffaccous sandstones and andesites are intercalated in the Paleocene sediments.

b) Andesites, tuffs and some basalts overlie locally the Middle Eocene-Oligocene gypsiferous formations.

c) Tuffs, agglomerates and andesitic lavas occur in the Aksaray area, where tuffs containing Pontian vertebrates were found.

d) Predominantly andesitic lavas were extruded during the Pliocene and Pleistocene.

More detailed descriptions of these volcanic occurrences have already been given in the foregoing account of the sedimentary stratigraphy.

II. TECTONICS

Structural features (Plate II) :

Two main groups of structural features can be distinguished in the area under consideration: *Crystalline Massifs* and *Intramontane Sedimentary Basins.*

For better understanding of the relationship of these features, a summary will be given of the stratigraphy of their Mesozoic and Tertiary covers (with the exception of the Neogene sediments which are unfolded or only slightly folded).

1. CRYSTALLINE MASSIFS

The crystalline massifs comprise the *autochthonous central Anatolian Massifs* and the *par-autochthonous Ankara Melange*. Both belong to the continental mass of Anatolia.

a. The central Anatolian Massifs

The central Anatolian Massifs are represented by the Kırşehir Massif in the east and Sivrihisar-Bozdağ Massif in the west.

The Kırşehir Massif consists of highly metamorphic rocks associated with acid intrusions. They are tectonically overlain by ophiolites.

On the Sivrihisar-Bozdağ Massif, metamorphic and Paleozoic rocks are unconformably overlain by the Mesozoic limestone group. Ophiolites are found overlying the Mesozoic and Paleozoic rocks on the northeastern edge of the Sivrihisar Massif.

No rocks of Upper Senonian-Tertiary age are found on these massifs but they occur as an onlap sequence on their edges. The Kırşehir and Sivrihisar Massifs were land areas from Upper Senonian to Oligocene, supplying sediments to the intramontane basins.

b. The Ankara High

On the Ankara High the exposed basement is made up of Paleozoic greywackes which are unconformably overlain by the Mesozoic limestone group.

In the sedimentary cover, which is called here the «Ankara Melange», ophiolites form an important part of the exposed rocks on the eastern and southern parts of the Ankara High. These occupy a definite structural position overlying the Mesozoic limestone group or, where these are eroded, the Paleozoic formations.

Upper Senonian sediments were deposited on the southwestern edge of the Ankara High. Some remnants are indicated on the M.T.A. geological maps.

Paleocene-Eocene rocks are absent or very reduced in the western part of the Ankara High. In the eastern part, where the Bala formation (Oligocene?) onlaps on the Ankara High, the Paleocene-Eocene sediments might have been deposited on the edge of the massif and then eroded before the deposition of the Bala formation.

c. Conclusions

From Lower Jurassic to Cenomanian the Ankara High, together with Central Anatolia, formed a single continuous carbonate shelf platform. The sedimentary history is similar in both areas, which formed part of the Anatolian continent.

Ophiolites originating from the northern Tethys ocean floor (Horstink, 1970) were overthrust onto this platform at the end of Santonian or in early Campanian time.

From Upper Senonian to Oligocene the Ankara High bordered the intramontane troughs to the north, while the Kırşehir and Sivrihisar Massifs (which were land areas at that time) bordered these troughs to the east and southeast and to the west and southwest respectively. Sedimentation during that time took place only on the edges of these massifs.

The Ankara Melange was thrust towards the south in late Oligocene or Miocene times, the Bala formation of Oligocene age being involved in the thrusting. In the Bala area, where the distance between the Ankara High and the Kırşehir Massif is small, high angle thrusts occur. Where the Ankara Melange overrides the intramontane troughs, low angle thrusting is present.

It can be seen that the Ankara High and the central Anatolian Massifs have similar geological histories. Accordingly, the Ankara High is considered as a unit belonging to the continental mass of Anatolia, rather than to the Pontids (as was suggested by Ketin, 1959). It is also not necessary to differentiate two separate major tectonic units in this area, as was proposed by Egeran-Lahn (1951).

2. THE INTRAMONTANE SEDIMENTARY BASINS

The Intramontane Basins comprise the following elongated sedimentary basins which originated mainly in Upper Senonian and Lower Tertiary times.

a. The Haymana basin

The basement of the Haymana basin consists of ophiolites and, where these are eroded, by the Mesozoic limestone group. The latter is only exposed in the core of the Haymana anticline.

The Haymana basin developed during the Upper Senonian-Middle Eocene as an extension of the Tuz Gölü depression. After the deposition of the Middle Eocene Nummulitic Limestone (Çayraz formation) the area was uplifted and together with the Karacadağ uplift it formed land areas. No deposition of the Bala formation is known in the Haymana area.

The Paleogene formations, exposed at the surface, show E-W trending folds which to the northwest turn in a SE-NW direction. This trend is more or less parallel to the front thrust of the Ankara High.

b The Tuz Gölü basin

The oil geological basement of the Tuz Gölü basin is believed to be formed by ophiolites overlying the Mesozoic and Paleozoic rocks of Central Anatolia.

In the Tuz Gölü basin, continuous sedimentation took place from the Upper Cretaceous to the end of the Oligocene but the graben form of this basin only began to develop during the Upper Middle Eocene-Oligocene.

The Tuz Gölü graben is bordered by NW-SE trending faults (the Aksaray fault zone in the east, and the faults bounding the Karacadağ uplift in the west). The rather sharp NW-SE trending folds in the eastern escarpment bordering the Tuz Gölü depression are mainly influenced by the NW-SE trending Aksaray fault zone. Northwards these structures change their direction, first becoming nearly N-S in the Paşadağ area, then NE-SW in the Bala area. These sharp folds in the Upper Cretaceous-Oligocene sediments disappear beneath a thick cover (400-500 m) of flat-lying Neogene sediments.

In the central part of Tuz Gölü, seismic surveys have shown a deep trough affected by gentle folding related to fault movements and to salt diapirism. To the northeast a major fault zone forms the edge of the basin (Aksaray fault zone) (Pl. XI).

Within this fault zone, seismic shows a complex picture of faulting, sedimentary wedging and folding. Hydrocarbon traps could be present in this area, although they would not be easy to define. In the western part of the basin, diapiric structures have been interpreted on seismic lines. These structures follow the general NW-SE trend of the Tuz Gölü basin.

Seismic data suggest that the diapiric structures are complex ridges, perhaps having off-shoots in the form of domes or plugs. The seismic coverage is at present not adequate to delineate these trends in detail, and gravity has been used as an aid in interpolating trends between seismic lines. A general relationship is seen between the seismic highs and the Bouguer lows, although the latter are sometimes slightly displaced.

The diapiric material in these structures is almost certainly salt. Salt lakes are found on the surface above two known diapirs seen on seismic (Akgöl and Bezirci Gölü), and their salinity is attributed to upward leakage of brines along fractures. Salt springs also occur above the western diapiric trend. The age of the salt is not known, but it may correlate either with evaporites present in the Middle Eocene or with those of the Upper Cretaceous.

Two main negative Bouguer trends have been mapped (Uğurtaş, in preparation), corresponding to two main diapiric ridges: an eastern and a western one. On seismic sections, the eastern trend does not seem to affect the Neogene unconformity, while the western trend disturbs this unconformity. Thus, on the eastern uplift (which is closer to the basin center), movements ceased earlier than on the western one. The western trend can also be followed in the field by the presence of a probably related topographic depression (Eşmekaya depression).

These diapiric structures are expected to form potential traps for hydrocarbons, especially on their flanks. Inter-domal traps of the «turtle-back» type are also a possibility.

c. The Bala basin

As in the two previously mentioned intramontane basins, in the Bala area the basement is in general formed by ophiolites or, where these are eroded, by the highly metamorphic rocks of the Kırşehir Massif. In the Bala area, sedimentation started in the uppermost Maestrichtian and continued until the end of the Oligocene. The structural trends of the Bala area are more or less parallel to those of the frontal thrust of the Ankara High.

d. Conclusions

In the north the trends of the structures in the intramontane troughs are governed by the direction of thrusting of the Ankara Melange.

In the south, the structures are mainly influenced by the NW-SE trending faults of the Tuz Gölü graben, and by the parallel diapiric trends which may have been induced by these faults.

III. GEOLOGICAL HISTORY

The distinctly metamorphic rocks of the massifs surrounding the Tuz Gölü basin are believed to be of Lower Paleozoic age, most likely Cambrian, and were probably metamorphosed during the Caledonian orogeny. They are overlain by Silurian graptolite schists (Taurus).

The Upper Carboniferous-Middle Permian limestones are apparently transgressive upon folded and slightly metamorphosed Upper Devonian-Lower Carboniferous rocks, which were probably affected by an early Hercynian orogenic phase. This was followed by a late Hercynian uplift possibly at the end of the Permian.

The Triassic beds observed in the Hasanoğlan area, near Ankara, are the only Lower Mesozoic sediments known in Central Anatolia. It is assumed that the Triassic has probably been eroded over large parts of the area.

The Jurassic transgression started locally with a thin basal conglomerate (Hasanoğlan area, near Ankara), and was followed by the deposition of predominantly calcareous sediments which continued through the Lower Cretaceous. Thus, Central Anatolia formed a vast carbonate shelf during the Jurassic - Lower Cretaceous.

Before the emplacement of the ophiolites, probably in the Lower Campanian, Central Anatolia was uplifted. The subsequent erosion removed the Mesozoic limestones over large areas, and in some places ophiolites are found resting directly upon the Paleozoic metamorphics.

After the emplacement of the ophiolitic nappe Central Anatolia was exposed to erosion, and abundant ophiolitic detritus was brought into the post-ophiolitic Upper Cretaceous basins (Pl. VI).

In the Tuz Gölü basin, sedimentation was continuous from the Upper Senonian to Oligocene, representing a complete sedimentary cycle (Pl. IV, V).

The transgression started in the Campanian-Maestrichtian which is represented by red beds on the basin edges, passing upwards and basinwards into coastal and shallow marine sediments (Haymana formation) (PI. VI).

The Upper Cretaceous-Tertiary boundary is often marked by the development of algal reefs. Elsewhere the passage is transitional. The intrusion of granites into folded sediments on the Kırşehir Massif occurred at this period.

The Paleocene-Lower Eocene is mainly composed of elastics, starting with red beds on the massifs and coarse sediments near the basin edges, and passing laterally and upwards into coastal and shallow marine sediments (Pl. VII) (Küredağ formation).

The Middle Eocene is marked by a marine transgeression beyond the margins of the original intramontane basins. Large areas on the Kırşehir Massif have probably been covered by the transgressive nummulitic limestones. This is an indication that the subsidence which started in Upper Senonian times persisted into Middle Eocene times. Due to the subsequent erosion, however, the Middle Eocene limestones have only been preserved on the basin margins, e.g. Savcılı and Bıyıkkebir.

The sea started to retreat towards the end of the Middle Eocene. The Tuz Gölü basin became a graben bounded by NW-SE trending faults, and no deposition took place on the uplifted massifs or in the Haymana area (Pl. IX). The subsequent erosion affected the uplifted areas, products of which were brought into the Tuz Gölü graben, where shallow marine to coastal sediments were deposited during the Middle Eocene, followed by continental sediments during the Upper Eocene-Oligocene (Pl. III, IV, V).

From Upper Senonian to Middle Eocene the Haymana area formed the northwestern part of the Tuz Gölü basin. After the deposition of the Nummulitic Limestone (Çayraz formation) this area was uplifted along the Karacadağ uplift.

The connection with the Bala basin which started to subside in the Maestrichtian, came into existence during the Paleocene and continued throughout the Middle Eocene-Oligocene.

The main deformation of these basins occurred in late Oligocene or Miocene times. Diapiric movements affect not exactly dated Tertiary sediments.

During the Neogene local basins accumulated varying thicknesses of volcanic material, lacustrine limestones and continental sediments.

The most recent deformation seems to have occurred in the Pliocene. Seismic line TG-7 indicates slight deformation of the volcanics dated as Pontian (PL XI). These movements are probably related to the last compressional tectonic phase affecting the whole of Turkey, which resulted in thrusting on the mobile edges of Anatolia while the Anatolian stable block was barely affected. Nebert (1958) proved the existence of post-Pliocene movements (Wallachian phase) in the Kayı-Bucuk area, 40 km WNW of Ankara (outside of map area).

Tensional movements took place in the Neogene and continued into the Pleistocene, leading to volcanic activity which extended into historical times.

IV. PETROLEUM GEOLOGY

1. SURFACE INDICATIONS OF HYDROCARBONS

(Plate II)

a. Oil seepages

Oil sands have been reported by Mobil in surface outcrops on the north flank of the Haymana anticline, south and southwest of Çayraz. These sands crop out immediately below the Algal Limestone unit and are about 1.5 m thick. Westwards, on the Ankara-Haymana highway, this thin oil-stained zone becomes conglomeratic and increases to 6.5 m in thickness.

In the same area oil sands also crop out in the Lower Paleocene section about 150 m above the Algal Limestone unit, where they are about 2 m thick.

A small active oil seep with heavy asphalt impregnating fractured basalt of post-Eocene age has been found along a fault zone in the valley of Karagüney Deresi, 2-2.5 km east of Pazar (Sorba) village. This is in the northern part of the Haymana basin, outside of the mapped area. Pazar is about 65 km northwest of Ankara, near the Ankara-Istanbul highway. Several unsuccessful shallow wells have been drilled by M.T.A. (Özbey, 1958).

b. Asphalt occurrences

Small local asphalt occurrences have been reported from several localities:

— South-southeast of Haymana, at Karahoca, about 1.5 m of asphalt-bearing limestones are poorly exposed on a gray shale slope. This part of the section is probably of Paleocene age. The limestone is brownish-gray, argillaceous and fractured, and some impregnation of the rock has taken place from the fractures. The asphalt boils over the flame of a match (Mobil reports).

— Immediately southwest of Sakarya Köy in the Haymana area, outside of the map area, very small specks of asphalt are found in calcite veins which cut through the Nummulitic Limestone (Taşman, 1950).

— In the area north and northeast of Haymana, asphalt impregnations have been found in sandstones of uppermost Cretaceous age as well as in the Paleocene Algal Limestone unit and in the overlying Paleocene sandstones (lower part- of the Küredağ formation).

— In the Polatlı area, asphalt is found in calcite veins in the Middle Eocene marls on the west bank of the İmamoğlu Creek, 1.5 km north of Karahamzalı farm (Taşman, 1950).

— South of Karamollauşağı, on the peninsula in Tuz Gölü, dead asphaltic residue has been reported to be present in a porous sandstone bed of the Paleocene-Eocene Küredağ formation, where saturated beds are alternating with barren ones (Druitt, 1959).

2. SOURCE ROCKS

In the Haymana area, possible source rocks occur in the Upper Senonian sequence. In particular, the upper part of the succession contains abundant black shales and open marine claystones. This possible source rock section is known to be subject to rapid thickness and facies changes.

In the Tuz Gölü basin, Upper Senonian and Paleocene-Eocene sediments occur only in outcrops along the northeastern border of the Tuz Gölü basin. They consist of continental, coastal and shallow marine deposits, and show some indication of deepening towards the basin center. This is also suggested by seismic line TG-7 (Pl. XI), on which reflections at various levels die out in a basinal direction, indicating a possible shaling out. It is therefore conceivable that potential source rocks of various ages may occur beneath the central Tuz Gölü depression.

3. RESERVOIR ROCKS

Potential reservoir horizons may occur in the Paleocene Algal Limestone unit which is expected to be developed mainly along the margins of the Tuz Gölü basin. In outcrops it has poor to fair primary porosity, but locally good vuggy secondary porosity has been observed. A thick section of Upper Maestrichtian rocks, including the Algal Limestone, was reported to contain residual asphalt (Erk, 1957).

Porous sandstones occur at several levels in the Paleocene, Eocene and Oligocene sequences, and could form good potential reservoirs.

Two oil-stained sandstones crop out immediately below and above the Algal Limestone unit on the north flank of the Haymana anticline (Mobil reports).

4. CAP ROCKS

Thick Tertiary claystones and shales, and the evaporitic sequence of the Bala formation are considered to form suitable cap rocks.

5. STRUCTURES AND TRAPS

In the Tuz Gölü basin, the only surface structures exposed are some rather sharp folds in the Aksaray fault zone along the eastern flank of the basin. The Esso wildcat (T.D. 8, 635 feet) drilled in this zone near Şereflikoçhisar reached the upper part of the Paleocene-Eocene section without encountering any oil or gas indications. The well penetrated six different fault blocks and Esso were unable to correlate the section drilled.

In the central part of the Tuz Gölü basin, seismic shows a deep trough bordered by two fault zones. Oil geological basement in the center of the basin may be as deep as 10,000 m and gradually rises towards the west and east (Pl. XI).

The following trapping possibilities may be envisaged:

In the western part of the basin:

— Traps associated with diapiric structures. Mainly on the flanks of diapirs and as interdomal traps of the «turtle-back» type.

In the eastern part of the basin:

— Fault traps: Gentle folding related to fault movements.

— Stratigraphic traps: Rapid fades changes on the basin margin could produce some stratigraphic traps. However it would not be easy to locate these traps, which might also be associated with fault traps.

V. CONCLUSIONS

Geological studies have been carried out in outcropping areas mainly to the northwest, north and northeast of the Tuz Gölü basin. These surface observations, in combination with geophysical data from the Tuz Gölü depression itself, indicate that this area forms part of a significant sedimentary basin having an Upper Cretaceous and Tertiary fill locally exceeding 10 km in thickness. This basin is virtually untested by the drill, only one exploration well having been drilled: Koçhisar-l (Esso, T.D. 8,635 feet). This well is poorly located on surface evidence only, and gives little information on stratigraphy due to the complex tectonic conditions encountered.

The generation of hydrocarbons is indicated by the presence of several oil and asphalt shows in outcrops. The thick Upper Cretaceous and possibly younger shale sections are considered to be potential source rocks which, due to deep burial, might have reached the gas generation stage in the center of the basin.

Potential reservoir horizons are expected in sandstones of various ages (Paleocene, Eocene, Oligocene), and in Paleocene carbonates.

The most prospective trapping environment is provided by diapiric uplifts revealed by seismic in the southwestern part of the basin. Other possibilities, regarded for the time being as secondary, are associated with faulting[1] and Stratigraphic anomalies on the northeastern basin flank.

ACKNOWLEDGEMENT

The author wishes to express his sincere thanks to N.V. Turkse Shell for permission to publish this paper.

Manuscript received October 31, 1974

BIBLIOGRAPHY AND REFERENCES

AKARSU, I. (1959): Ankara bölgesi, Polatlı ve civarının petrol jeolojisi. *M.T.A. Bull.,* no. 52, Ankara.

BAILEY, E.B. & McCALLIEN, W. J. (1950): The Ankara Melange and the Anatolian Thrust. *M.T.A. Mecm.,* no. 15/40, Ankara.

BAYKAL, F. (1941): Kırıkkale-Kalecik ve Keskin-Bala mıntıkalarındaki jeolojik etütler. *M.T.A. Rep.,* no. 1448 (unpublished), Ankara.

BİLGÜTAY, U. (1960): Geology of the Hasanoğlan-Ankara region. *M.T.A. Bull.,* no. 54, Ankara.

BLUMENTHAL, M. (1937): Sur la repartiton des gisements de lignite, d'hydrocarbures et de schistes bitumineux dans la region entre le Kızılırmak et le Yeşilırmak *M.T.A. Rep.,* no. 164 (unpublished), Ankara.

———(1941): Un aperçu de la geologie du Taurus dans les vilayets de Niğde et d'Adana. *M.T.A. Publ.,* ser. B, no. 6, Ankara.

BRELIE, G.v.d. (1958): Palynologische Untersuchungen zur Alterstellung des Braunkohlen-Vorkommens von Kayı-Bucuk (Vilayet Ankara). *M.T.A. Bull.,* no. 50, Ankara.

BUCHARDT, W. S. (1957): Rapport über die in Sommermonaten 1953 und 1954 in Zentralanatolien durch geführten geologischen Kartierungs-arbeiten im Masstabe 1:100 000. *M.T.A. Rep.,* no. 2675 (unpublished), Ankara.

DİNÇEL, B. (1958): Geology of Haymana-Çaldağ Anticline (District II, licences no. 146-147) *Turkish Gulf Oil Co. Petr. Adm.*

DRUITT, C.E. (1959): Preliminary report on the petroleum possibilities of the Tuz Gölü and Ereğli licences. *Turkish Gulf Oil Co. Petr. Adm.*

EGERAN, N. & LAHN, E. (1951): Note on the tectonic position of the Northern and Central Anatolia. *M.T.A. Mecm.,* no. 16/41, Ankara.

ERENTÖZ, C. & TERNEK, Z. (1959): Oil possibilities in the sedimentary basins of Turkey. *M.T.A. Bull.,* no. 53, Ankara.

ERK, S. (1957): Çayraz-Haymana (Küçük Çaldağ). A stratigraphic study. *Turkish Gulf Co. Petroleum Administration.*

EROL, O. (1956): A study of the geology and geomorphology of the region SE of Ankara in Elma Dağı and its surroundings (Summary). *M.T.A. Publ.,* ser. D, no. 9, Ankara.

GANSSER, A. (1958): Report on a short visit to the Çankırı and Haymana blocks of the Turkish Gulf Oil Co. *Turkish Gulf Oil Co. Petroleum Administration.*

HORSTINK, J. (1970): The late Cretaceous and Tertiary geological evolution of Eastern Turkey. *Proceedings of the First Petroleum Congress.*

KETİN, İ. (1955): On the geology of Yozgat region and the tectonic features of the Central-Anatolian massif (Kırşehir crystallines) (Summary). *Bull. Geol. Soc. Turkey,* vol. VI, no. 1, Ankara,

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

KLEINSORGE, H. (1940): Kurze Erlaeuterung einer geologischen Übersichtskarte der Umgebung des Tuz Gölü von Ko9hisar. *M.T.A. Rep.,* no. 1048 (unpublished).

LAHN, E. (1941): Aksaray-Konya arasındaki volkanik arazi. *M.T.A. Mecm.,* no. 1/22.

———(1946): Les depost pliocenes et quaternaires de la region de Konya-Burdur. *Rev. Fac. Sc. Universite d'İstanbul,* ser B, t. XI, fasc. 2.

———(1949): On the geology of Central Anatolia *Bull. Geol. Soc. Turkey,* vol. II, no. 1, Ankara.

MOBIL (1960): Surrender report. Licences 360-361-362-363 District II, Turkey. *Petroleum Administration.*

NEBERT, K. (1958): Ein Beitrag zum jüngsten geologisch-tektonischen Werdegang Inneranatoliens-Nachweis der Wallachischen Orogenphase im Vilayet Ankara (bei Kayı-Bucuk). *M.T.A. Bull.,* no. 50, Ankara.

NORMAN, T.N. (1969): A method to study the distribution of heavy mineral grain abundance in a turbidite. *Sedimentology,* vol. 13, no. 3/4.

OKAY, A.C. (1954): Kayseri, Niğde ve Tuz gölü arasındaki bölgenin jeolojisi. *M.T.A. Rep.,* no. 2252 (unpublished), Ankara.

ÖZBEY, S. (1958): Ruhsat No. 152 nin Jeolojisi II. Bölge Sorba sahası. *Turkish Gulf Oil Co. Petr. Administration.*

PAREJAS, E. (1940): La tectonique transversale de la Turquie. *Rev. Univ. İstanbul,* ser. B, t.v., fasc. 3/4.

PERRY, Jr. C.D. (1959): II Bölge 287 hak sıra numaralı Sorba mıntıkasının petrol jeolojisi. *Turkish Gulf Oil Co. Petr. Administration.*

RECKAMP, J.U. (1959): Petroleum geology of Ar/TGO/FOG/II/281-282 Polatlı Area. *Turkish Gulf Oil. Co. Petr. Administration.*

ROMBERG, H. (1937): Bericht uber die Lignitvorkommen bei Koçhisar, Vilayet Ankara. *M.T.A. Rep.,* no. 162 (unpublished), Ankara.

Encl. 1 GEOLOGICAL MAP TUZ GÖLÜ BASIN
Ek: 1 TUZGÖLÜ HAVZASININ JEOLOJİK HARİTASI

Scale 1:250,000
Ölçek 1:250,000

ANKARA

5 0 5 10 Km.

AGE	MAP SYMBOL	STRATIGRAPHICAL UNITS	MAP SYMBOLS	IGNEOUS ROCKS
CENOZOIC — RECENT	Al	ALLUVIUM		
CENOZOIC — PLEISTOCENE	Pt	TERRACES		HASANDAĞ VOLCANICS / KARACADAĞ VOLCANICS
CENOZOIC — PLIOCENE	Pl	CLASTICS		
CENOZOIC — MIOCENE	Mi	CLASTICS - LACUSTRINE LIMESTONE		AKSARAY VOLCANICS
MAJOR UNCONFORMITY				
CENOZOIC — OLIGOCENE (INCLUDING EM IN THE BALA AREA)	Ol	RED BEDS+GYPSUM - BALA FM.		VOLCANICS
UNCONFORMITY				
CENOZOIC — MIDDLE EOCENE	EM	NUMMULITIC LST - CAYRAZ FM.		
CENOZOIC — PALEOCENE-L.EOCENE (INCLUDING EM CLASTICS)	Pe-EL	CLASTICS - KÜREDAĞ FM.		VOLCANICS IN ANKARA HIGH
CENOZOIC — PALEOCENE	Pe	ALGAL LIMESTONE	GY	ACID INTRUSION (GRANITES, SYENITES, GRANODIORITES)
MESOZOIC — UPPER CRETACEOUS (POST OPHIOLITE EMPLACEMENT - MAESTRICHTIAN)	KUe / KUs	MARINE CLASTICS / EVAPORITES / RED BEDS — HAYMANA FM.		
UNCONFORMITY				
MESOZOIC — EMPLACED IN L.CAMPANIAN	Oph	OPHIOLITE SUITE		
			Oph	OPHIOLITE SUITE
MESOZOIC — JURASSIC-L.CRETACEOUS	J-KL	MESOZOIC LIMESTONE		
UNCONFORMITY BETWEEN MESOZOIC AND PALEOZOIC				
PALEOZOIC — L. CRETACEOUS U. CARBONIFEROUS —	CU-KL	LIMESTONE		
UNCONFORMITY				
PALEOZOIC — L. CARBONIFEROUS U. DEVONIAN —	D	METAMORPHICS - DİKMEN GRAYWACKE		
UNCONFORMITY				
PALEOZOIC — CAMBRIAN OR/TO PRECAMBRIAN	₹	METAMORPHICS (IN GENERAL)		
	M	MARBLES		
	Gn	GNEISS, MICASCHISTS WITH FOLDED ACID INTRUSION	Gn	ACID INTRUSION (GRANITES, SYENITES, GRANODIORITES)

Petroleum District Boundary.
East of Aksaray, West of Zeresk-Elhankayi and southern part according to the MTA maps.
Photogeology by Y. Arıkan

DISTRICT-I
DISTRICT-VII

DISTRICT-II
DISTRICT-VIII

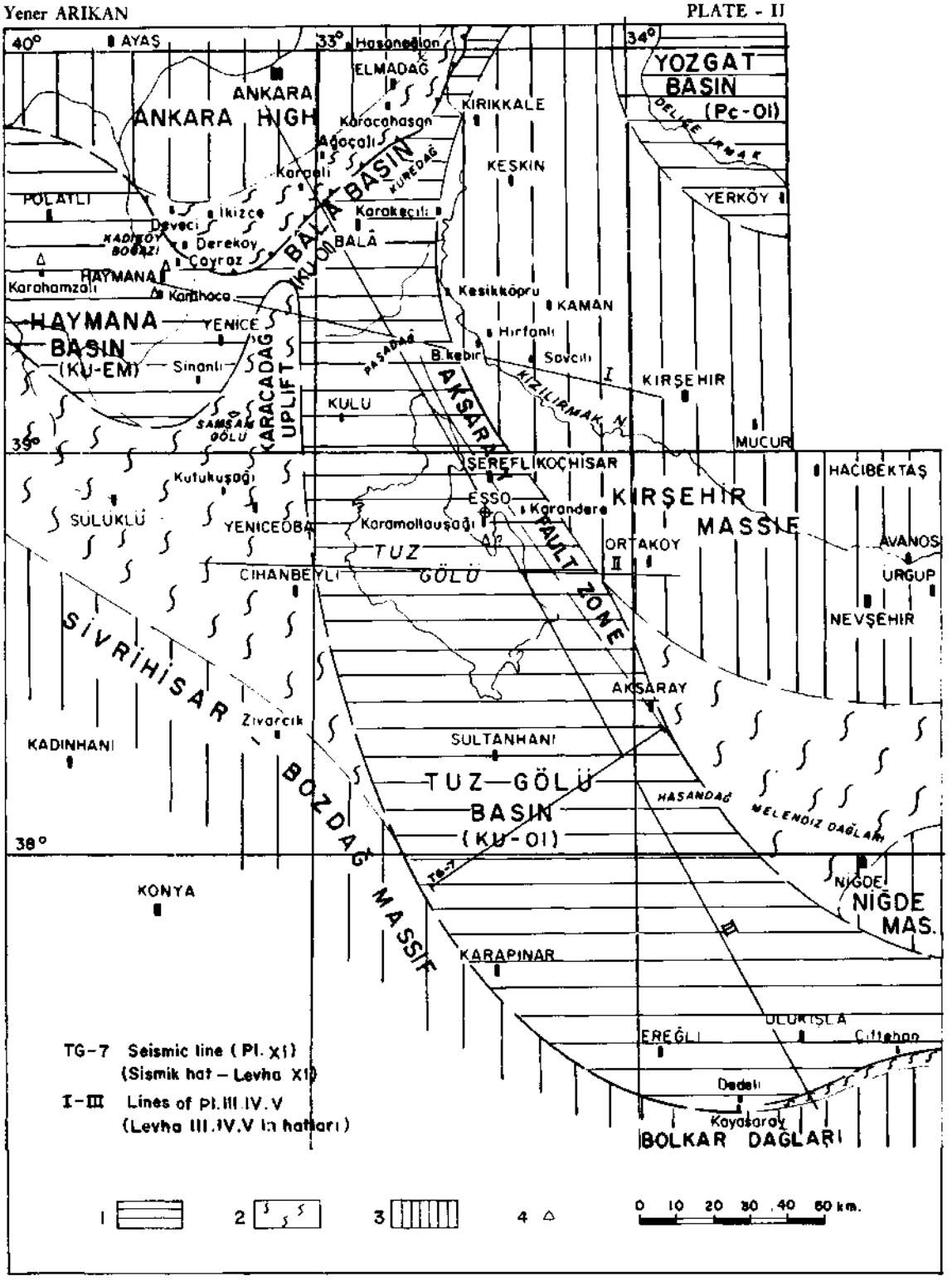
TUZ GÖLÜ

KIRIKKALE
KIRŞEHİR
KESKİN
BALA
KAMAN
MUCUR
SAVCILI
SULUCA
BULDUK
KOÇHİSAR
AKSARAY
YEŞİLOVA
DEDELER
ZİYARET
TÜMEK
KONYA
SULTANHANI
OBRUK
KARAPINAR
ERMENEK
HALKAPINAR

32°30' 33° 33°30' 34°
40° 39°30' 39° 38°30' 38°00' 37°30'

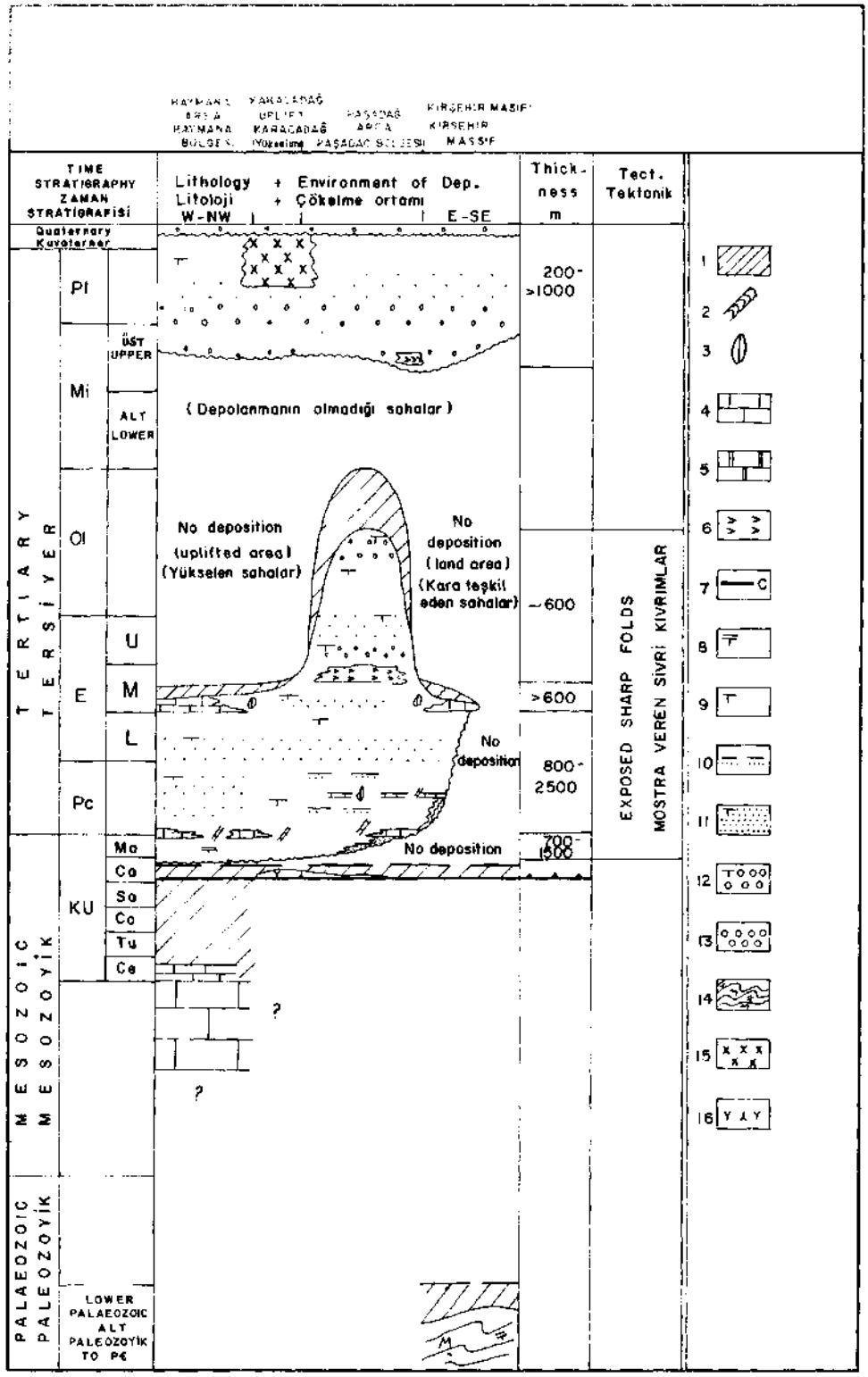
GEOLOGICAL MAP, TUZ GÖLÜ BASIN

Gm.4 - 3363



LOCATION MAP, CENTRAL ANATOLIA

INTRAMONTANE TROUGHS: 1 - Upper Cretaceous - Oligocene; BASEMENT: 2 - Ophiolites + Exotics; 3 - Paleozoic + Mesozoic; 4 - Asphalt shows.

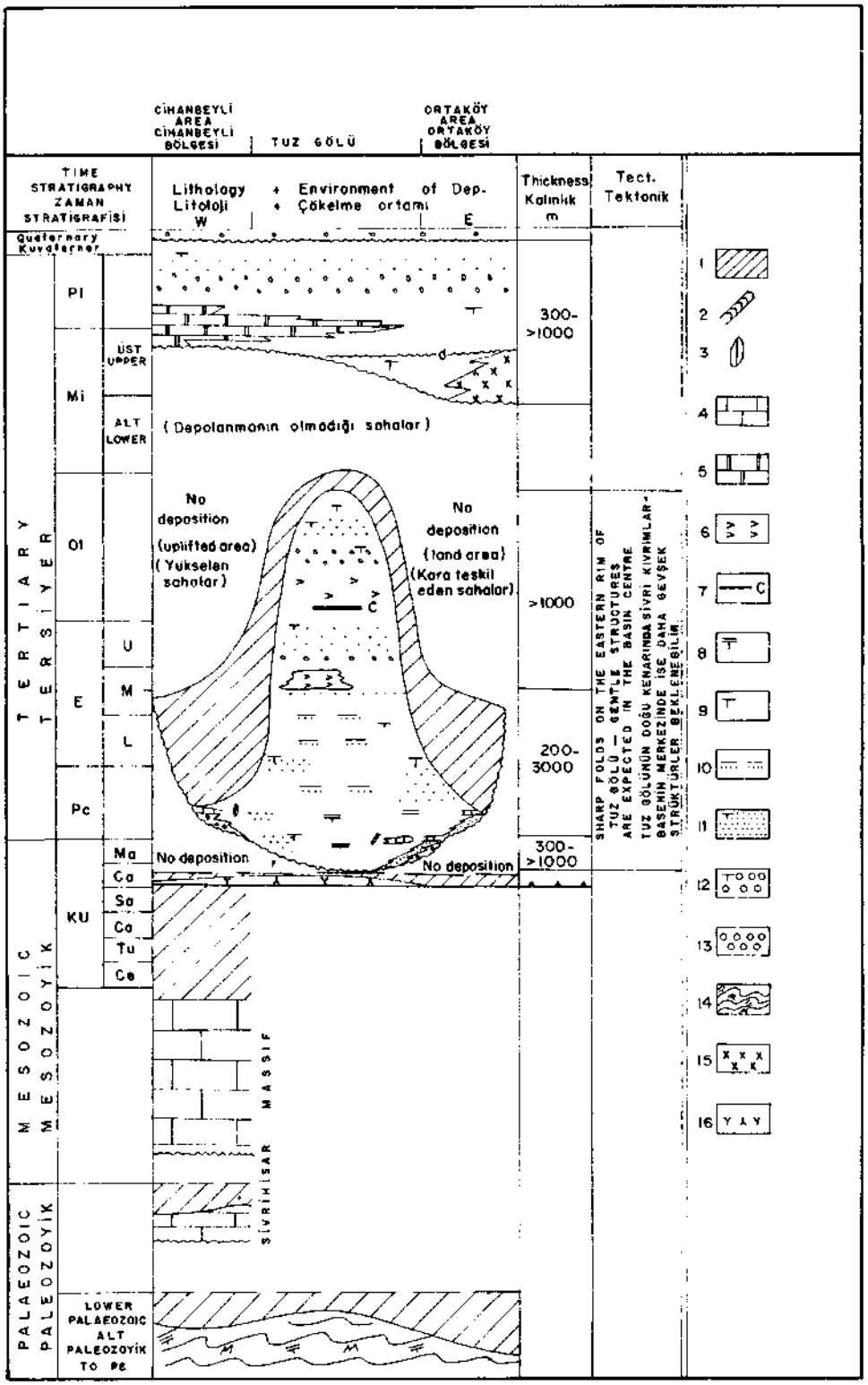


(For location, see Pl. II)

Lokasyon haritası için levha II'ye bkz.

STRATIGRAPHIC SYNOPSIS I, CENTRAL ANATOLIA

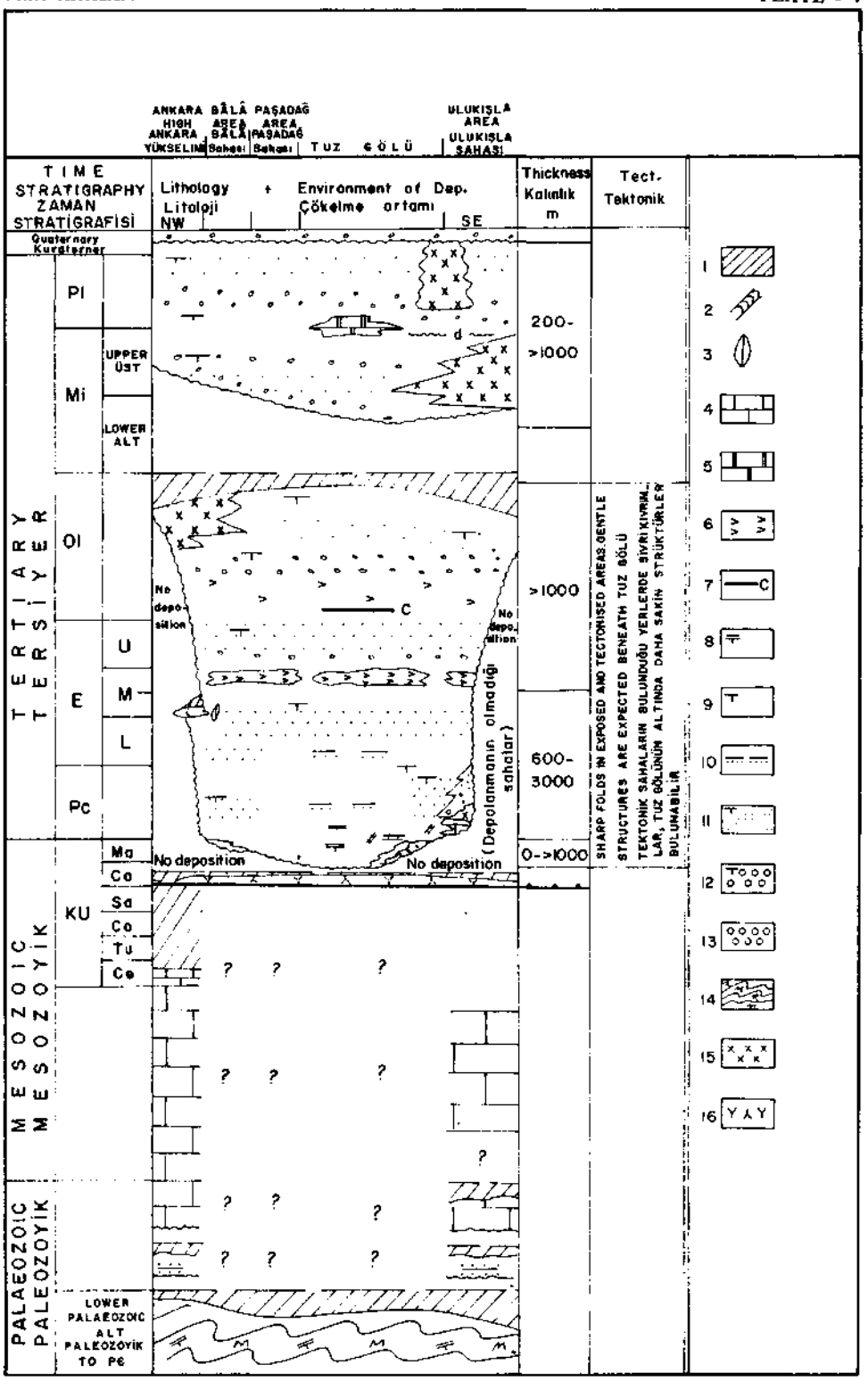
1 - Area of erosion; 2 - Algae; 3 - Foraminifera; 4 - Limestones: 5 - Lacustrine limestones; 6 - Gypsum; 7 - Coal; 8 - Shales; 9 - Claystones; 10 - Turbiditic sandstones; 11 - Sandstones; 12 - Conglomerates; 13 - Gravels; 14 - Metamorphics; 15 - Volcanics; 16 - Ophiolite suite.



(For location, see Pl. I)
Lokasyon haritası için levha I'ye bkz.

STRATIGRAPIC SYNOPSIS II, CENTRAL ANATOLIA

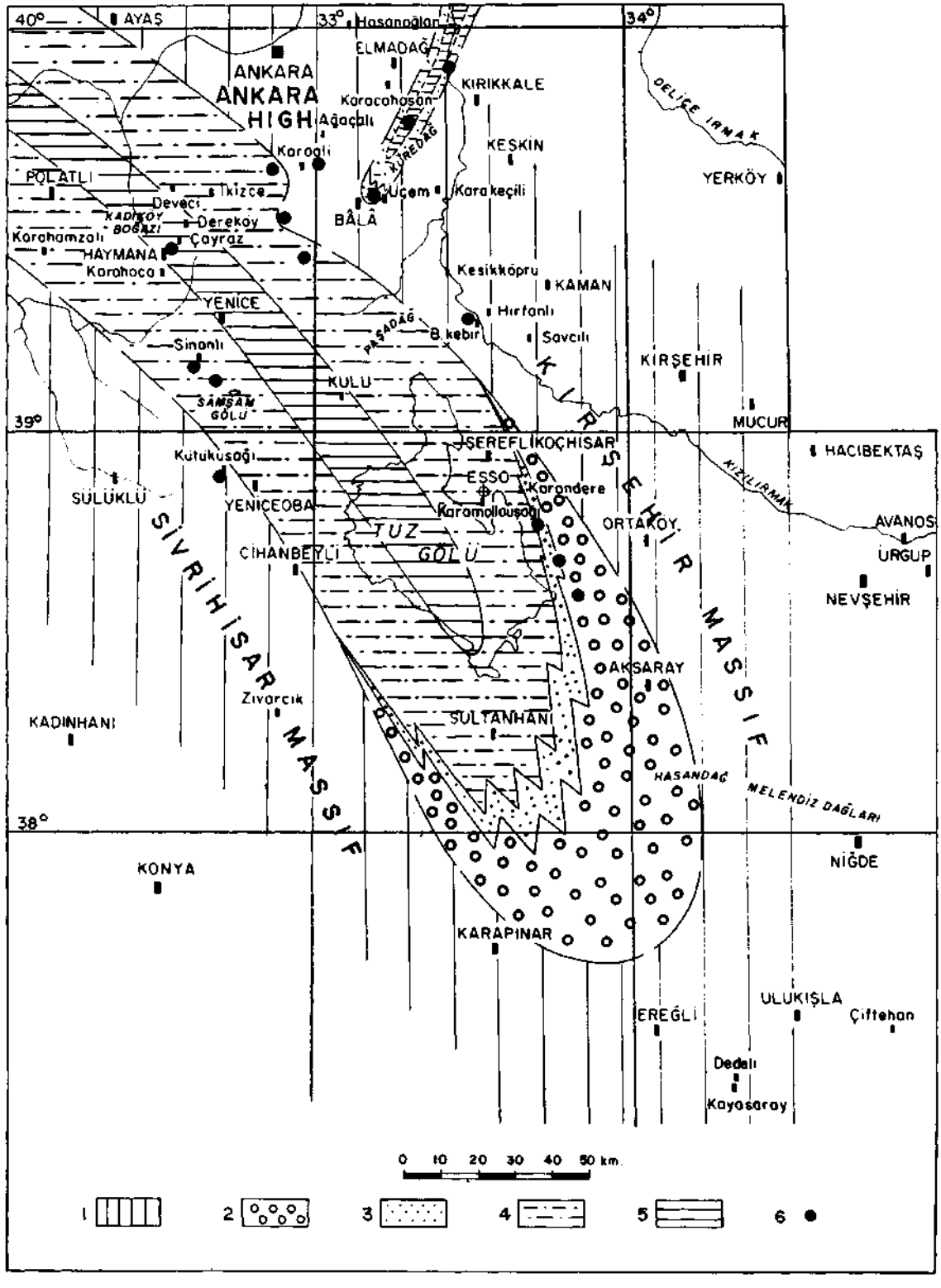
1 - Area of erosion; 2 - Algae; 3 - Foraminifera; 4 - Limestones: 5 - Lacustrine limestones; 6 - Gypsum; 7 - Coal; 8 - Shales; 9 - Claystones; 10 - Turbiditic sandstones; 11 - Sandstones; 12 - Conglomerates; 13 - Gravels; 14 - Metamorphics; 15 - Volcanics; 16 - Ophiolite suite.



(For location, see Pl II)
Lokasyon haritası için levha II ye bkz.

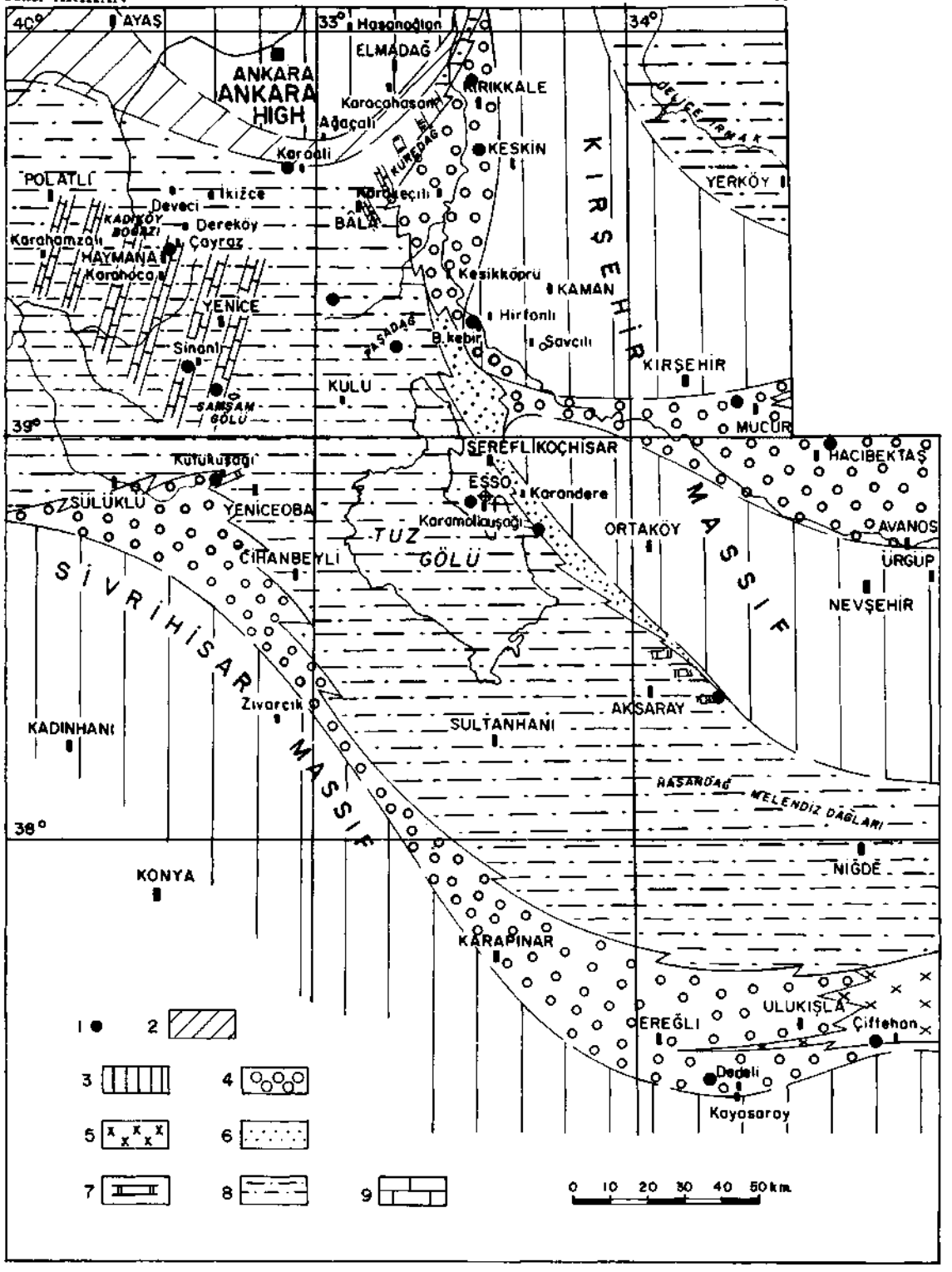
STRATIGRAPHIC SYNOPSIS III, CENTRAL ANATOLIA

1 - Area of erosion; 2 - Algae; 3 - Foraminifera; 4 - Limestones: 5 - Lacustrine limestones; 6 - Gypsum; 7 - Coal; 8 - Shales; 9 - Claystones; 10 - Turbiditic sandstones; 11 - Sandstones; 12 - Conglomerates; 13 - Gravels; 14 - Metamorphics; 15 - Volcanics; 16 - Ophiolite suite.



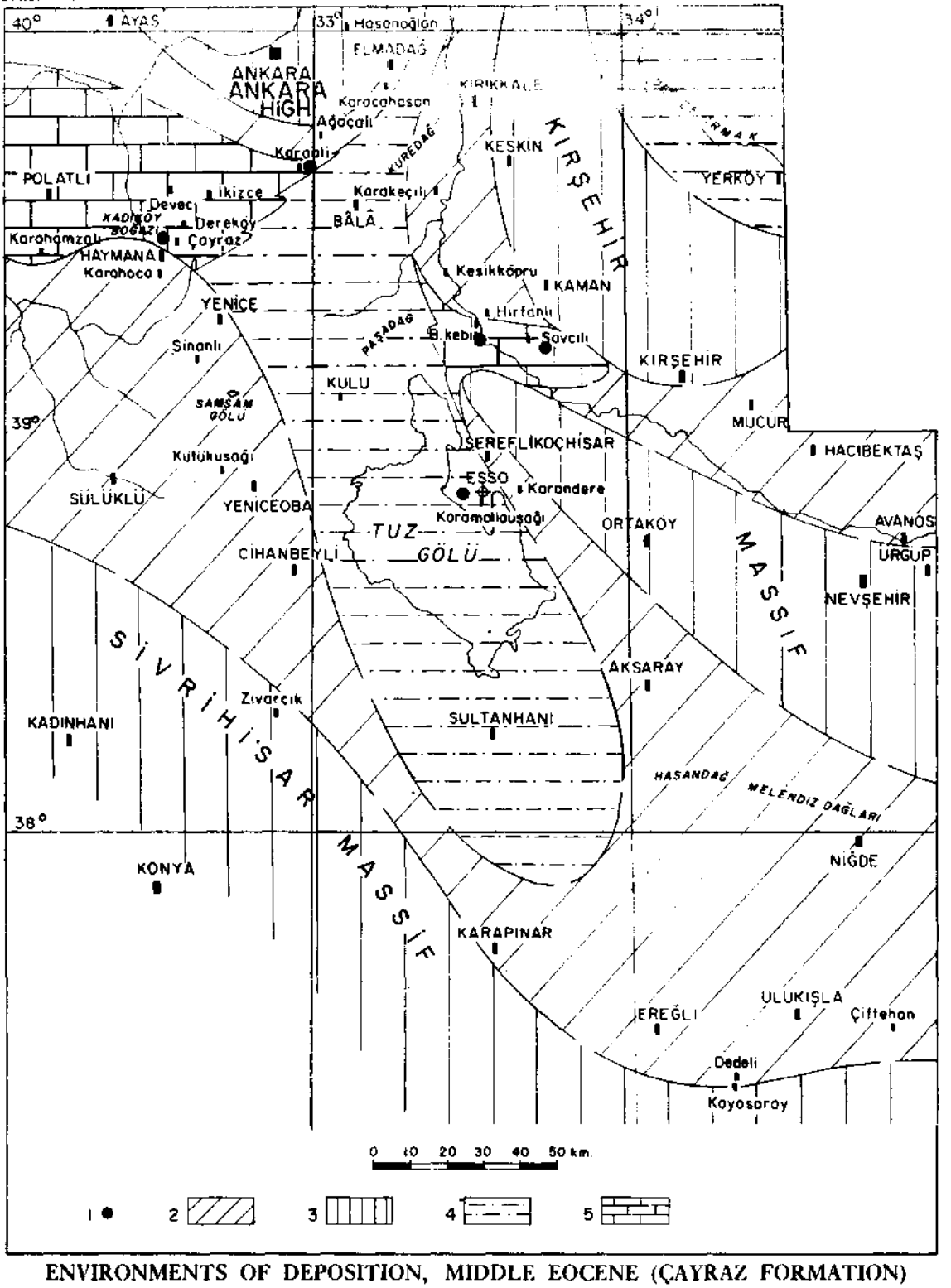
ENVIRONMENTS OF DEPOSITION, POST-OPHIOLITIC UPPER CRETACEOUS (HAYMANA FORMATION)

1 - Area of no deposition; 2 - Continental; 3 - Coastal; 4 - Shallow marine; 5 - Deeper marine; 6 - Control points.



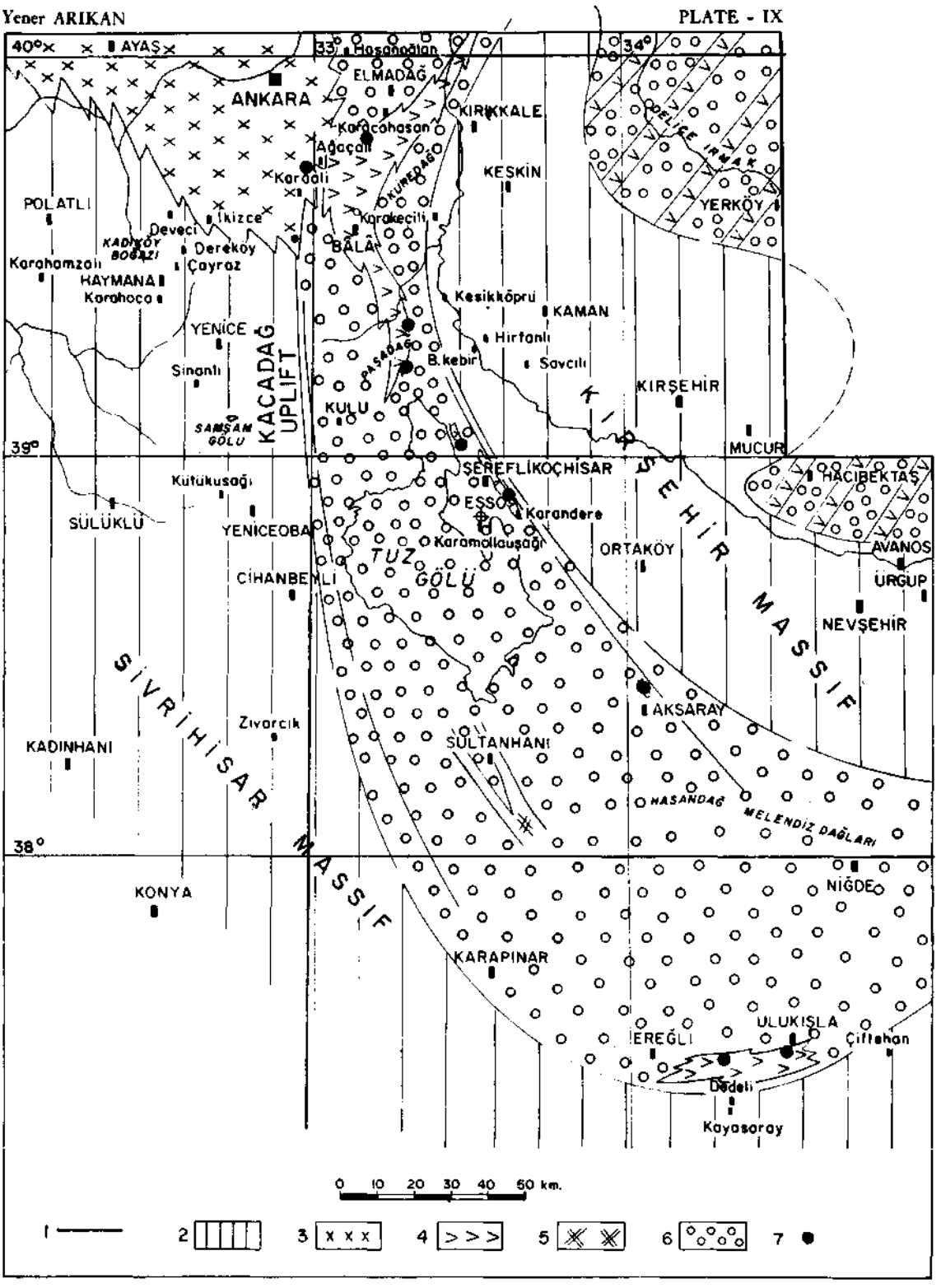
ENVIRONMENTS OF DEPOSITION, PALEOCENE - LOWER EOCENE (KÜREDAĞ FORMATION, INCLUDING ALGAL LIMESTONE)

1 - Control points; 2 - Area of erosion, 3 - Area of no deposition; 4 - Continental sediments; 5 - Continental volcanics; 6 - Coastal sediments; 7 - Restricted shelf limestones; 8 - Shallow marine sediments; 9 - Shallow open marine limestones.



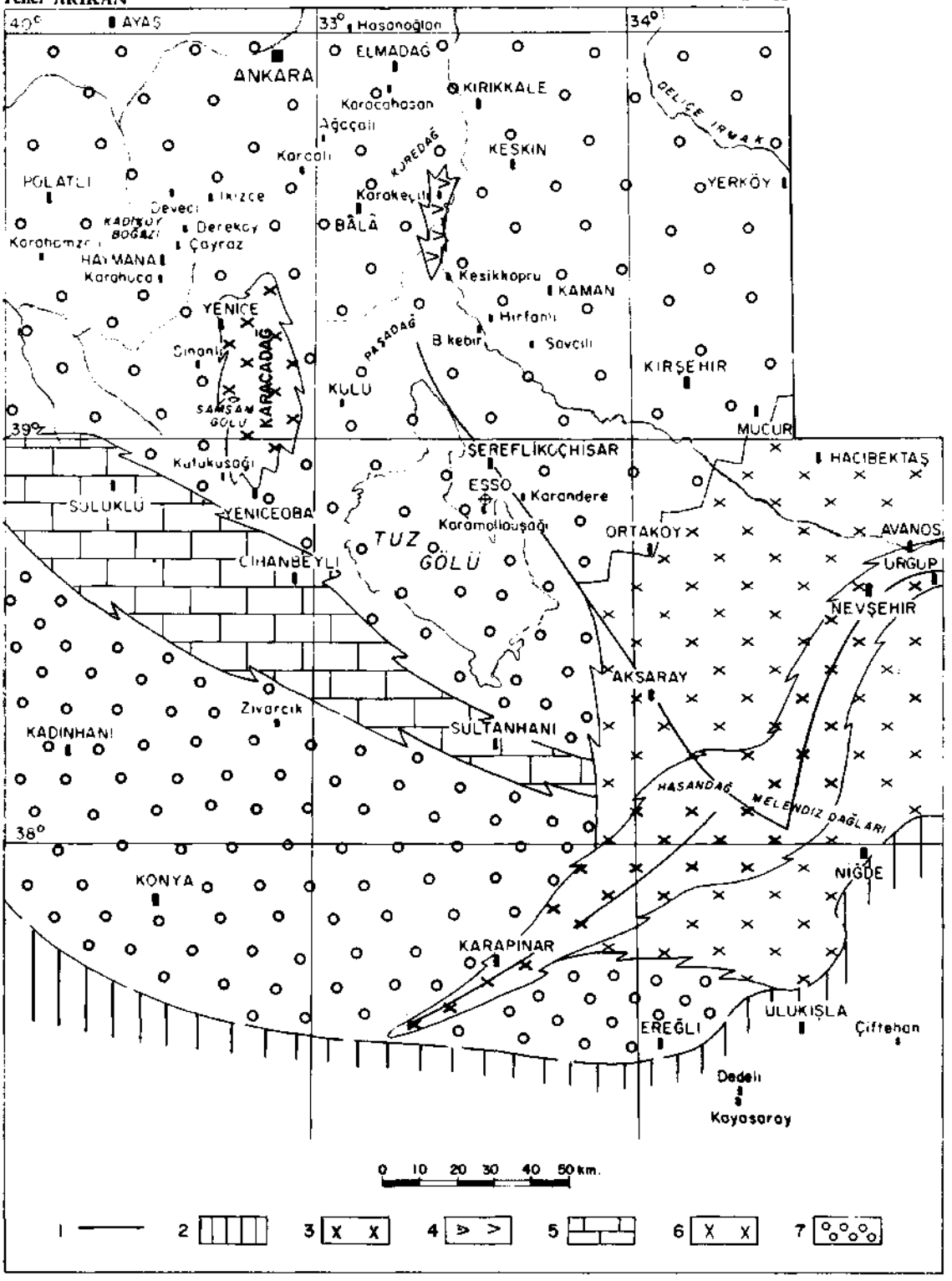
ENVIRONMENTS OF DEPOSITION, MIDDLE EOCENE (ÇAYRAZ FORMATION)

1 - Control points; 2 - Area of erosion; 3 - Area of no deposition; 4 - Shallow marine sediments; 5 - Shallow open marine limestones.



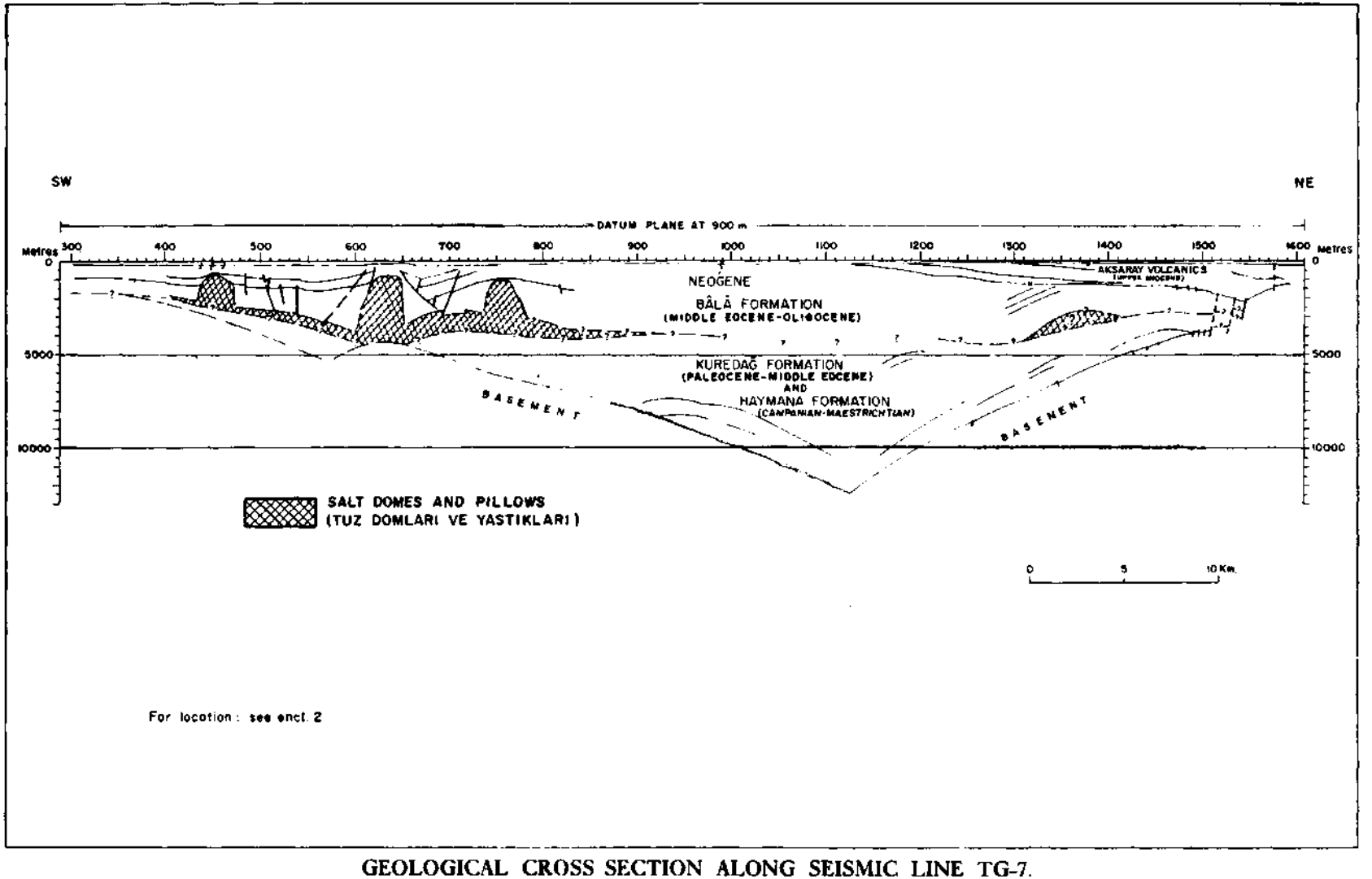
ENVIRONMENTS OF DEPOSITION, MIDDLE EOCENE-OLIGOCENE
(BÂLÂ FORMATION)

1 - Fault trends; 2 - Area of no deposition; 3 - Volcanics; 4 - Gypsum; 5 - Interpreted diapiric evaporites; 6 - Continental clastics; 7 - Control points.



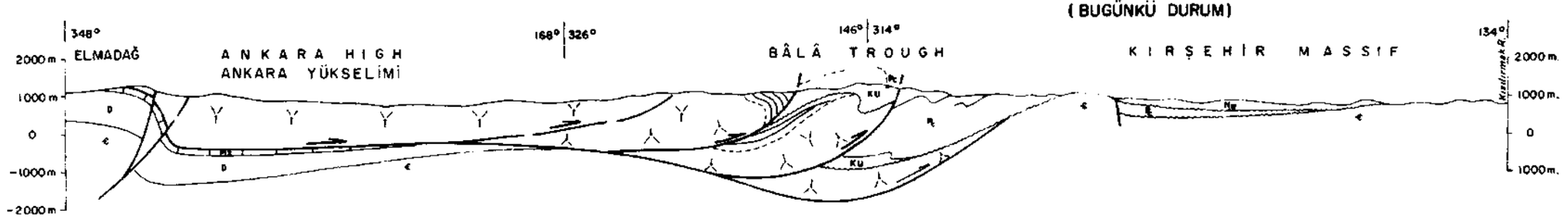
ENVIRONMENTS OF DEPOSITION, NEOGENE (INCLUDING PLEISTOCENE)

1 - Fault trends; 2 - Areas of no deposition; 3 - Karacadağ and Hasandağ volcanics; 4 - Gypsum: 5 - Lacustrine limestones; 6 - Aksaray volcanics; 7 - Continental clastics.

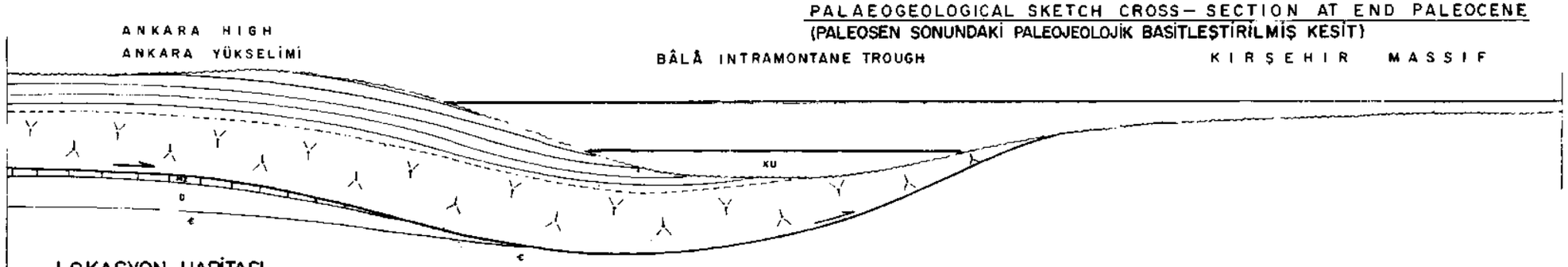


GEOLOGICAL CROSS SECTION ALONG SEISMIC LINE TG-7.

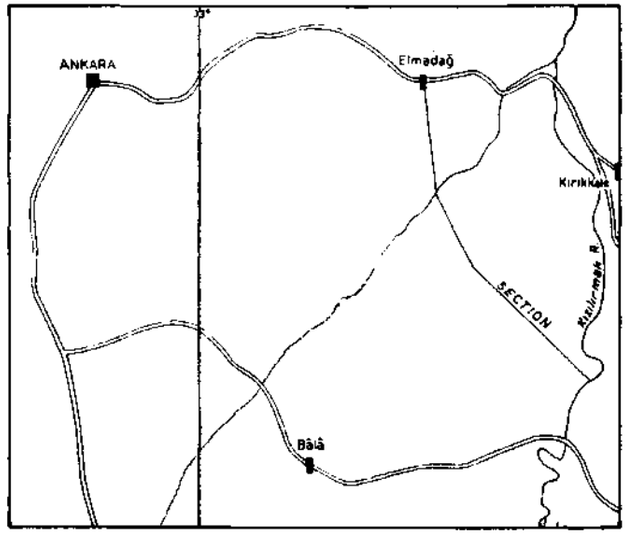
PRESENT DAY CROSS-SECTION
(BUGÜNKÜ DURUM)



PALAEOGEOLOGICAL SKETCH CROSS-SECTION AT END PALEOCENE
(PALEOSEN SONUNDAKİ PALEOJEOLOJİK BASİTLEŞTİRİLMİŞ KESİT)



LOKASYON HARİTASI
LOCATION MAP



0 5 10 15 20 25 Km.

0 1 2 3 4 5 Km.

LEGEND

1 Ng — Neogene;
2 Pc — Küredağ Fm. (Paleocene)
3 KU — Haymana F'm. (uppermost Maestrichtian);
4 — Ophiolites and associated sediments;
5 Mz — Mesozoic Limestone Group;
6 D — Dikmen graywacke (Upper Devonian);
7 € — Lower Paleozoic (Cambrian?).

STRUCTURAL CROSS SECTION. BÂLÂ AREA

SCHMIDT, G.C. (1960): Geologic evaluation of licences MEM/360-363 and MES/365-367 District II. *Mobil Report Petroleum Administration.*

TAŞMAN, C.E. (1950): Türkiye'deki bitümlü tezahürlerin stratigrafik yayımı. *M.T.A. Mecm.,* no. 15/40, Ankara.

TROMP, S.W. (1942): Geological observations in the areas between Niğde-İncesu, Kızılırmak and Tuz Gölü. *M.T.A. Rep.,* no. 1456 (unpublished).

TURKSH GULF OIL CO. (1961): Regional geology and oil exploration in the Tuz Gölü Basin of Central Anatolia. *Petr. Adm. Publications Bull.* no. 6.

TÜRKÜNAL, M. (1958): Note on some Lower Cretaceous Ammonites from Karalar Köyü, northwest of Ankara. *M.T.A. Bull.,* no. 50, Ankara.

UĞURTAŞ, G. (1975): Geophysical interpretation of part of the Tuz Gölü Basin. *M.T.A. Bull.,* no. 85, Ankara.

WIJKERSLOOTH, P. de (1941): Einiges über den Magmatismus des jüngeren Palaeozoikums (des Varistikums) im Raume West-Zentral-Anatoliens. *M.T.A. Mecm.,* no. 4/25, Ankara.

YALÇINLAR, İ. & İZBIRAK, R. (1951): Les vertebres du Miocene superieur au Nord de Kayseri (Turquie). *Bull. Geol. Soc. Turkey,* vol. III, no. 1, Ankara.