

A GENERAL REVIEW OF THE GEOLOGY OF TURKEY

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I. INTRODUCTION :

Since the publication of the book «Geology of Turkey» (Türkiye Jeolojisi) by Dr. N. EGERAN and Dr. E. LAHN in 1948, there has been no detailed publication on the general stratigraphy of Turkey. Most of the later publications are confined to detailed studies of various regions.

We have compiled various data in a very general manner, together with those that have come out since 1948, to introduce before the sessions of the «Symposium on Applied Geology in the Middle East», held on Nov. 14, 1955 in Ankara. However, we were not able to read it in detail and had opportunity only to show some geological maps.

For this reason we have decided to publish this documentary compilation in the present bulletin.

We have given just a few references, since it is impossible to give here the names of all books and papers published to this day.

II GEOGRAPHIC POSITION :

In general, Turkey consists of longitudinal mountain ranges, extending along the Black Sea and the Mediterranean shores, and of the high Anatolian plateaus between these ranges.

The littoral mountain ranges have formed large orogenous folded belts. Practically up to the Upper Cretaceous,

these belts show common features, and their features vary as of the Tertiary.

The depressions and culminations on the axis of these longitudinal belts are crossing transversals, particularly in the N. - S. direction of Anatolia (the Çanakkale - Menderes transversal, the Antalya transversal, the Istanbul transversal, the Tuzgölü transversal, the Kızılırmak transversal, the Malatya transversal and the Van transversal) (32).

The Central Anatolian orogenous complex, situated between the Pontides folded belts in the north and the Taurides folded belts in the south, has formed important units in Central Anatolia.

With the exception of Ağrı Dağı (Mt. Ararat) in Eastern Anatolia, reaching an elevation of 5,165 meters, all the other mountain ranges vary between 3,000-4,500 meters in height.

III. STRATIGRAPHY :

1 - Old Substratum

The oldest formation known in Turkey, determined by means of fossils, is the Cambrian, which is found on Mazi Dağı, in the vicinity of the town of Mardin, district of Derik, in South-eastern Anatolia. The old strata of this region is exposed under the Upper Cretaceous limestones through a fault.

This series is, from the bottom to the top, as follows (40) :

- Red, brown quartz - porphyry
- Dark-red sandstone
- Conglomerate and sandstone with volcanic elements
- Red, clayey sandstone
- Dark-grey, massive limestone
- Conglomerate and fine sandstone
- Metamorphosed limestone and dolomite
- Schist, schistose sandstone, glauconitic schist

In sandstones, constituting the uppermost levels of this series, *Trilobites* have been found. These belong to the Lower and Middle Cambrian, and the series with volcanic elements beneath are Algonkian.

Leaving aside this oldest fossil-bearing strata, the old substratum in the other regions of Turkey is the crystalline schist series which has undergone metamorphism.

Many authors maintain that the Thracian Block in Thrace (the old strata of the Rodop, Istranca, Ergene, Çatalca massifs) is a continuation of the Anatolian Block. These crystalline schist series are encountered in places at Uludağ, in the region of Kütahya-Balıkesir and south of Çanakkale, at the Menderes massif, in Central Anatolia, and even continue towards east.

The Istranca massif, forming the principal heights of the Thracian Block, consists of gneiss, mica-schist, quartzite, phyllite and marble. The gneiss is the core of the massif, which is covered in the north by more metamorphic rocks and in the south by Tertiary formations. This massif is crossed in many places by a granitic batholith and by aplite veins. The gneiss is frequently alternating with mica - schists;

sometimes chalco-schists and now and then quartz veins are found. The marbles form the uppermost part of the metamorphic series; granitic contacts are clearly observed in these marbles. The crystalline schist gravels of the Istranca massif form the elements of the basal conglomerate of the Istanbul Silurian, which proves that the age of the massif is older than the Silurian (16).

The metamorphic series located at Eskişehir, Kütahya -Balıkesir, in the south of Çanakkale, at Kazdağ and at Uludağ (Bursa), are crossed by granitic plutons and other intrusions. The granites are in contact with marbles on one side and with gneiss and amphibolites on the other; particularly at the marble contacts large skarn and scheelite occurrences are found. The granitic intrusion has taken place during the last stage of the crystalline schist folding. These series are found towards the north, in Kapıdağı and the isles of Marmara (22).

On the other hand, the old crystalline schist formations) which continue towards the east from the Pontides and which constitute practically the core of the principal range, have been also crossed by chloritic schists, basic and acidic intrusions. Of these formations, the Tokat - Yıldızeli granites have an economic value.

Speaking of the old substratum, the Menderes Massif in Western Anatolia is worth mentioning. This massif has undergone strong metamorphism and contains various gneiss, mica-schists, quartzites, marbles, phyllites, amphibolites and chalco-schists. Phyllites and marbles form the upper part of this series. The eastern extensions of the massif are covered by the Central Anatolian Neogene and the northern and southern parts by Paleozoic and Mesozoic formations.

This old massif, which plunges under the Taurides beyond the Muğla district, reappears now and then and constitutes the core of the sedimentary strata along the Taurus Mountains. Finally, it forms towards east the Niğde Complex in the foreland of the Taurides. The old Kırşehir or Kızılırmak massif, covering large areas north of this complex, is a continuation of the same complex to the north.

The Kırşehir massif consists of gneiss, mica-schist, quartzite, phyllites and marbles, also strongly metamorphosed. Since the acidic and basic intrusions are intermixed here, it is not possible to see everywhere which intrusion is older than the other. However, during recent surveys (Dr. BUCHARDT, 1953-1954), the contact influences of the acidic intrusions on the radiolarite, greenstone and plaquetted limestone complex have been observed. It is presumed that these plaquetted limestones, containing *Globo truncana*, and the acidic intrusions have taken place after the Maestrichtian and before the Eocene. Very rich scheelite occurrences have been observed in the large skarn bands, formed at the contact points of the marbles with acidic intrusions. Furthermore, the fluorite veins, related mostly to syenites, give unique radioactive evidences of the area.

Metamorphic series constitute the principal substratum of the Bitlis massif, south of the Lake Van, in Eastern Anatolia. Here, also, are found various gneisses, amphibolites and mica-schists. Quartzites are alternating in these series. Marbles are also found in the upper levels.

2 - Silurian

The Silurian strata in Istanbul, at Pendik, on Sedef Island and to the east of Çengelköy cover a large area

towards the east. This Silurian is generally comprised of conglomerate, sandstone, arkosic and mainly quartzitic series. According to recent surveys, *Graptolites* have been found in the black schists, constituting the lower levels of these series in the eastern creeks of Çengelköy (47).

In the Zonguldak basin and southeast of Ereğli, there exist the Graptolite-bearing Silurian strata. The strata consist of marly schists, phyllites and dark-red sandstones (11; 40).

The black schists and the siliceous schists beneath the Mesozoic strata, west of Muğla in Southern Anatolia, are considered to be of Silurian age. There is much resemblance between these schists and the fossiliferous Silurian strata of the Istandaköy Island.

From the Taurus range as far as Adana no definite fossil-bearing Silurian is observed. However, during recent surveys, Graptolite-bearing Silurian formation has been established along the Kozan - Saimbeyli road, north of Adana. This graptolitic series found in dark-grey, black schists, lies unconformably, especially under the Devonian and the Permo - Carboniferous strata (48). The fossil-bearing black schists of the Silurian continue to the north as far as Pınarbaşı (18). On the other hand, it has been known for some time that the greyish-grey, black, thick, micaceous sandstones, quartz, and schists, located between Fevzipaşa and Bahçe, are Silurian.

3 — Devonian

The Devonian covers quite an extensive area in Turkey. The Devonian sea has flooded almost the whole of the country, turning the old massifs into islands.

The Devonian covers large areas in the Istanbul region. The Lower Devonian consists mostly of quartzites, limestones and secondarily of graywacke and schists; the Middle Devonian, of nodular limestones and of siliceous schists; and the Upper Devonian, of alternating clayey schists, graywacke and conglomerates. The Upper Devonian schists, so far named as the Thrace series, have been considered as Carboniferous, according to the recent surveys (46).

The Devonian of Istanbul extends to Şile, Adapazarı, Karadeniz Ereğlisi, Bartın, Kastamonu and further east and shows similar facies in parts.

At Bartın, the Devonian is important because it has three layers which can be clearly distinguished. The Lower Devonian starts with red, brown sandstone - schists. Higher up, come quartzites with dark-grey limestones, which are abundant in fossils. The Middle Devonian consists of the crystallized and dolomitic limestones, dark or light-coloured; and the Upper Devonian comprises a thick limestone series containing many fossil fragments, between the Middle Devonian and the Carboniferous (44).

In Western Anatolia, the Devonian is found near Izmir, at Karaburun, and on the island of Chios; it consists of alternations of arkose, graywacke, schist and limestone. In the south, there exist certain Paleozoic schists, encircling the Menderes massif, but no fossils could be found there. These schists are considered to be Silurian or Devonian. These formations are dark schists or siliceous schists, west of Muğla, and towards the west, from Marmaris to Reşadiye, in the sliced zone, they are grey, yellowish, sandy schists and clayey limestones (20).

Towards the east, in the Taurus range, the *Brachiopod*, *Polyp-bearing* strata in the shore-line formations of the Alanya massif belong to the Upper Devonian. These Devonian strata, abundant in fossils and almost resembling each other, continue to the east in the depressions and culminations of the Taurus mountains. Two thirds of the Paleozoic formations outcropping on the Taurus belts are Devonian in age and belong mostly to the Upper Devonian. These formations alternate with bluish-grey or light - coloured limestones, bluish-black, calcareous schists, marly schists and sandstones (6, 8). These series extend to the Malatya massif, between the main crystalline basement schists and Graptolitic schists, and the Permo - Carboniferous formations.

In the east, on the Bitlis massif, no Devonian could be observed; whereas there exist fossil-bearing Lower and Middle Devonian formations consisting of clay, marl and sandy limestones and sandstones on the Hacertum Dağı, at Hazru, northeast of, Diyarbakır. In the middle parts of this series there are thin, bituminous sandstones and these are the only formations bearing hydrocarbons on the lower levels of Paleozoic in the Southeastern Anatolia (39, 41).

Further east, in the Hakkari region, the dark - brown, fossil-bearing, marly schists, superimposed on quartzites and phyllites, are Devonian in age (45). To the north, there exist Devonian outcrops south of the Büyük Ağı Dağı.

4 — Permo-Carboniferous

The Permo - Carboniferous formations are rather extensive in Turkey. In Northern Anatolia these formations are terrestrial and marine in the Zonguldak basin, and generally marine in the southern Taurus region.

The Carboniferous of the Ereğli-Zonguldak basin plays an important part in the economy of Turkey, from the point of view of the fuel supply, and hence this basin has been studied in great detail by the Carboniferous Services of the Mineral Research and Exploration Institute of Turkey. We shall mention this basin very briefly here.

The Lower Carboniferous in Zonguldak, as everywhere else, is of the marine facies, whereas the Upper Carboniferous bears coal and is terrestrial. The dolomitic limestone bearing *Productids*, *Syringopora* and *Lithostroton* in the Zonguldak basin are Visean in age. The existence of Tournaisian between the Devonian and the Visean is doubtful. The Visean limestones extend nearly as far as Amasra.

Of the coal-bearing formations, which are designated by their local names, the Alacağzı formation consists of clayey and sandy shales; the Kozlu formation of alternation of conglomerates and hard sandstones; and the Karadon formation mainly of conglomerates with sandstones and refractory clay.

The principal coal-yielding strata of this region lie between Çamlı - Kandilli - Zonguldak - Kilimli - Gelik and these formations extend partly as far as Amasra (43, 44).

The Permian is seen only as a thin layer overlying the Carboniferous series at the Ereğli - Amasra district.

In the district of Ankara there are also Permo - Carboniferous formations between Elma Dağı and Haymana. The Permo - Carboniferous deposits, in many outcrops, consist of light, dark, detritic or sometimes compact limestones bearing *Fusulinids* and in the neighbourhood of Yalıncağ, southwest of Ankara, there exist Visean lime-

stones bearing *Productids*. among thin, black limestone bands, conglomerates and sandstones, lying under limestones, whose age is probably Triassic (9).

In the northeast, the dark limestones, bearing *Fusulinids* and *Corals* west of Kargı, which overlie the crystalline schists and amphibolites forming the main core of the Ilgaz Mountains, belong to the Permo - Carboniferous. Further east, towards the Tokat Mountains, Permian limestones are found scattered at isolated places. From here as far as Bayburt, the Permo-Carboniferous strata, which cannot be properly determined, attain a great thickness (up to 1500 meters). Here, the dark-grey limestone banks, rich in *Fusulinids*, *Corals*, and *Spirifer* fossils, together with pinkish-red sandstone, arkose and quartzites, are found (25).

According to the recent surveys carried out at Cebeciköy, near İstanbul, many fossils have been found in the blue limestones identifying the Visean. Since these limestones are below the Thracian schists of the Devonian age, these clayey schists must also belong to the Permo-Carboniferous, if the new theories prove to be true (46).

The bluish or blackish sandstones, marbles and limestones, abundant in fauna in the southern shore - line of the Marmara Sea, at Dursunbey between Bursa and Gemlik, and at Balya, are of Carboniferous or Permian age. Further south, in the vicinity of Soma, *Fusulinids* have been found in the limestones between phyllites and schists. These limestones extend, further south, as far as the gulf of Çandarlı. Apart from these, there is a sandstone, schist, limestone, conglomerate series, abundant in *Fusulinids*, overlaying unconformably the Devonian at Karaburun, İzmir; this series is compared with the Carboniferous of the island of Chios.

Further south, on the western extremity of the Taurus ranges, the Permian near Muğla consists of black plaquetted limestones. Here, no Carboniferous could be detected. These Permian limestones extend towards the east as far as Fethiye.

Further east, the Permo - Carboniferous covers a wide area in the Taurus ranges, extending as far as Malatya. While the Mesozoic formations extend over wide areas on one side of the Taurus Mountains, schist and sandstone series, containing important limestones of Permian age, continue far away in the form of complexes.

In the littoral formations of the Alanya massif, the marmorized, bluish Permian limestones abound in *Fusulinids*. Usually it is not possible to distinguish between the Carboniferous and the Permian formation in this region.

The highest orographic peak of the eastern Taurus is Aladağ (3,700 meters). The northern part of this mountain, the Black Aladağ, is Carboniferous and shows milder morphological lines; whereas the southern part, the White Aladağ, belongs to the Cretaceous (5,6,8).

The Permo - Carboniferous of the Kayseri - Malatya region is a dark-blue, often blackish limestone formation. In these limestones are found calcareous, marly schist layers containing thin layers of sandstones, or mostly bitumen. A major part of the southern mountains of Malatya consist of grey limestones, all belonging to the Permo - Carboniferous age.

In the east, on the Bitlis massif, Permian limestones are observed lying unconformably over the old substratum of crystalline schists. Furthermore, the Permian is found overlying the lacust-

rine. Carboniferous at Hazru, in the northeast of Diyarbakır, and consists of ferruginous, hard, yellow greenish quartzitic sandstones and limestones (38, 41).

The Carboniferous at Hakkari starts with a light-yellow, thin marl, overlain by dark limestones which contain many fossils. Tanin Dağı, situated in this region, is of Permo - Carboniferous age, and these are referred to as Tanintanin formations in the literature (2, 45).

5 - Mesozoic

The Mesozoic in Turkey begins with the Triassic transgression and is spread over extensive areas. Since the series in some of the limestone facies belonging to Mesozoic cannot be distinguished from one another, they are considered as «Comprehensive Series»; however, in these series containing the Triassic, the Jurassic and the Cretaceous, the Cretaceous limestones are more predominant.

In these massive limestones sometimes plaquetted series and sometimes, on lower levels, dolomitic, radiolaritic and siliceous series and even marmorized limestones are found, which constitute important horizon landmarks.

Apart from these, there exists the greenstone complex, which is widespread in Anatolia and which we include in the Mesozoic. This is a complex made up of acidic and basic intrusions, spilites, diabase, serpentized rocks, peridotites, radiolarites, clayey schists, sandstones and lenticular or seam limestones. Usually Rosalines are found in the limestones of this series. Likewise in this series the serpentines contain rich chrome bedding.

Quite a lot of discussions have been made concerning the age of the

comprehensive series and the greenstone complexes. Even today this question has not been quite settled. Certain authors claim that the greenstones begin with the Paleozoic, particularly in the southwest, and some others consider that they begin with the Triassic or the Jurassic in the Taurus Mountains, and still others assert that they begin with Lower Cretaceous or Upper Cretaceous, and many others are of the opinion that they are, generally speaking, Mesozoic in age.

Kocaeli-Şile District; the Kocaeli Triassic is in transgression with the Silurian and Devonian layers, situated in the west, where the Lower and Middle Triassic exists. At the base it is conglomeratic, and contains, from the bottom upwards, red sandstones, grey massive limestones, nodular limestones and lignitiferous clayey schists with intercalations of plaquetted limestones. These plaquetted limestones are yellow externally and when broken are blue-black in colour. The grey limestones are Werfenian, the plaquetted ones Ladinian and the nodular limestones are probably Virglorian (4).

Werfenian formation, found in Şile, is also present in Gebze. However, while in Şile the Virglorian contains nodular limestones, in Gebze massive and coral-bearing limestones are found in the same formation. The Upper Triassic is not found in Gebze (3).

In this region the Cretaceous appears above the Triassic. There is no Jurassic. The Cretaceous begins with grey conglomerates and is represented, upwards, by flysch, marl series, intercalated with limestones, and white limestones. The flysch is Turonian or earlier in age; it is intercalated with tuffs. Towards the upper parts it passes to a coarser flysch, where sandstones and microfossils abound. Some macro-

fossils, collected in this formation, have been determined as : *Micraster, Alecrionia, Cyclolites, Hippurites* etc.. (3).

The calcareous marl series passes in the upper parts, to tuffaceous sands. This series is considered to belong to the Upper Campanian, as it lies between the Turonian - Lower Campanian flysch and the Maestrichtian limestones.

As for the white limestones, at the uppermost level, these are found over or buried in the Eocene marls in the Şile district. These series become thicker in the Agva Creek, towards the east. *Echinoeorys, Coraster, Inoceramus, Hippurites* etc. are found in these white limestones (3).

The Cretaceous formation of Sarıyer and Zekeriya Köy, near İstanbul, consists of massive, calcareous, dacitic lava, tuff, marl and conglomerate intercalations (9).

The Mesozoic formations of Ereğli, Zonguldak and Bartın region constitute the roof of the productive Carboniferous. The Triassic and Jurassic have not been found here until present time. Thus, the Mesozoic in this area starts with the Lower Cretaceous overlying unconformably (with a basal conglomerate) the Carboniferous and the Permian. Higher up, until Senomanian, these basal conglomerates are followed by massive limestones, Velibey sandstones, sandstone and marl series and finally by Wild-Flysch horizons. Volcanic rocks, that are first observed in the Turonian, are found together with marls, radiolarites, flysch and marly limestones. Then, the agglomerate-tuff series are followed by a flysch which is an alternation of marly and bedded limestones. Thus the stratigraphic cycle is completed up to the Maestrichtian or probably the Danian. The geological sections of all the Cretaceous

formations in this area have been determined in detail by Dr. M.TOKAY (43,44).

The Mesozoic in the Çankırı-Kızılirmak region is generally in the form of a complex facies and is widespread, the Cretaceous being predominant. The enormous andesitic masses of the Senonian (the Galatia massif) are overlying these beds.

The Triassic - Jurassic formation cannot be observed between the Paleozoic massif of Bolu and the Cretaceous, and the latter is represented mainly by limestones and eastwards by flysches. In this region the Upper Cretaceous is better recognized than the other levels of the Mesozoic. Further east, towards Mengen, the limestones and the dark - coloured schists, as a whole, are supposed, with some reserve, to be Triassic. Here the Cretaceous consists of the radiolaritic series or schistous limestones. At Kabalı Dağ, Çerkeş, the Lower and Upper Cretaceous massifs predominate. The presence of the Jurassic is doubtful.

In the northern districts, Karabük - Safranbolu, the Cretaceous is represented by large massifs of the limestone and flysch facies.

Despite the fact that the white marmorized limestones and the Çaldağ massif, in the Mezarlık Tepe district north of the city of Ankara, are assumed to be Permo-Triassic, no fossils could be found to confirm this assumption in surveys conducted recently.

In this district, the Jurassic begins with a base conglomerate, Liassic in age, and continues in an alternation of marls and sandstones (flysch) or with grey limestones and red sandstones. *Ammonites*, *Belemnites* and *Crinoids* are found in ample quantities in these red sandstones which are overlain by a complex series with calcareous sand-

stones and radiolarites. This series belongs to the Upper Liassic. Overlying these layers, appears the Dogger formation containing Ammonites. The Malm is represented by thin-layered limestones which outcrop especially at Yakaçık and the Bosphorus gorge. They are light in colour, now and then pinkish, and contain siliceous fragments. *Aptychus* is abundant in these layers.

In the west, in the Ayaş region, from the north of Eskişehir to the southeast of İznik Lake, Jurassic formations are found in many places.

In the Tokat region, the Mesozoic is Cretaceous and is represented by limestones, marls, sandstones, conglomerates and flysches. Between Ordu and Giresun and on the southern mountains, andesitic lava, tuffs and conglomerates intercalated in these series become predominant; they alternate with flysches, marls and limestones towards the east. The fossils found in the limestones and marls invariably show the Upper Senonian. Along the shore-line in these series, *Inoceramus* is more abundant, whereas the Rudistes are less frequent.

In the Bayburt region, the Mesozoic begins with the Jurassic. The Liassic is represented by black, sandy, oolitic limestones and shows a thickness of 2,000 meters. The Malm is transgressive over the Liassic. The pink-coloured thick-layered limestones form a detritic series with sandstones and conglomerates.

In the same region the Lower Cretaceous, like the Jurassic, is also widespread and is from 2,500 to 3,000 meters thick. The bottom of the Cretaceous formation consists of white plaquetted limestones and marls, and the top of a sandy, conglomeratic, detritic series.

The Upper Cretaceous, in this region, is represented by the greenstone complex series, containing reef (Rudistic) limestones. These limestones have 800 meters of thickness; at the base they are rich in fossils. In the same region an Upper Cretaceous flysch is also present (25).

In places, Jurassic limestone of Bayburt passes laterally into a flysch facies towards the east. Especially south of Yusufeli this flysch facies shows a wide extension. The lower horizons of the Liassic limestones, south of İspir, belong probably to the Upper Triassic, since some micro-organisms are found in the alternating clayey and sandy horizons that show facies changes towards the lower formations.

In the south of Erzincan and in the Tunceli region, the Mesozoic is generally of the Lower Cretaceous age. This formation consists of limestone, serpentine and radiolarite complex. The limestones in this complex are white, grey and pink. It is very likely that the age of this greenstone complex is Lower Cretaceous.

The Upper Cretaceous in this region lies discordantly with a conglomerate over the Lower Cretaceous complex. They are of the flysch and limestone facies. The limestones are reddish-pink, blue and grey in colour, fine-grained, with an abundant micro-fauna. The flysch facies begins with a conglomerate consisting of serpentines and radiolarites, and shows a thickness of 1,800-2,000 meters (24).

In the southern Marmara region, between Gemlik and Bursa, lies the Triassic formation which is represented by the *Halobia* sandstones, micaceous marls, conglomerates and limestones. The Jurassic, widespread on the littoral mountain ranges, between the Man-

yas and Apolyont- Lakes, is of Liassic age and contains Belemnites and Crinoids. Overlying these limestones of the Liassic age are *Phylloceras* - bearing limestones, grey sandstones, marly puddings, flinty and crystallized limestones (1, 17).

The dolomitic limestones lying in the vicinity of Soma are probably Liassic. At Balya, the Triassic is represented by conglomerates, sandstones and, over them, by black schists containing *Halobia*. This is an Upper Triassic formation and it overlies the Permo-Carboniferous.

The age of the grey massive limestones in Kemalpaşa is Cretaceous.

Further south, in the Ege region, the Mesozoic is not extensive; it is in the form of massive and plaquetted limestones, becoming schistous towards the top. In the Izmir region, the Cretaceous is generally represented by flysches, which comprise lenses of limestone with Rudistes, conglomerates, schists and marls.

In the Muğla - Fethiye region, the dark-coloured dolomitic limestones are Triassic in age. In many parts of these limestones fossils have been found. The limestones containing *Diplopora* extend down to the Bodrum harbour. The same Triassic occurs now and then as far as Fethiye.

It is possible that the plaquetted limestones overlying the Triassic formations are Jurassic - Lower Cretaceous in age. At contact points of these plaquetted limestones with large peridotite masses, the limestones contain, here and there, Hornstein levels. These plaquetted limestones pass into flysch facies in the Marmara Island. Occasionally, reef limestones overlie these plaquetted limestones; the former are probably of the Upper Cretaceous age. At

places, under this formation, the Lower Cretaceous and Jurassic is encountered.

In the Beyşehir - Seydişehir - Antalya region, the Triassic is represented by the blackish - blue limestones or the dark-coloured dolomites. Towards the top of this formation, the limestones containing *Diplopora* can be distinguished with some difficulty. These are overlain by alternating series of bluish-black limestones and schists of great thickness; their age is Liassic - Malm. Bituminous limestones recur in this formation group. At places, the black, calcareous schists contain *Posidonomya*, which indicate Liassic age. Further up, the flysch layers alternate with thin-layered limestones. The schistous and bituminous limestones, in which *Exogyra* levels are encountered, belong to Dogger and Malm. These series are overlain by light-coloured, reefy, massive and thick-bedded limestones of neritic facies; the major part of these limestones are Cretaceous. The Lower Cretaceous is not apparent (6).

In these regions, the Mesozoic formations extend in the form of a continuous limestone series («Comprehensive Series») till the Eocene. The pink limestones and schists in these series represent the radiolarite formation. The Cretaceous limestones form the mountains situated between the lakes of Suğla - Beyşehir, and are mainly zoogenic, massive limestones. These limestones, which contain *Rosalina*, are of the Senonian age. The Jurassic - Lower Cretaceous in the Comprehensive Series, in the Akseki district, is in the form of marly limestones, rich in Ammonites-

This «Comprehensive Series» continues without change towards the east as far as Bolkardağ and Aladağ; no clear boundary between the Paleozoic and the Triassic can be noted in the lower levels of the series in these re-

gions. It is probable that the dolomitic series and the light-red limestones are Triassic. However, no sufficient information is available on this subject. Naturally, the presence of the Jurassic is very probable in a formation of such great thickness. The Upper Cretaceous limestones, which have spread in the form of a neritic facies over the marine Permo - Carboniferous, display more clearly the tectonics of this region; these thick limestones overlie a great greenstone mass (8).

In the east of the Bitlis massif the Mesozoic is Maestrichtian in age and is in the flysch facies.

The Triassic series in the Hakkari region is known as the Goyan Formation, which outcrops here and there in the south of Hakkari; the lower levels of this series consist of brown sandstones and limestones. Over these sandstones and limestones are yellowish marly limestones. Cilo Dağı is, generally speaking, Cretaceous. *Rhynchonella* and *Nerinaea* levels are found in the lower parts of this mountain; these levels are probably Upper Jurassic in age (2, 45).

In the southeast of Siirt and south of Hakkari, the Cudi Dağı limestones are in the form of Comprehensive Series; this formation consists of the Mesozoic limestones. The Hakkari Cretaceous limestones are found to be mixed with radiolarites.

At Hazru, the Hacertum Dağı Triassic consists of marly limestones and clays rich in *Pseudomonotis* and *Myophoria*. At the northern flank of this mountain there is a coarse, reddish, dark-grey, sandy, massive limestone, which extends from the Jurassic to the Turonian; in these limestones there are asphalt horizons. The Cretaceous formations covering a wide area overlie

these limestones. During preliminary drilling executed in the oil area and in drilling, the Kentalan wells, the Triassic layers have been encountered. These layers are formed of green, red shale, sandstones and plaquetted limestones, where *Pseudomonotis* and *Myophoria* have been observed (39).

Again in this oil area exists a limestone series, uniform in structure, known as «massive limestone» in the geology of petroleum, and which is Jurassic - Lower Maestrichtian in age. These massive limestones outcrop in the east as well as in the north and also at the Derik Dağı, and are generally dolomitic in structure; they are the only oil reservoir rocks of the area. Their thickness varies between 400 and 1,000 meters and they show invariably a lateral facies alteration. These massive limestones begin with Aptian in the south; however, as we go northward, almost all the stages of the Mesozoic can be observed. Although the ceiling parts of these massive limestones have been assumed to belong to the Lower Senonian, it was discovered during the recent surveys that these limestones go as far as the Lower Maestrichtian (34, 41).

All of these massive limestones are covered by a clayey and sandy soft formation alternating with grey, greenish - grey, thick, marly strata. This formation, which is of the Upper Cretaceous - Paleocene age, is known as the «Germav Formation». Here the Tertiary - Mesozoic boundary is only discernible paleontologically and the thickness varies between 350 and 850 meters. In the Mardin region this formation is named the «Mardin Formation» and is Upper Cretaceous and Paleocene in age. It is the same as the Germav Formation so far as the colours are concerned, but dis-

plays facies changes in the latter formation (42).

Becirman limestones. These limestones are of the Paleocene-Ypresian age and constitute in certain localities the upper boundary of the Germav Formation. Particularly at Hermis, Kerbent, Softak and Espondika, south of the Dicle Nehri (Tigris River), they form, at places, a dolomitic limestone zone, white in colour, close in texture and 10 -110 meters thick, between the Germav Formation and the clastic, Ypresian «Gercüş Formations». These limestones disappear completely in the Raman and Reşan areas. Certain authors consider that these limestones belong to the Middle Eocene, while others attribute them to the Lower Eocene.

6 - Tertiary

The Tertiary is very widespread in Turkey. In many places the Tertiary layers either overlap completely the older formations or remain as islands, where they could not reach the higher regions. In some other localities, as the Cretaceous sea continued also in the Eocene, these two formations have formed a series, the boundary of which cannot be determined. In such places the boundaries are only discernible by fossils.

In Turkey the Eocene begins generally with the Ypresian. These lower levels are mostly sandy, marly series and in the flysch facies. The Lutetian is represented by limestones and the upper parts consist of flysch with conglomeratic and detritic limestones.

The Oligocene is generally terrestrial, with the exception of the Gaziantep region in the southeastern Anatolia and the Thracian region. However, it is possible that some of the flysch and

marly formations in Anatolia are Oligocene. In many of the formations it has not been possible to establish a definite paleontological boundary.

The Neogene sea has followed up certain routes to Anatolia and has flooded partly the eastern, southeastern and southern Anatolia and Thrace.

a - Eocene, Oligocene:

The Eocene in the Istanbul district, and at Küçük Çekmece in particular, advanced up to the skirts of the old Devonian massif in İstanbul and the crystalline Istranca massif and deposited the marly, sandy, thick sediments at the bottom, and the detritic, reef Eocene limestone at the top. The higher levels of the Eocene end with the conglomeratic series, at Terkos, in the north (16).

These Eocene series extend to Kırklareli and further to the west, along the Istranca massif, and continue on the other side as far as south of the Ergene region and north of Gelibolu.

The Oligocene series is of the Priabonian - Sannoisian age and extends in the flysch formation to the north of Tekirdağ, to Malkara and to Ergene. These flysches are in intercalation with thick sandstones, conglomerates and marls. The upper levels of Oligocene consist also of marly series. To the end of the Oligocene the area is a lagunary basin, where lignites have been formed. The deposits overlying them contain a completely mixed fauna (37).

The Eocene in the Şile district consists, from the bottom to the top, of blue marls, grey dense sandstones of the Ypresian age, and of yellow limestones and marls of the Lutetian age (3).

The Ankara district. In the southwest of this district, at Sivrihisar and Polatlı, the Paleocene is known by its fossils, it is represented by the flysch and sandstone, marl facies; whereas in the Haymana district, the flysch begins with the Cretaceous and extends up to the Paleocene.

The nummulitic formations extending towards the east, in the limestone facies, are seen in the Pontides and particularly in the eastern regions in the form of facies intercalated mostly with andesitic tuffs, agglomerates and lava. In the Giresun - Ordu southern mountains their elements are more volcanic, whereas in the Bayburt region they are generally in the flysch facies. They consist of sandstones and conglomerates, 1,600 meters in thickness at the bottom and of limestones, marls and sandstones, 350 - 400 meters thick in the middle and at the top (25).

These formations extend, by displaying facies changes, to the Bitlis massif, south of Monzurlar on one side, and to the Aras basin, to the east of Van and to Hakkari on the other side. In the Northern Anatolia mountains this facies has more or less flysch and volcanic elements, whereas in the south it consists mainly of flysch, sandstones, marls, schists and thin-layered limestones.

In Hakkari, the Nummulitic is formed by the greyish-black, plaquetted or detritic limestones, rich in fauna, at the bottom, and of the flysch, alternating with the black micaceous schist and sandstone at the top; these are 2,000-2,500 meters in thickness. Further up lie the Oligocene sandstones (45).

The Eocene formations continuing in the flysch facies to the south and west of the Bitlis Mountains, undergo lateral facies changes in the Raman and Gaziantep regions.

These formations consist of reddish, clayey sandstone and conglomerates alternating with marly limestones and of shales containing gypsum lenses in the Raman and Reşan basins, south of the Dicle Nehri. These formations, locally known as the «Gercüş Formations», are of the Ypresian age. Some authors assert that these formations are terrestrial, whereas according to other authors they have been formed from the materials of the strong erosion in the «arriere-pays» of the Paleocene neritic sea, which is bordered by lateral folds. In certain strata of these formations many Nummulites have been identified in the intermediate limestone layers.

The Eocene limestones cover wide areas here and occupy the Midyat plateau, hence called the «Midyat Formations». These limestones are Lutetian in age. At the bottom they are yellowish, flinty and nodular, and contain many microfossils; the upper part is a chalky, soft limestone. On the boundary of these two limestone facies, at Ramandağ, an «Echinoid Zone» has been established. In the Urfa area these limestones are more chalky (41).

The Oligocene is regressive in the Mardin area and no sedimentation can be observed there; on the other hand, reference is made to the existence of the marine Oligocene in the Gaziantep district.

The Eocene is transgressive in the Taurus-Aladağ region, north of Adana. Breccias and marly sandstones constitute the base here. There are conglomeratic layers towards the top. The Oligocene is at places in the limestone, marl facies and constitutes the most recent filling of the Ecemiş Corridor; these consist of the variegated sandstones and marls. This facies is terrestrial.

In the Fethiye and Muğla intermediate zone, the Eocene is in the flysch and limestone facies, which extend as far as İzmir. The Oligocene is incorporated in the Eocene flysch in the neighbourhood of Acıgöl and is in the form of a continuous series.

b - The Central Anatolian Gypseous Formations:

These series generally cover large areas in the districts, of Çankırı-Yozgat and Sivas-Zara. This Central Anatolian Oligocene is in a terrestrial and lacustrine facies. After the withdrawal of the Eocene sea, brine and gypseous formations have been deposited in the lakes formed in these districts during the Oligocene. These deposits have taken place between the Eocene formations and the Miocene strata and are in the form of red, green clay, gypsum and white limestones. Many salt deposits in these regions belong to this formation. Although the lower levels of this gypseous formation are of the Oligocene age, the upper ones go as far as the Neogene. Indeed, further east, in the Aşkale and the Aras river basin, these series, which have been so far considered as Oligocene, have been proven to exist between the fossiliferous marine Neogene and the fossiliferous Upper Miocene.

c - Neogene:

During the Neogene, the seas have partly flooded Turkey from the northwest, the south, the southeast and from the east.

The Neogene transgression begins with the Aquitanian. The Burdigalian and the Middle Miocene are widespread and distinct. The marine regime does not exist after the Middle Miocene. Although repeated invasion of the sea took place during the Pliocene, this

was restricted to a few areas. The marine Quaternary is seen at Sinop, Black Sea, probably at Çanakkale, in the gulf of İzmir and at Süveydiye, south of Antakya.

The northern Neogene sea begins with the Aquitanian in the Ağaçlı district, northwest of Istanbul, and between the Ergene - Saros gulf. No Burdigalian could be observed here, whereas the Tortonian and the Sarmatian deposits are found at Çamurluhan, Büyük and Küçük Çekmece, west of Istanbul.

The Neogene is more or less widespread in the Ergene - Saros gulf basin. The Aquitanian in the Ağaçlı area consists of the lignitic sandstone and marl series. The marl series at Çamurluhan, west of İstanbul, is Tortonian in age; however, in the intermediate zone of the Küçük and Büyük Çekmece lakes the Neogene is represented at the bottom by limestone series identifying the Sarmatian and by fresh-water deposits towards the top.

In the Ergene - Saros gulf basin the Neogene is covered by the Middle Miocene (Tortonian) strata and by the Sarmatian and Pontian deposits. These series consist of sand, marl and limestones (37).

The Southern Neogene sea of the Mediterranean. This Neogene sea has transgressed on the land in the form of three gulfs (one small and two large ones) advancing from the Lower Miocene to the north-east. The small sea arm is in the Kerme gulf, at Muğla, and begins here with the Aquitanian; the large sea arms are at Antalya and Adana. In Antalya the sea arm is narrow and long, whereas the one in Adaria is very wide.

The western area of the second large gulf extends, between Mersin and

Silifke, to the south of Karaman on one side, and towards the west, following the Göksu area, on the other side. The Burdigalian sea remained further south, but the Vindobonian sea has transgressed much more on the land (15).

The eastern extension of the second large sea arm advanced as far as Malatya and from there reached Sivas and Koyulhisar. This sea by means of another narrow arm, advancing almost as a gorge, extended towards the east, to Bingöl, Erzincan, Erzurum and Iran and joined the Van Lake region, coming from the Eastern Anatolia.

The marine invasion in the south-east enters Turkey at the southwest of Hakkari, near İmadiye in Syria, and at Gizre, further to the southeast, and after coming close to the south of Siirt - Şirvan-Garzan-Lice and Ergani it turns again towards the SW and reaches Gaziantep. On the other side, it touches the east of the Amik Lake at Reyhanlı, where it joins with two arms, one coming from Kozeir - Süveydiye and the other from İskenderun, which crosses Amanos Mountains by the way of Belan.

The Adana Burdigalian is in transgression sometimes on the Paleozoic, but most frequently on the Cretaceous and partly on the Oligocene (only in the Ecemiş Corridor); at the bottom there are conglomerates and towards the top algal limestones. These limestones alternate always with the marl layers. In this area, the Helvetian is represented, from the bottom upwards, by green marls, sands and gravels. The marl and sandstone layers alternate. As for the Tortonian, it has sands and marls at the base, and sandy limestones towards the top (26). At the end of the Tortonian the sea has regressed from this area and has left remnants

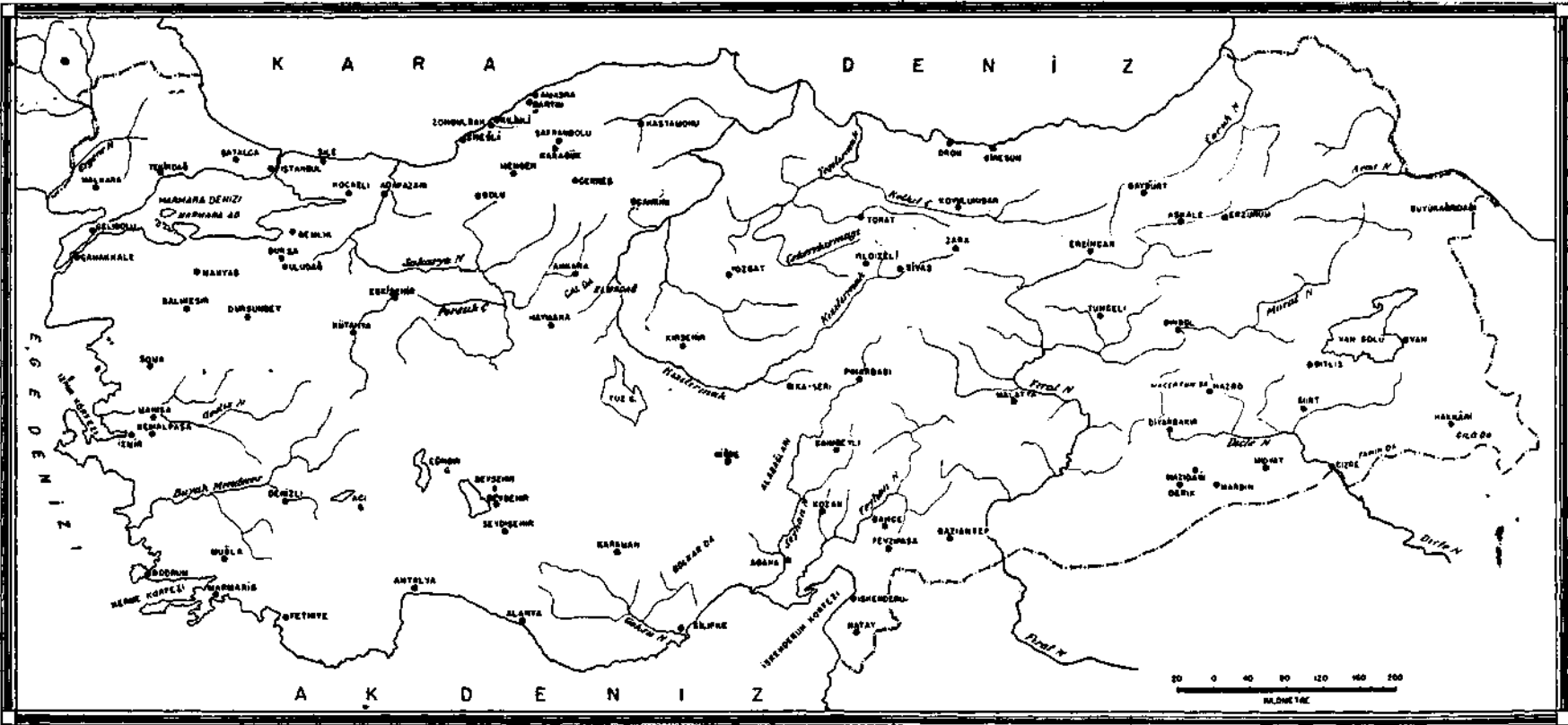
of fresh - or salt - water fauna in some local deposits.

In Hatay, at Kozeir, the Burdigalian consists of the variegated, glauconic sandstones and conglomerates at the bottom, and of limestones towards the top (10).

In this district, the Helvetian begins with a conglomerate; to the top there is a marly and sandy limestone series. The Tortonian contains marly series at the bottom, and the sandstone series upwards. The Pliocene in this district is marine. This formation extends from Süveydiye to the north of Antakya as far as Kozeir and contains marl series at the bottom and sandy series at the top.

The Burdigalian formations, which are very widespread between Mersin and Silifke and particularly in the littoral districts, leave their place to higher strata in the south of Karaman. Here the Vindobonian is well developed, consists of sandy and marly series and is rich in fossils. In this region the Vindobonian sea has later on regressed to the south and lacustrine formations took place from Karaman in the north as far as the Konya plain (15).

The Neogene sea, which began with the Aquitanian towards the west on the Mediterranean shores, has deposited sandy series here. The marine Pliocene is present on the Reşadiye peninsula; it consists of conglomeratic, sandy, marly, tuff series.



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