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ON THE GEOLOGY OF İZMİR-TORBALI-SEFERİHİSAR-URLA DISTRICT

Mehmet AKARTUNA

University of Istanbul, Geology Department

ABSTRACT. — The oldest formations of the area under study are crystalline schists. These formations, which we take to be of Paleozoic age through comparison with neighboring areas, consist of gneisses, mica-schists, chlorite-schists and schisty quartzites on the bottom and marbles on the top.

Here Cretaceous beds unconformably overlie the old crystalline formation. This first fossiliferous sedimentary formation in our area presents flysch facies on the lower sections and limestone facies on the upper ones. This flysch is usually composed of argillaceous schists, arkoses, conglomerates, sandstones, crystalline calc-schists with intercalations of crystalline limestones that may be encountered in the layers containing radiolarite. At all levels gradual transition, both lateral and vertical, is visible.

This formation has been subjected to metamorphism, intensity ranging from somewhat weak to quite strong. It sometimes included slightly crystalline calc-schist layers only a few millimeters thick, which were encountered in radiolarites and schists forming some parts of the flysch and contained characteristic Upper Cretaceous fossils (Globotruncana species). Therefore, this formation—reported to be Paleozoic by some authors— is beyond doubt Cretaceous.

The overlying Upper Cretaceous gray limestones show a gradual transition with the flysch below. In some places these limestones are found unconformably overlying layers of crystalline schists.

Although no Eocene outcrops were encountered, the presence of limestone pebbles with Nummulites in the Miocene conglomerates indicates that the Eocene sea must have existed in this area.

It was possible to distinguish lower and upper series of Miocene age unconformably overlying still older formations.

Lower series consists of conglomerates, sandstones, marls, clays and volcanic tuffs together with limestone beds.

Upper series, in addition to the limestones, contains marl, clay and volcanic tuff layers. In the light of many fossil specimens collected largely from the upper levels of the Miocene, the age of the area under study appears to be in the neighborhood of Neogene-Dacian or Dacian.

Pliocene is represented here by reddish beds consisting of clays, marls, sands and pebbles. Cross-bedding is also displayed. The whole unconformably overlies the Miocene.

In the area, movements dating back to the Hercynian and Alpine orogenies were noticed. Crystalline schists, which we have marked down as Paleozoic, were folded and fractured during the Hercynian orogeny (?), while Cretaceous and Neogene formations have undergone similar changes during the Alpine orogeny. This area, subjected to the effects of the Rhodanian phase between Miocene and Pliocene, must have taken its final shape under the tectonic movements that occurred towards the close of the Pliocene (Wallachian phase).

Serpentine outcrops, encountered in the Cretaceous formations, are related with underwater ultrabasic intrusions that occurred during this period and were brought to their present sites in the course of subsequent tectonic movements.

Of the volcanic rocks, rhyolites, rhyodacites, andesites and the tuffs are results of volcanic activities during the Miocene, while basalts and diabases were similarly formed both during the Miocene and later.

INTRODUCTION

Fig. 1 - Map showing the area under study

This study was carried out for the M.T.A. Institute, using 1/100,0000-scale topographic maps. My thanks are due to Miss S. Başad, who determined a major portion of the Cretaceous microfossils, and to Dr. P. Calas, who did a similar job on the Neogene macrofossils; to Prof. Dr. G. Sağıroğlu and Dr. v. der Kaaden for petrographic determinations done on the samples brought in; and of course to the M.T.A. Institute for making it possible for me to carry out this work.

The area studied lies to the south of the Gulf of Izmir. It is rather hilly and is covered with forests where wild animals, such as leopards, may occasionally be seen. The more important peaks in the area range from 500 to 1042 meters (Karabelen 1042 m., Beşpınar 965 m., Çatalkaya 872 m., Kapaklıtepe 850 m., Kartaltepe 913 m., Karaca Mt. 750 m., Keçipınarkaya 750 m., Sığındı Mt. 700 m., etc.).

On the southern border of the studied area is situated the estuary of the Küçük Menderes River, one of the major rivers of Western Anatolia. There are other smaller streams in the area.

The following are among the geologists who, at one time or another, have conducted geological investigations within this area or in the vicinity : Strickland, H. E. (7), Tchihatcheff, P. de (8), Philippson, A. (6), Chaput, E. (2), Pamir, H. N. & Akyol, İ. H. (4), Parejas, Ed. (5), Yalçınlar, İ. (9) and Kalafatçıoğlu, A. (3).

STRATIGRAPHY

In the area of study, there are crystalline schists determined as Paleozoic, in addition to Mesozoic, Tertiary and Quaternary formations.

Crystalline schists

Crystalline schists represent the oldest sedimentary rocks in the district. From the bottom up two series may be distinguished. The first series includes : (a) Gneisses, mica-schists, chlorite-schists, micaceous schisty quartzites, and the second, forming the upper part, consists of (b) Marbles.

a. Gneisses, mica-schists, chlorite-schists, micaceous schisty quartzites (lower series).— Gneisses usually are of pink or white color, grain sizes varying from fine to much larger. They show a paragneissic character. The rock contains feldspar (18-22 % plagioclase)., fine elongated muscovite flakes, quartz and opaque minerals (magnetite or hematite). Mica-schists, ordinarily brown in color, are the predominant constituents of this series. Micaceous quartzites are whitish gray, very fine-grained and of a schistous texture. Sometimes they contain very little mica and are of saccharoidal type. These rocks, making up the lower series, usually form alternating thin layers.

No clearly defined boundary exists between these two series. Layers of the lower series show a gradual transition into the marbles and in these transition levels layers of both series are seen to follow one another.

b- Marbles.—The marbles,, which follow the lower series after a gradual transition and conformably overlie this latter, cover the largest portion of the area in the southeast. These rocks, with colors ranging from black to pure white, show a wide variety of crystal sizes as well, but mostly small crystals and white color predominate. One variety which may be found in very thin layers, at times not over a few millimeters, is usually of a darker color. Of the marbles showing layering some display a cipolin character. As for massive marbles, these usually occur in white and grayish colors and occupy larger areas.

Complete lack of fossils in these crystalline schist rocks makes a strict age determination impossible. On the other hand, the oldest sedimentary strata unconformably overlying these crystalline schists belong to Cretaceous. Hence, these latter must have formed earlier and subsequently metamorphosed. By comparison with known formations in the vicinity, we are inclined to set the age for the crystalline schists in our area at Paleozoic.

Philippson (6) accepts the mica-schists to be the beginning of the argillaceous schists (lower layers). However, as it will be shown later on, the argillaceous schists in question, together with some other rocks, form the Cretaceous flysch deposits in the area under study.

Cretaceous

Cretaceous in our area is represented by : (a) Flysch and (b) Gray limestones.

a. Flysch.—This type of deposition which is widespread in the area covers quite a large territory between the Gulf of İzmir and Doğanbey—a small administrative district center some 40 km. to the south.

These flysches, usually of a dark brown color, are represented by a variety of argillaceous schists, micaceous sandstones, arkoses, conglomerates, crystalline or dolomitic limestones, reddish-pink or grayish schistous limestones and radiolarites. The layers are cut by veins of quartz or calcite, or both. Various argillaceous schists, predominant in the formation, and sometimes crystalline limestones likewise encountered, indicate that these formations were subjected to rather strong folding and metamorphism.

Arkoses and sandstones are frequently found together with argillaceous schists. They constitute thicker layers than the latter and form benches. Arkoses outcropping in the midst of argillaceous clay deposits, between Kızılbahçe and Büyükkaya, resemble sandstones and are essentially composed of slightly kaolinized feldspars, sericitized with quartz. In lesser quantities muscovite, opaque minerals and schist fragments are also present. These minerals are angular or rounded. Quartz in the rock displays undulated extinction due to mechanical stresses. With fine to medium size grains, texture is clastic or cataclastic.

Sandstones, conglomeratic sandstones and conglomerates are, as a rule, of brown color, with various types of crystalline schist and argillaceous schist fragments as constituents. Sandstone and conglomerate layers sometimes have a schistose structure. In the cement substance of the dark-gray sandstones and conglomerates, lying 2-3 km. to the north of the Kuşçu Dağ, the following fossils were identified: *Orbitoides* cf. *media* d'Arch. (Campanian-Maestrichtian), Siderolites, Textulariidae, Bryozoa, Lithothamnium, Lithophyllum and Archaeolithothamnium.

Radiolarite-bearing layers hold an important place within the flysch formation. They are red in color and usually form regular layers a few centimeters thick, but they also outcrop as massive rocks without any sign of stratification. Sometimes these beds are of schistous structure. They may occur as isolated outcrops or alternate with red and brown limestones and calc-schists. Only part of these radiolarite outcrops is represented on the map.

It is most probable that the formation of radiolarite layers was due to the ultrabasic magmatic intrusions which took place during the deposition of the flysch and helped increase the silicium content of the sea water, thus creating a favorable medium for the multiplication of Radiolaria.

Thin calcareous beds, reddish-pink or grayish-brown in color, are more frequently seen among the argillaceous schists and radiolarite layers. They are sometimes only a few millimeters thick. These calcareous beds are partially marly and from place to place indicate strong folding and crushing. As they are extremely localized within the flysch, it was not possible to show them on the map.

Pinkish limestone layers found intercalated with layers of radiolarite and phyllite-like schists on the road from Sandıklı to Efençukuru and the gray limestone beds likewise showing intercalation with argillaceous layers, 1.5 km. southwest of the Venice village, are rich in microfossils; namely,

Globotruncana lapparenti lapparenti **Bol.**
Globotruncana lapparenti tricarinata **(Quer.)**
Globotruncana **sp.**
Gümbelina globulosa **Ehrenb.**

Accordingly the age of these formations must be Middle Turonian-Lower Campanian.

Schistous limestones found in the reddish argillaceous schists, about 5 km. to the northeast of Değirmendere, contain :

Globotruncana leupoldi Bol.
Globotruncana stuarti de Lap. (?)
Globotruncana lapparenti tricarinata (Quer.)
Gümbelina sp.
Globigerina infracretacea Glaes.

The age of these formations is therefore considered to be Upper Campanian.

Radiolaria are present in fine-grained, silicified, cream-colored limestones lying between flysch deposits at the İzmirli pass and siliceous limestones found among radiolarites on the road from Seferihisar to Ulamış.

Crystalline limestones in flysch often form lenses. They are usually compact and hard, color varying form white to brownish-gray. They show very little stratification and are sometimes strongly crystallized (marmarized) and dolomitic. Portions of them may seldom be found to show a gray compact limestone character. In places they are cut by numerous calcite veins.

Crystalline limestones generally show gradual transition with layers composed of argillaceous schists and sandstones. Coming nearer limestone lenses, limestone replaces argillaceous beds. These gradual transitions are best visible in the lenses outcropping along the road from Kavacık to Seferihisar. White or grayish crystalline limestones, of which Çatalkaya hills are formed, show thin layering in the lower parts. On the southeast slopes, lateral and vertical transitions of these formations into schists are more pronounced.

Although on the profile (Plate II-profile VII) Çatalkaya and Karabelen limestones are shown to overlie flysch sediments—because of their high resemblance to the crystalline limestones found in the flysches and the lateral transition into argillaceous schists of the southern fringes of the limestones forming the Çatalkaya hills—these have been distinguished from the gray compact limestones (b. Gray, compact limestones) conformably overlying the flysch and placed among the latter.

Crystalline limestones are poor in fossils. Thin-sections reveal fragments of Lituolidae, Textulariidae, Miliolidae, Bryozoa, Echinoid spicules and remnants of Algae.

The flysches—whose various characteristics were described above—cover wide areas between the Gulf of İzmir and Doğanbey and also show outcrops in the valleys of Dereboğazı and İzmirli. They are composed of rather metamorphosed rocks (schists resembling phyllite, various types of argillaceous schists, calc-schists, crystalline limestones, schistous conglomerates, arkoses, etc.) giving the appearance of Paleozoic formations. However, the calcareous layers found among these beds, which are rich in fossils and comparatively little altered, enabled us to determine the age of these deposits. On the other hand, the strata unconformably overlying the crystalline schists, which outcrop in the vicinity of Degirmendere and also at various points to the south and east of it, exhibit a typical flysch character.

Tchihatcheff (8), who studied this area, accepted the said argillaceous schists and the successive layers as Paleozoic.

Philippson (6) pointed out the presence of argillaceous schists, graywackes and conglomerates in the same area. He also found in the gravels of Sanda (Sandık village) alluvium some Hippurite sections. As he was unable to determine the origin of these gravels, he attributed this formation to Paleozoic.

The flysch reported by Ed. Parejas (5)—which he observed between Belkave pass and the schoolhouse on the road from İzmir to Kemalpaşa —shows great similarity, both lithologically and paleontologically, to the flysch of our area. Here, the author collected from the flysch consisting of intercalations of argillaceous schist, sandstone, conglomerate and limestone, the following fossils :

Globotruncana linnei **d'Orb.**
Globotruncana stuarti **J. de Lap.**
Globigerina cretacea **d'Orb.**

and also Gümbelina, Lagena, Radiolaria, sponge spiculcs and Inoceramus prisms.

S. Başad, who examined specimens collected from the radiolarite-bearing layers in our area, estimated their possible age to correspond to somewhere between Jurassic-Cretaceous. Since no characteristic Jurassic fossils were found in other flysch beds, as mentioned before, we accepted the age of the flysch in question to be mainly Cretaceous, as numerous fossils of Upper Cretaceous (Turonian-Campaniani were identified here.

b. Gray, compact limestones. — In addition to covering large areas in the southeastern parts of our area, these limestones give outcrops approximately 6.5 km. southwest and again 7 km. northwest of the town of Urla.

These gray compact limestones are rather hard and sometimes show a mylonitic texture. They are either dolomitized or slightly crystalline and arc generally cut by calcite veins. Mylonitic limestones are more frequently seen to the northwest of Değirmendere, in the areas of Dereboğazı and İzmirli. The crystalline structure is observed in the valleys of Dereboğazı and İzmirli.

These limestones conformably overlie flysches, while in the case of crystalline schists an unconformity is noticed. Sometimes there is gradual transition between crystalline schists and flysches.

The limestones in question are not rich in fossils. Thin-sections showed Lituolidae, Rotaliidae, Biloculina, Triloculina, Quinqueloculina, Textulariidae, Bryozoa, Corals, Crinoid stems, Echinoid spicules, Algae and also, very occasionally, oolitic concretions. Although none of these fossils could be taken as characteristic of any given geologic period, the fact that the conformably underlying flysch (Turonian-Campanian) contained characteristic fossils and that a lithological resemblance could be established between these limestones and limestone lenses found within the flysch in addition to the presence of fossils common to both, permits to attribute the gray compact limestones to the upper levels of the Upper Cretaceous (Maestrichtian).

Philippson (6) states that the marbles near the Palamut Mountain plunge under limestones of unknown age. These are, however, none other than the gray, compact, crystalline or dolomitic limestones which we have attributed to the upper levels of the Upper Cretaceous.

The Cretaceous formations, reported by Kalafatçıoğlu (3) in the Karaburun Peninsula, were generally of a different facies than the ones in our area, but the extension of the limestones across our area's western border is also shown by this author as Upper Cretaceous formations.

Neogene

Neogene in our area is represented by Miocene and Pliocene lacustrine or brackish-water deposits.

a. Miocene-— In addition to covering large areas in the northeastern and western parts, Miocene formations in our district also show outcrops in localized groups or continuous strips. They occur either unconformably overlying crystalline schists and Cretaceous beds or forming successive layers with volcanic tuffs. Sometimes they are found cut by lava flows.

Among the rocks of this period, which attract attention with their white and red colors, we have been able to distinguish two series :

1) Lower series: conglomerate, sandstone, marl, clay, limestone, volcanic tuff.
2) Upper series: limestone, marl, clay, volcanic tuff.

Volcanic tuffs which occupy an important place between these two series are considerably thick and contain volcanic rocks. The matter will be taken up again in the section dealing with volcanic activities.

1) Lower series: Besides the conglomerates, predominant in this scries, layers of sandstone, marl, clay and limestone occur in notable proportions. Sometimes conglomerates form successive layering with thin sandy and argillaceous beds. Tuffs occupy the upper parts of the lower series. Conglomerates and sandstones attract attention with their color, which is usually red. Marls may have various colors, but they are often brown, reddish or grayish-white. Tuffaceous layers are usually whitish. The limestones are mostly bedded, yellowish-white or brown in color. They constitute hard rocks and, in the vicinity of lava flows (southeast of Gümüldür Köy), exhibit considerable mineralization, the color then changing to black.

Lower series are known to contain lignite deposits of economic value. One of the more important of such deposits, presently exploited, lies 1.5 km. to the southwest of Sandık Köy and there is an other one about 1 km. to the northwest of Yeniköy.

Lower series discussed up to here are cut by lava flows. In fact, rhyolite dikes are plainly visible to cut through limestone beds in the southeast of Gümüldür and conglomerates in the vicinities of Akyar hills and Karadağ Mountain. In the vicinity of İzmir the marls cut by andesites can be clearly seen. Furthermore, there are places where lava hills are invaded by conglomerates.

Although plant remains were encountered in some of the layers of this series, which constitutes the basal- part of the Miocene formation in our area, no key fossils were determined. However, about 1 km. northeast of Yeniköy, conglomerates containing various pebbles of limestones, generally 1-2 cm. large, were found in a red-colored cement substance. Their thin-sections revealed that the gray, compact limestone pebbles of these conglomerates were rich in fossils, although no traces of organisms were observed in the cement itself. The micro-fossils identified in these pebbles are : Nummulites, Assilina, Discocyclina and Rotaliidae. The fact that in this series were found pebbles with Nummulites and that the upper series, conformably overlying it, contained characteristic Dacian fossils show that these rocks would either be of Dacian age or formed even earlier in a Neogene lake.

Chaput (2) reports *Helix* aff. *pseudoligata* Sinzow and Bulimus from conglomerates found in the neighborhood of Altındağ, east of İzmir, near the east border of our area. That these conglomerates constitute a continuation of the ones in our area is quite probable.

2) Upper series: The major part of the Neogene in our area is represented by this series, with limestones predominating. These latter, usually white or yellowish-white in color are rarely chalky and soft. Hard variety sometimes has a cavernous structure. They may be found silicified, hard and massive and again argillaceous or sandy. Marls and clays are of white, yellowish-white and rarely greenish-gray color. As they are softer and more readily disintegrating than the limestones, they make better soils for agriculture.

The sequence from bottom to top in the upper series is generally as follows :

— White, yellowish, grayish or greenish marls. They contain intercalations of volcanic tuff.

— Marls of various colors with alternating layers of limestone and sandy limestone.

— Stratified hard limestones.

— White or yellowish, hard, sometimes cavernous or compact limestones, without show of stratification. These usually make the crests and ridges.

This general profile, however, cannot be applied to the entire area. Especially in lower layers, both lateral and vertical, gradual transitions may be encountered.

Between the upper and lower series, alternations of marly and sandy layers predominate. Hence, it was impossible to draw a separating line for these series. Sometimes the presence, here and there, of some volcanic tuffs helped to distinguish these two series. On the other hand, while red-colored argillaceous beds are found among the conglomerates of the lower series, they are not present in the upper series.

Layers of lower series may be found cut by various volcanic intrusions or they may cover them entirely.

Now, a brief review of the two regions we have distinguished in the upper series of the Miocene formations follows.

a. Kızılbahçe - Urla region: The upper series layers in this region stretch out from the western banks of the Çamlı creek up to the vicinity of Urla; then they continue towards the south of Urla and the Armutlu Mountain in the northwest. The area in question is more or less entirely covered with Miocene limestones. Here marly and sandy beds are less frequent than in the İzmir district, as will he discussed later on.

Upper series limestones near Urla contain oolitic or larger concretions.

From place to place, layers of upper series of the Miocene in this region are found to include richly fossiliferous beds. The following fossils were determined from rock samples collected from layers of grayish-white, rather hard limestones and sandy limestones, lying along the coastal highway, about 7.5 km. northwest of Urla.

***Planorbarius* sp. aff. *corncus* L.**
***Planorbis* *(Gyraulus?* or *Armiger?)* sp.**
Segmenlina sp.
Bulimus sp. aff. *labiatus* Neum. (operculum)
Carychium sp. *(pachychilus* Sdb. ?)

and also Ostracods, Oogones, Characcae.

According to these fossils, Miocene in this region is represented by lacustrine or brackish-water deposits of Dacian (or nearly Dacian) age.

b. İzmir region: Upper series layers cover a large area in the south, east and southeast of Izmir. They are either continuous or in patches and include limestones, marls and sandy limestones.

Upper series of the Miocene in the İzmir region contains fresh- or brackish-water mollusk remains. Specimens collected here were too fractured and unfit for exact determination. It may, however, be stated that the fossiliferous limestones here were identical to those near Urla.

According to observations made during an exploration trip in the Karaburun Peninsula, that lies to the northwest of our area of study, Neogene formations in both places appear to be identical. Among the fossils collected from various localities in the Karaburun Peninsula, the following are attributed to Dacian or close to Dacian :

***Bulimus* cf. *tentaculatus* L.**
***Melanopsis (Canthidomus)* sp. (aff.? *hybostoma* Neum.)**
***Melanopsis (Melanopsis) sandbergeri* var. cf. *rumana* Tourn.**
***Melanopsis* sp.**
***Melania (Melanoides) tuberculata* Müll.**
***Melania (Melanoides)* cf. *tuberculata* Mull.**
***Melania (Melanoides) curvicosta* Desh.**
***Melania (Melanoides)* sp.**
***Lymnaea (Stagnicola).* sp. (aff. *palustris corvus* Gmel.)**
***Planorbarius thiollierei* Mich.**

and also *Hydrobia* sp., *Helix* (? *Eobania)* sp., *Pupilla* sp., and *Theodoxus.*

It may further be stated that the Neogene deposits between Menemen and Foça are likewise identical to those in our area. At a place along the Menemen-Foça highway, about 10 km. to the northwest of Menemen, yellowish limestones rich in Gastropods were found underlying yellowish-white hard limestone beds. Some of the fossils taken from this spot were identified as follows :

Pseudamnicola (Sandria)
Planorbarius sp.
Bulimus sp. aff. *labiatus* Neum.
Ancylus (Velletia) sp.
Helix sp.

their age being Dacian or nearly so.

In the Neogene of the İzmir region, Hamilton and Strickland (7) have found the following fossils :

Helix cf. *carthusiana* Drap.
Planorbis cf. *alba*
Limnaea cf. *peregra*
Paludina cf. *acuata*
Cyclas cf. *pusilla*
Unio sp.
Cypris

Although mentioning the presence of Neogene in the vicinity of Izmir, Tchihatcheff (8) described as Cretaceous the Neogene area of the Urla region.

Philippson (6) mentions Neogene conglomerates, marls, limestones, sandstones and tuffs occurring in the vicinity of İzmir. He also reports the presence of conglomerates topped with limestones and limy sandstones in the Neogene formations near Urla (west of the Çamlıdere valley). Moreover volcanic tuffs were encountered by the same author between Urla and Seferihisar.

A rather detailed study of the Neogene in the İzmir region was made by Chaput (2).

Yalçınlar (9) has shown a large portion of the limestones belonging to the upper series, between Menemen and Foça, as volcanic tuffs. As just noted in the preceding paragraphs, the limestone beds here contain, from place to place, numerous fossils.

Neogene formations in Karaburun Peninsula reported by Kalafatçıoğlu (3) also display volcanic facies and constitute a continuation of those in our area.

b. Pliocene. — These formations, showing outcrops on the ridges lying to the east, northeast and southeast of the Cumaovası railroad station, are argillaceous, marly, sandy and contain pebbles and gravels. Their color is red. Pebbles and gravels are sometimes seen sufficiently cemented to form conglomerates. Some outcrops are formed only by slightly sandy, red clays that exhibit no stratification. Cross-bedding is occasionally noticed in pebbly and sandy layers.

Pliocene in our area is quite localized and forms a thin layer over older formations.

Ending our stratigraphy discussion, it may be mentioned that the Quaternary in this area is represented by some alluviums along the seashore and those covering the bottoms of some of the valleys.

MAGMATIC ROCKS

In our area of study were distinguished two groups of magmatic rocks: Serpentines and Volcanic rocks. These rocks were formed as a result of magmatic activities during different periods of time. Let us briefly review them in the given order.

Serpentines

Serpentines are generally scattered and outcrop in narrow tracts. They constitute hard ultrabasic rocks, dark-green, black or light-green in color, and have a more or less fractured structure. They are always found in Cretaceous formations and those occurring near Beyler village contain chromite.

Microscopic study of serpentines which outcrop along the coast, 6 km. south of Seferihisar, showed them to be old ultrabasic deep-seated rocks, completely serpentinized, containing chlorite as secondary mineral. During the serpentinization magnetite was also formed as an other secondary mineral. The fact that magnetite particles were formed in parallel lines indicates that strong movements have taken place at the outset, thus affecting the original rock. These movements must have facilitated the serpentinization process. Serpentines here are of an extremely cataclastic texture.

It is not possible to determine the age of these serpentines very definitely. The rocks in question cut through some of the Cretaceous formations and follow their general direction. On the other hand, even if very seldom, Neogene beds contain serpentine pebbles. It is most probable that the formation of the radiolarite layers, found within the Cretaceous flysch, was related to the ultrabasic intrusion, which in turn gave birth to the serpentines. Moreover, the youngest ultrabasic rocks in the neighborhood producing serpentine are Mesozoic. In the light of the above data, it is accepted that these rocks were formed in relation with submarine ultrabasic magmatic activities and that they took their final position under the effect of subsequent tectonic movements, which brought about the folding of the Cretaceous beds.

Philippson (6) points out the existence of serpentines cutting through argillaceous schists in the mountainous area, lying south of İzmir-Urla road, which he accepted to be Paleozoic.

Volcanic rocks

Definite separating lines can not be drawn between volcanic rocks, nor can this be done between these jocks and tuffs.

Volcanic rocks, unlike serpentines, show more frequent outcrops in Neogene area and are rarely seen in, Cretaceous formations.

We shall discuss below three groups of rocks: (a) Basic volcanic rocks, (b) Acidic volcanic rocks, and (c) Volcanic tuffs.

a. Basic volcanic rocks,—These occupy much smaller areas than the acidic volcanic rocks and occur *in situ.* They are usually represented by basalts and rarely by diabases.

Sample taken from outcrops approximately 4.5 km. southeast of Urla was determined as a typical basalt with augite and olivine. The rock contained plagioclase in the form of labrodorite. In addition magnetite was observed. Texture is pilotaxitic.

An other sample, that came from southern end of the outcrop lying about 1.5 km. to the northwest of Seferihisar, is a diabase. Microscopic examination revealed the plagioclasc to be basic, containing augite, and as secondary mineral—-calcite. Texture is pseudo-ophitic.

Sometimes, basalts are observed to have cut through both Cretaceous flysches and Miocene beds. In some other instances they have taken place in the tuffs lying underneath the upper series of the Miocene. Hence, magmatic activities that gave birth to the basalts during the Miocene, must have gone through many phases.

b. Acidic volcanic rocks-—This group of rocks is represented by rhyolites, rhyodacites and andesites.

Andesites are comparatively harder than the other rocks and their color changes from dark-brown to gray. The darker ones, with smaller crystals, are harder. Those with large feldspars are comparatively more altered. It is not possible to distinguish on the map all the andesite varieties of different colors and crystal sizes.

Rhyolites and rhyodacites can be easily distinguished from andesites, being whiter in color. Altered portions are extremely brittle.

Though all acidic volcanic rocks are kaolinized, disintegration ability in rhyolites and rhyodacites is higher than in andesites.

Acidic volcanic rocks are closely related to tuffs, which they may either underlie or overlie.

Compared with basalts they are more widespread. Acidic volcanic, rocks cover large areas that include northwest of Urla, Karadağ, Akyar hills, Çakmak hill, Dikmen Mountain, Dede Mountain, Çubuk Mountain and the vicinities of İzmir. Through microscopic study of samples brought from these places, it was possible partially to determine rock types predominant in each region.

The sample that came from a spot 1 km. southwest of the wharf of Urla was determined as rhyolite. The rock had phenocrysts of sanidine either idiomorphic or as Carlsbad twins, together with disseminated biotite and a vitreous matrix that contained numerous feldspar microlitcs.

Rhyolites, outcropping on the southeastern skirts of the Dikmen Mountain, also had sanidine phenocrysts, sometimes idiomorphic, sometimes in Carlsbad twins. A number of phenocrysts are found that are determined as quartz exposed to magmatic corrosion and partially opaque brown biotite. These occur in a vitreous fluidal matrix containing light-brown pigments together with only a few feldspar microlites. Texture is vitreous.

Part of the lava beds found intercalated with agglomerates and tuffs, of which Kadifekale in the vicinity of İzmir is built, consists of augites-biotites-andesites. Here, plagioclase : 46 % An. The rock also contains augite, biotite and opaque minerals. Biotite is highly pleochroic. It is partially turned into iron oxides. First crystallization phase covers phenocrysts of minerals mentioned above. The same elements participate as microlites in the secord crystallization phase, namely that of the matrix. Texture is hyalopilitic.

Andesites stretching from Kadifekale on to the Göztepe heights are of a pyroxene-andesite character.

Acidic volcanic rocks are strongly related to the tuffs and they otfen form successive beds with the latter.

The volcanic rocks in question usually cut through the lower strata of the Miocene, but remain covered by the upper layers of the same formations. In fact, it was observed that the rhyolitic volcanics of the Karadağ and Akyar Mountains were cut by the conglomerates at the base of the Miocene, the marls belonging to the lower strata of the Miocene were again cut by the Kadifekale andesites, along the İzmir-Buca road and, finally, Neogene beds of the upper series were likewise penetrated by rhyolites near the Mountain of Topalhasan. On the other hand, limestones of the upper series of the Miocene are noticed to overlie the volcanic rocks to the east of Izmir.

Based on the discussion above, we are inclined to believe that the magmatic activities, responsible for the formation of acidic volcanic rocks, took place during the Miocene and were especially intense in the middle of this period.

Various geologists, who took trips within our area of study, tried to attract attention to these volcanic rocks.

TchihatcTieff (8) has spoken of those in the vicinity of İzmir, as trachytes.

Philippson (6) classified the Kadifekale andesites as pyroxene-andesites, in accordance with Washington's determination.

Study of samples from the Kadifekale region has shown the existence of a variety of andesites in the area.

Dacitic and andesitic lavas, cutting through Neogene formations, were observed by Chaput (2) in the neighborhood of Izmir.

c. *Volcanic tuffs and agglomerates-* — As these deposits occur close to large lava outcrops or contain lava flows, it was decided to discuss the matter in the section dealing with vulcanic rocks.

Volcanic tuffs and agglomerates are abundant in the northwest of Urla, covering Akyar, Çakmak, Karadağ, Dikmen and Dede mountains and their skirts, in the west of Cumaovası and in the vicinity of İzmir.

As a rule, these soft, sometimes medium hard, tuffs and agglomerates, which attract attention with their white color, and form deep-cut valleys, cover wide areas As far as possible it was attempted to plot them separately on the map. Yet, sometimes in places shown as lavas on the map, actually tuffs also exist to a limited extent.

Among these tuffs, occasionally layers belonging to the lower series of the Miocene are also encountered.

In general, tuffs and agglomerates are widespread between the upper and lower Miocene series. Especially in the south, the" lowermost tuffs, as a rule, overlie the lower series of the Miocene; they are followed upward by lavas, younger tuffs or agglomerate beds. Limestone layers of the upper series of the Miocene, constituting the uppermost part of this "series, overlie the tuffs in question (east of Kadifekale).

Since the age of these limestone layers forming a part of the upper series was accepted to be Dacian, volcanic activities responsible for the deposition of these tuffs must have taken place during the same period or before.

Yalçınlar (9), who recently studied the area around Foça and Menemen, points out that tuffs do exist in the region, but he includes a major part of the richly fossiliferous Dacian limestones into the tuff area.

TECTONICS

The effects of the Hercynian and Alpine movements in our area will be discussed below.

Hercynian movements

During the formation of the lower parts of crystalline schists, which we accept to be Paleozoic, the sea floor in this area must have undergone effects of the periodic movements. Marbles situated in the upper parts and forming-thick layers show that seas, where these were formed, must have been quite deep and well balanced.

Various layers alternating in the lower levels and the thin marble beds found in the upper parts appear to have identical plasticity, which is indicated by their identical folding under lateral forces. However, between these layers and the thick and sometimes massive marbles lying on top of them, a lack of harmony in folding is apparent. The said marbles are folded to a lesser degree. On the other hand, fine-grained gneisses and micaschists, at times, show excessive folding within short distances.

This crystalline formation, which constitutes a continuation of the Muğla-Menteşe massif, stretches in an E-W direction. Layers dip from 8° up to 55°, the majority being between 25°-35°.

It is not possible to give a definite idea as to the time of folding of these metamorphic series within our area. It is true that the first fossil-bearing bed that overlies the marbles belongs to the Upper Cretaceous. However, a very large stratigraphic gap that exists between the marbles and the Upper Cretaceous formations makes an age determination very difficult. We are inclined to think that these highly metamorphosed crystalline schists, which we take to be of Paleozoic age, must have folded during the Hercynian or even a still earlier orogeny.

Alpine movements

There are Cretaceous and Neogene formations in our area that were exposed to the Alpine movements and folded from time to time. Our area of study took its final shape and position under the effect of the movements towards the close of Pliocene (Wallachian phase).

Now let us review the effects of Alpine orogeny during different periods.

a. Cretaceous.— Cretaceous in our area is represented by a flysch formation topper with gray, compact limestones. The flysch comprises a variety of more or less strongly altered alternating beds with folds and fractures. Conglomerates and arkoses found in the flysch are the products of a rather shallow sea. On the other hand, argillaceous schists, calc-schists, radiolarites and crystalline limestones testify to a greater depth of the sea. Furthermore, argillaceous schist fragments with Globotruncana are occassionally found in the conglomerate and limestone layers.

As stated above, the bottom of the Cretaceous sea did not stay calm for a long time. It underwent periodic oscillations which resulted in the deposition of alternate layers of the rocks described above. The fact that schist fragments of the flysch and the gravels containing Globotruncana reappear in the conglomerate and sandstone layers of the same flysch, suggests that Cordilleras may have been formed in the geosyncline in question, or—even if only locally—that rather important regressions took place here, which resulted in the formation of new shorelines.

The fact that the flysch formation contains elements from the crystalline schists, may only be explained by accepting that the nearby Muğla-Menteşe (Menderes) massif undoubtedly constituted a land at that period, which furnished the material for the sediments in the Cretaceous sea. On the other hand, during the Cretaceous, this massif went through a series of upward and downward movements which caused the periodic deepening and shallowing of the sea. This in turn was responsible for the deposition of the alternate layers with fine and coarse material that formed the Cretaceous flysch.

Among themselves all layers of the flysch show conformity and gradual transition. Nothing to the contrary was ever observed. However, these successive layers, which conformably overlie each other and mark gradual transition, exhibit different degrees of plasticity, hence different degrees of folding under lateral pressures. Excessive folding is apparent in more plastic argillaceous schists, while thick layers of limestone, sandstone and conglomerate yielded to folding comparatively less. Calc-schists are strongly folded, their folding is conformable with argillaceous schists. Radiolarites are also strongly folded, but their structure is of quite a different nature. Conglomerates sometimes exhibit a schistous structure. As a result, there is a disharmony in folding among layers with different degrees of plasticity.

Flysches lie in a general N-S direction and dip from 20 to 85 degrees, most of them changing between30°-40°. Among the rocks that constitute the flysch, especially argillaceous schists generally show folding in the directions of NE-SW and NW-SE. Same may be noticed in the other layers, but not quite so clearly.

Flysches sometimes are badly fractured. This proves that after folding, flysches were exposed to lateral pressures as well.

It is noted that the flysches outcropping between the Gulf of İzmir and Doğanbey are more altered and more folded, as compared with those near Değirmendere. It was likewise observed that some of the argillaceous schists changed into phyllites and that the limestone lenses acquired the character of crystalline limestone. It must be accepted that this region corresponds to deeper horizons of the geosyncline and that, squeezed between two massifs — namely, crystalline Menderes massif in the east and Paleozoic Karaburun massif (outside our area) in the west—-the sediments here have acquired the characteristics of lustre schists, due to the action of great lateral forces during the Alpine orogeny. In general, microscopic examination of rock samples brought from varipus parts of the area (such as, 3 km. northeast of Beşpınar Tepe, İzmirli pass, stretch between Kızılbahçe and Büyükkaya villages, south of Büyükkaya village, northwest of Seferihisar, stretch between Kızılbahçe and Yağdere, etc.) gave evidence of strong tectonic activities. In fact, when examined under a microscope, quartz particles in samples taken from silicified, sharp-edged rocks, lying to the southeast of Büyükkaya and northwest of Seferihisar, showed strong undulatory extinction. These particles were found tightly clustered. The rock structure is indicative of tectonic movements. Subsequent to fracturing under pressure, quartz veins were formed in the cracks with the infiltration of siliceous solutions. The quartz in these veins also showed undulatory extinction, indicating that the pressure must have been a continuous one.

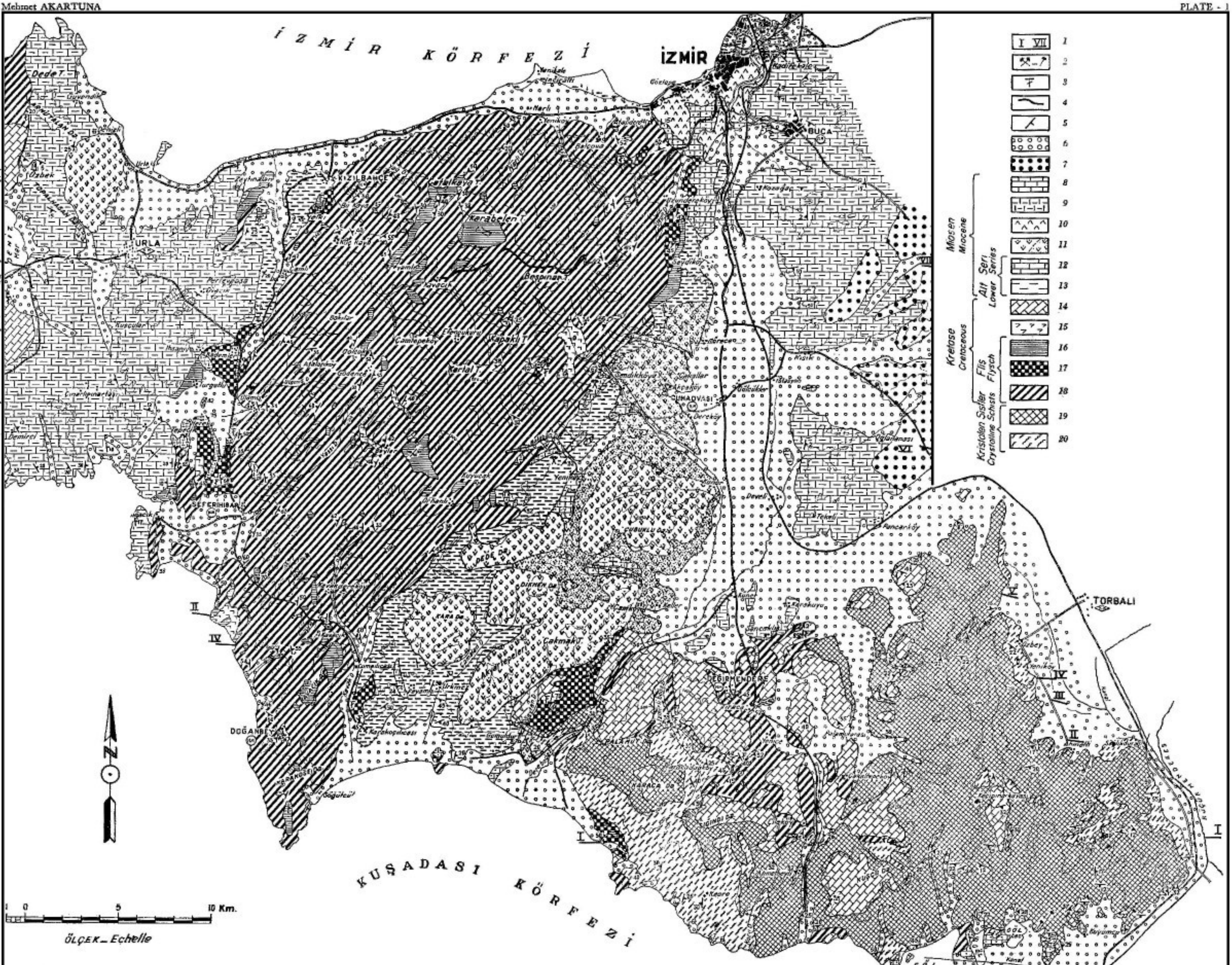
The upper part of the Cretaceous consists of gray compact limestones. They conformably overlie the flysches and here and there show gradual transition. However in some cases gray-colored limestones overlie crystalline schists with evidence of unconformity in between.

Therefore, these thick-layered gray limestones must be a continuation of the flysches. They indicate that, after the formation of these flysches, the sea deepened and stayed in this condition for a considerable length of time with occasional creeping over the crystalline schists.

In these limestones folding is not quite so apparent as in flysches. Folding is only noticed in the lower parts where brown gray thin layers show gradual transition into the flysch. In massive upper parts this is very rare. As in the lower layers, general folding direction in the upper layers is N-S, beds dipping from 25 to 55 degrees.

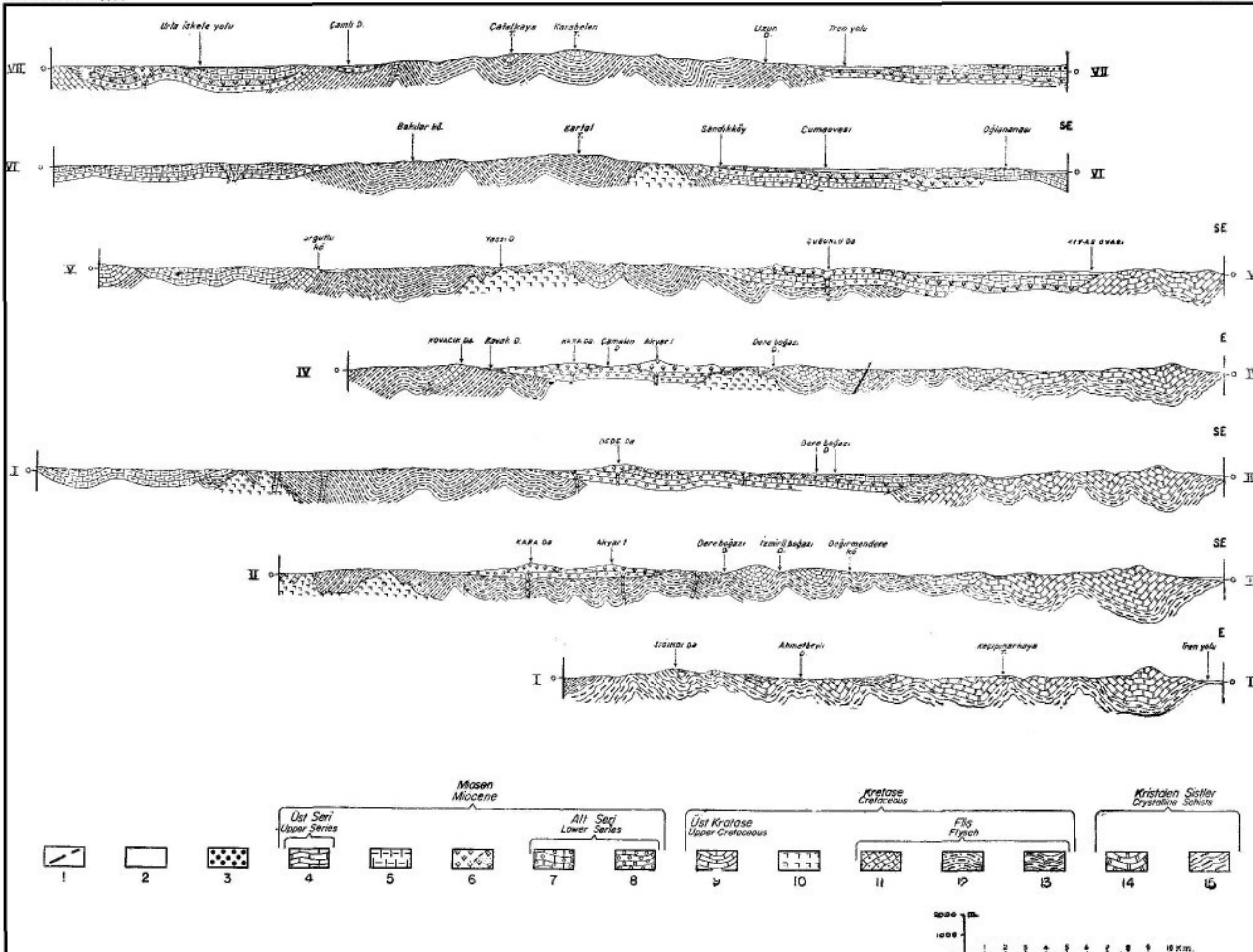
Since the Cretaceous formations are overlain by Neogene sediments, folding here must necessarily belong to a pre-Neogene period. Although Neogene conglomerates contained pebbles with Nummulites, Assilina and Discocyclina, it was not possible to state definitely in what phase of the Alpine oiogeny the folding of the said formations took place, as no relation between any one of the Eocene sediments and the Cretaceous strata was established.

Mylonitic and crystalline textures are often encountered in limestones. A most typical example of mylonitic texture is given in the outcrops lying to the northwest of Değirmendere. Here gray, compact limestones, occurring along a fault line in the NW-SE direction, have turned completely mylonitic. Along this fault, stratified Miocene limestones appear excessively broken up and dislocated and plunge under the Cretaceous limestones. Therefore, gray, compact limestones



GEOLOGIC MAP OF THE İZMİR - TORBALI - SEFERİHİSAR - URLA DISTRICT

1 - Profiles; 2 - Lignites - quarries; 3 - Fossil beds; 4 - Fault; 5 - Direction and dip; 6 - Alluvium (Quaternary); *7 - Pebbles, sands, clays, marls, sandstones, conglomerates* (Pliocene); *8 - Limestones, marls, clays, volcanic tuffs* (Upper series); *9 - Basalts, diabases; 10 - Andesites, volcanic tuffs; 11 - Rhyolites, rhyodacites, volcanic tuffs; 12 - Limestone beds; 13 - Conglomerates, sandstones, marls, clays, volcanic tuffs; 14 - Gray limestones* (Upper Cretaceous); *15 - Serpentines; 16 - Crystalline limestones; 17 - Layers containing radiolarites; 18 - Argillaceous schists, arkoses, conglomerates, sandstones, crystalline calc-schists; 19 - Marbles; 20 - Gneisses, mica-schists, chlorite-schists, quartzites.*



GEOLOGIC PROFILES OF THE İZMİR - TORBALI - SEFERİHİSAR - URLA DISTRICT

1 - Fault; 2 - Alluvium (Quaternary); *3 - Pebbles, sands, clays, marls, sandstones, conglomerates* (Pliocene); *4 - Limestones, marls, clays, volcanic tuffs; 5 - Basalts, diabases; 6 - Rhyolites, rhyodacites, volcanic tuffs; 7 - Limestone beds; 8 - Conglomerates, sandstones, marls, clays, volcanic tuffs; 9 - Gray limestones; 10 - Serpentines; 11 - Crystalline limestones; 12 - Layers containing radiolarites; 13 - Argillaceous schists, arkoses, conglomerates, sandstones, crystalline calc-schists; 14 - Marbles; 15 - Gneisses, mica-schists, chlorite-schists, quartzites.*

of the Cretaceous and fractures in the flysches must be related both with folding movements at the end of the Mesozoic and also with orogenic movements which continued afterward.

It may be accepted that the serpentine outcrops lying parallel to the folding direction in the Cretaceous flysch and magmatic activities which took place during the formation of the said sedimentary beds were related and that these serpentines took their final position in the flysches under the effect of subsequent Alpine movements in our area.

As the Neogene conglomerates contained Nummulitic pebbles, Nummulitic sea also must undoubtedly have affected our area, or the surrounding areas, after the Cretaceous.

b- Miocene— The presence of red-colored continental conglomerates at the bottom and their reappearance later on among the marly and limestone layers, indicate that the Neogene sediments were first deposited in a shallow lake which subsequently underwent periodic deepening and shallowing processes, thus producing the lower series strata.

Speaking of layers of the upper series, during their formation, the lake must have deepened and reached its maximum depth when the limestones in the uppermost layers were in the process of formation.

Neogene strata usually dip about 10°. However, some layers are found to dip 50°, while some others are nearly horizontal. As a rule, they all showed mild undulations, with occasional faults cutting across them. In the northwest edge of Değirmendere, Miocene limestone layers, with an excessively fractured and dislocated structure, plunge under the mylonitic limestones of the Cretaceous. Again, in the west of Seydiköy, although not very clearly defined, Neogene beds come face to face with Cretaceous layers. At the eastern contact of the Miocene, near Altındağ village in the vicinity of Izmir, Chaput (2) has also noticed the unusual contact of the Neogene with the Cretaceous. Therefore, Miocene formations in İzmir district may have taken shape in a depression basin with faults running along both sides.

Besides those mentioned above, some unusual and abnormal contacts were noted on the skirts of Armutlu Mountain, lying to the northwest of the wharf of Urla.

Some rhyolitic, andesitic and basic lavas which are widespread in our area of study, together with volcanic tuffs, are found to have come up to the surface, through fissures due to the orogenic movements during the Miocene, and usually settled between the upper and lower series of the Miocene. The general direction of these fissures is N-S.

The influence of the Alpine movements is apparent in the fact that Miocene and Pliocene formations follow each other with an unconformity in between. It corresponds to the Rhodanian phase of the Alpine orogeny.

c. Pliocene— This formation is red in color and consists of pebbles and gravels, sands, clays and marls in successive layers. Cross-bedding is sometimes visible especially in pebbly and sandy horizons. This shows that the lake bottom, where these beds formed, must have fluctuated up and down in the course of time.

d. Quaternary.— The presence of terraces along the sea shores, as well as on the valley sides, is an indication of Alpine movements still being continued.

Ending our discussion on tectonics, let as add that this area took its final shape under the effect of the post-Oligocene Alpine movements (Wallachian phase).

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