THE GEOLOGY OF AHLAT-ADİLCEVAZ AREA (NORTH OF LAKE VAN)

Erdoğan DEMIRTAŞLI and Carlo PISONI

Mineral Research and Exploration Institute of Turkey

ABSTRACT. — The area investigated lies to the north of Lake Van and covers, approximately, 600 km^2

The oldest rocks outcropping in the area are Upper Cretaceous in age. They form the Ahlat - Adilcevaz complex, which is composed of ophiolites, conglomerates, sandstones, marls, shaly limestones, limestones, pyroclastics and reefs. Over this complex lies, unconformably, the continental Ahlat conglomerate, possibly of Eocene-Oligocene age. Lower Miocene Sediments are represented by the transgressive Adilcevaz limestone, mainly Burdigalian in age. The Adilcevaz limestone is unconformably overlain by the Aktaş conglomerate and by the Develik formation, which is composed of sandy, marly and shaly Sediments. The Develik formation is conformably overlain by the Çukurtarla limestone, of lacustrine Origin. These three formations range in age from Middle Miocene to Lovver Pliocene. The Quaternary deposits are represented by travertine, terrace deposits and new alluvium. Large portions of the area are covered by different kinds of lavaş and pyroclastic rocks, late Cenozoic in age. The structure of the area is mainly characterized by the Ahlat-Adilcevaz uplift; its axis trends NE-SW.

During the Upper Cretaceous times, the area was under geosynclinal conditions, while, in the Eocene-Oligocene times continental conditions prevailed. A regional marine transgression took place at the beginning of the Miocene epoque; the sea withdrew from the area at the end of this epoque.

I. INTRODUCTION

The area discussed in this paper lies to the north of Lake Van and it falls within the towns of Ahlat and Adilcevaz, covering approximatly 600 km^2.

The original field work was carried out during the summer of 1961, in order to collect data on the stratigraphy, sedimentation and orogenic history of this area. This project was a part of the activities of the Petroleum Exploration Service of the Mineral Research and Exploration Institute of Turkey. Geologie mapping was carried out ori a scale of, 1 : 25,000 and the following sheets were used as base maps : K 49-al, a2, a3, a4 and b4.

An attempt has been made to differentiate the rock units outcropping in the area and to correlate these units with the hitherto unnamed and unclassified units of the adjacent areas.

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II. GEOGRAPHY

The surveyed area lies to the north of Lake Van. The average height above sea level is around 2.000 m; the lowest level is on the Lake Van at an elevation of 1.646 m and the highest peak is that of Süphan volcano, which reaches 4.058 m. The area is drained by three different drainage systems. One of them discharges into the enclosed Lake Van basin, which is formed due to the damming of the Bitlis Ganyon, by the lavaş of Nemrut volcano. The second drainage system discharges into Süte Lake, which is situated in a basaltic depression. Northwestern part of the area is drained by the tributaries of Murat River, which joins the Fırat (Euphrates) River and is the larger stream in the region.

A very severe continental and semiarid climate prevails in the area, in spite of the existence of Lake Van.

The vegetation cover is, generally, very poor except along the perennial creeks.

The main road crossing the area is the Bitlis - Van highway, which may be closed in the winter. Unsurfaced roads are suitable for vehicles only in dry weather.

III. PREVIOUS INVESTIGATIONS

Although a number of geologists had the occasion, from time to time, to deal with the Muş-Van region, the area discussed here, has never been subject to detailed Studies.

The following previous investigations were carried out on different occasions in the Ahlat-Adilcevaz area :

D. B. Ericson visited the area in 1938 in order to investigate the petroleum possibilities of the northwest Van region.

C. Öztemür prepared the geological map of the area at a scale of 1:100.000 in 1947.

İ. Akarsu investigated the area from a petroleum geology viewpoint in 1957 and compiled a geological map at a scale of 1 : 100.000.

İ. E. Altınlı (1964) made a general revision of the geology of the area, for the compilation of the Van sheet of the geological map of Turkey at a scale of 1:500.000.

IV. STRATIGRAPHIC GEOLOGY

General statement

In order to facilitate the understanding of the following pages, a schematic description of the stratigraphy of the area is given here below.

The formation and other unit names are proposed for the first time.

The correlation chart shown as Table 2, shows the time relations among the rock units outcropping in the Ahlat-Adilcevaz area and the unnamed units of the adjacent Muş and Van regions, based on the Studies of earlier workers.

Table - 1

Rock units	*Age*
Çukurtarla limestone Develik formation Aktaş conglomerate	*Middle Miocene - Lower Pliocene*
unconformity	
Adilcevaz limestone	*Lower Miocene (Burdigalian)*
unconformity	
Ahlat conglomerate	*Eocene - Oligocene*
angular unconformity	
Ahlat-Adilcevaz complex	*Upper Cretaceous*
Quaternary deposits	new alluvium terrace deposits travertine
Late Cenozoic volcanics	volcanic ashes pumice basalt cemented tuff andesite and rhyolite

Ahlat - Adilcevaz complex (Plate I and II)

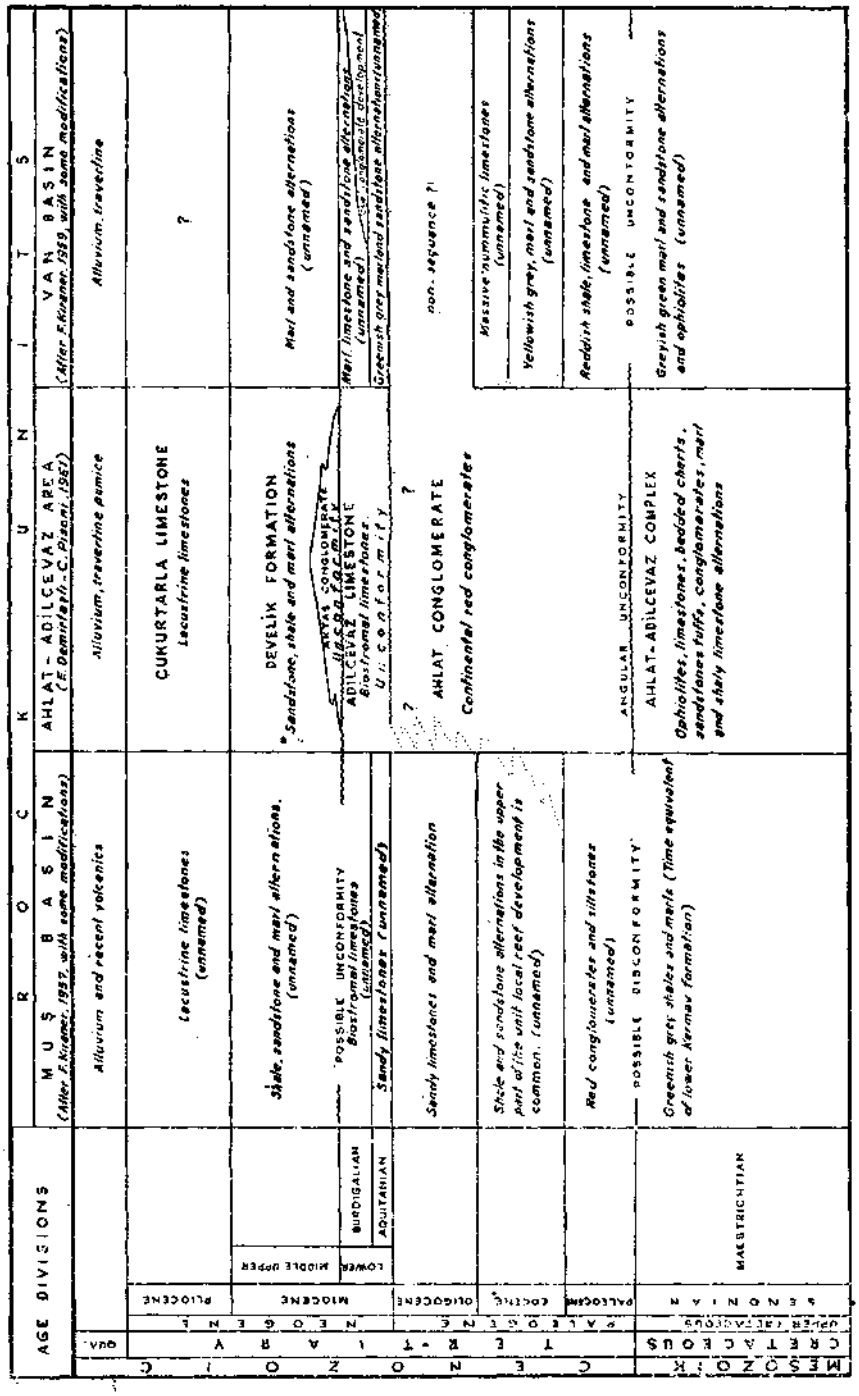
This complex, exposed in wide areas between the towns of Ahlat and Adilcevaz, has been mapped as six basic units, namely :

1. ophiolites
2. limestone unit (denoted by K_1)
3. bedded chert unit (K_2)
4. arenitic, pyroclastic and conglomeratic unit (K_3)
5. fine clastic, marl and shaly limestone unit (K_4)
6. reefs (K_5)

Due to the sudden facies changes within these units and to the generally complicated stratigraphic relations among them, the authors avoid to propose formal names at this stage of their study of the area. However an attempt has been made to provide type sections, as far as possible, for each unit. According to the authors, the Ahlat-Adilcevaz complex is a result of the sedimentation in the main Toros-Zagros eugeosyncline, which extended to the Ahlat-Adilcevaz area during Cretaceous period.

1. Ophiolites. — During the formation of the Ahlat-Adilcevaz complex, different ophiolitic extrusions took place. These rocks have the petrographic composition of a pyroxenitic basalt, in which the plagioclase components are represented by labradorite, bytownite and/or albite. Olivine, more or less serpentinized, is also generally present.

Table - 2


AGE DIVISIONS
MUŞ BASIN
(After F.Kozlu; 1987, with some modifications)
AHLAT - ADİLCEVAZ AREA
(E.Demirtaşlı-C.Pişkin, 1987)
VAN BASIN
(After F.Kozlu; 1989, with some modifications)
Alluvium and recent volcanics
Alluvium, travertine pumice
Alluvium, travertine
Lacustrine limestones (unnamed)
CUKURTARLA LIMESTONE
Lacustrine limestones
?
Shale, sandstone and marl alternations. (unnamed)
DEVELİK FORMATION
*Sandstone, shale and marl alternations
Marl and sandstone alternations (unnamed)
POSSIBLE UNCONFORMITY
Biostromal limestones (unnamed)
KAYAS CONGLOMERATE
ADİLCEVAZ LIMESTONE
Biostromal limestones
Unconformity
Marl limestone and sandstone alternations (unnamed)
Lateral development
Greenish grey marl and sandstone alternations (unnamed)
Sandy limestones (unnamed)
?
non. sequence ?
Sandy limestones and marl alternation
AHLAT CONGLOMERATE
Continental red conglomerates
Massive nummulitic limestones (unnamed)
Shale and sandstone alternations in the upper part while unit local reef development is common. (unnamed)
Yellowish grey, marl and sandstone alternations (unnamed)
Red conglomerates and siltstones (unnamed)
ANGULAR UNCONFORMITY
Reddish shale, limestone and marl alternations (unnamed)
POSSIBLE DISCONFORMITY
POSSIBLE UNCONFORMITY
AHLAT-ADİLCEVAZ COMPLEX
Greenish grey shales and marls (Time equivalent of lower Kermav formation)
Ophiolites, limestones, bedded cherts, sandstones tuffs, conglomerates, marl and shaly limestone alternations
Greyish green marl and sandstone alternations and ophiolites (unnamed)
MAASTRICHTIAN

The oldest extrusion crops out 2 km east of Ahlat, at the locality known as Dargaban, At Kırmalar Tepe this extrusion is overlain by the red bedded chert unit and at Kulaksu Tepe, by the limestone unit (Plate III- 1.k).

In the central-soıuthern part of the area, rocks of basaltic type are intercaleted in the Upper Gretaceous Sediments near Bahçedere and İpekçayır villages. The basalt forms sheets up to 100 m thick. South of İpekçayır the basalt has a pillow structure. Further east, northwest of Dikiş village, the basalt is unconformably overlain by the Ahlat conglomerate and, in the Adilcevaz valley, by the Adilcevaz limestone.

2. Limestone unit (K_1). —The unit crops out at Kulaksu Tepe, 3 km north-east of Ahlat (Plate III-2.k) Here 20 m thick limy sandstone overlies the ophiolites of Dargaban, and itself is overlain by a dark gray, thin-bedded, highly fossiliferous limestone, approximatly 150 m thick. To the west, the -limestone interfingers with the sandstones of the lowermost part of K_3 (Plate III-1.k).

Although the northern extension of the limestone unit is covered by large pumice deposits, it seems that the limestone interfingers also with the bedded chert unit.

The fossils observed in the limestone unit are the folknving :

Globotrımcana lapparenti tricarinata Ouereau
Globotrımcana linneiana d'Orb.
Globotruncana cf. *stuarti* de Lapparent
Globotruncana arca Cushman
Globigerina cretacea d'Orb.
Gümbelina globulosa Ehrenberg

They are indicating a Maestrichtian age for this unit.

3. Bedded chert unit (K_2). — The type section of the bedded chert unit is exposed at Kırmalar Tepe (Plate III-2.k), where thin-bedded radiolarian chert directly overlies the ophiolite. The rock is generally red and occasionally green-colored, hard, compact and brittle. Red color is due to high limonite infiltrations. Greenish parts of the chert are due to chlorite. More than fifty per cent of the rock mass is composed of cryptocrystalline chalcedonite, the rest being radiolarian skeletons. Ojuartz veinlets are common.

No fossils have been observed in the unit, except Radiolaria. As to south and southwest the bedded chert unit interfingers with Maestrichtian Sediments, its age can be assumed to be as Maestrichtian.

4. Arenitic, pyroclastic and conglomeratic unit(K_3). — The lowermost part of this unit is well exposed at Tonus (Plate III - 3.k). There, it directly overlies the ophiolite of Dargaban, which is the oldest rock in the area. At the lowermost part of the unit there are conglomerates, a few meters thick, which grade upwards into sandstones and calcareous sandstones. The arenitic sequence at Tonus shows several sandy limestone intercalations corresponding, most probably, to the intertongues of the limestone unit of Kulaksu Tepe.

In the arenitic part of the unit under description, generally two types of sandstones are recognizable. The first type shows limonitic-chloritic cement, whereas the cement of the second type is highly calcareous. The grains of the two types are more

or less the same, being fragments of ophiolite, limestone, quartz, feldspar, augite and hornblende.

In the upper part of the Tonus section, in the calcareous sandstone intercalations, were found the following Foraminifera, indicating Maestrichtian age :

Globotruncana cf. *arca* Cushman
Orbitoides cf. *media* d'Arch.
Siderolites cf. *calcitrapoides* Lmk.
Lepidorbitoides cf. *socialis* Leym.

generally associated with the same Foraminifera found in the limestone unit at Kulaksu Tepe. This may indicate the same stratigraphic horizon for the two units.

The middle and upper part of this unit is exposed in the Kepirli and Dargan creeks (Plate III-4.k). However, due to thrust faulting, which involves the ophiolite of Dargan, at least 300 m of the unit is missing. Starting from the fault and going north, along the Başlıkaya section, 200 m of the unit is composed of sandstones with limonitic-chloritic cement. The sandstones gradually change into calcareous sandstone and sandy limestone intercalations. They are conformably overlain by fairly light-colored, 80 m thick bedded tuffs, which are very fine-grained, compact, hard and with the groundmass of altered vitreous matrix composed of acidic plagioclase, orthoclase and rare hornblende and augitic crystals. The tuffs are conformably overlain by calcareous sandstone and arkosic sandstone alternations, 420 m thick, followed by 150 m thick-bedded chert and 100 m thick tuffs, of similar types to those described above. After that, 100 m thick calcareous sandstones follow. The calcareous sandstones are, then, overlain by very thick (880 m) conglomerates, which include tuff and ophiolite intercalations.

All this part of the section is completely barren of fossils.

Outside the type section area, to the west of Bahçedere village, the unit is composed of massive conglomerates, corresponding to those above mentioned. The rock is dark green in color, made up almost entirely of rounded pebbles of basaltic nature and rare large granitic pebbles, set in an arenaceous matrix. The conglomerates are followed upwards and partially interfinger with generally well-bedded sandstones, from gray to dark green in color, medium textured, with some intercalations of greenish and dark gray marl and thin-bedded red chert. No fossils have beed found here.

5. Alternatioıı of fine clastlcs, marls and shaly limestone unit (K_4).— This unit is well exposed south of Başlıkaya Tepe (Plate III-4.k), where it conformably overlies the conglomerates of K_3. It consists of an alternation of fine sandstones, siltstones, shales, .marls and shaly limestones. its lower part is rather sandy and shows pillow and ball structures (Photo 3).

The sandstones are possibly of graywacke type. The grains are fragments of ultrabasic rocks and the cement is either clayey or calcareous. Indications of-unstable conditions of sedimentation exist.

In the middle and upper parts of the unit, carbonates, mostly shaly limestones and marls, are well developed.

The section between the Somkar Mountain and Lake Van. in the central southern part of the area, is composed of variegated, compact, lithographic, well-bedded

marly limestone, rich in Foraminifera, a few hundred meters thick, with intercalations of gray sandy limestone. Here, the stratigraphic relation between this unit and K_3 is not clear, especially due to extensive surface deposits around Bahçedere village. it seems, however, that the two units are facies which partially pass, into each other laterally.

Generally, the uppermost part of the unit is of sandy nature. The overall thickness is about 400 m.

The Foraminifera association recognized in the marly deposits of the units, is characteristic of a Maestrichtian age and is composed as follows :

Orbitoides cf. *media* d'Arch.
Globotruncana linneiana d'Orb.
Globotruncana lapparenti tricarinata Quereau
Globotruncana lapparenti lapparenti Bolli
Globigerina cretacea d'Orb.
Gümbelina globulosa Ehrenberg

6. Reefs (K_5). —The more important reef in the area, can be seen at Başlıkaya Tepe. It is a patch reef of rather small dimensions, that is 100 m wide, 200 m long and 40 m thick. The reef is composed of thick-bedded or massive, highly fossiliferous limestone, which changes laterally into a limestone breccia. In its core, aphanitic limestone has been observed.

Another small patch reef, four times smaller in size than the above described, can be seen 500 meters southeast of Kafir Kalesi Tepe. It shows exactly the same lithologic characters of the Başlıkaya Tepe patch reef.

The following Maestrichtian Foraminifera have been found in these two reefs:

Globotruncana linneiana d'Orb.
Globotruncana lapparenti tricarinata Quereau
Orbitoides cf. media d'Archiac

Ahlat conglomerate

This formation can easily be recognized in the field due to its red color and predominant conglomeratic texture. It unconformably overlies the Ahlat-Adilcevaz complex and is overlain by the Adilcevaz limestone.

The general rock composition of the formation is characterized by thick-bedded, red conglomerate and occasional thin layers of reddish, non fossiliferous siltstone. The pebbles of the conglomerate are generally of large size and are derived from the different units of the Ahlat-Adilcevaz complex. No single pebble containing fossils of Eocene or Oligocene has been found in the Ahlat conglomerale.

A good section of the Ahlat conglomerate can be seen near Cemalettin village, 9 km northeast of Ahlat (Plate III-5.k).

The formation is very extensive in the central, southern and southeastern part of the area. The thickness at the section of Cemalettin village is 1250 m, but gradually becomes thinner towards east and south. The maximum thickness of the formation around İpekçayır village is 550 m. Further east, near Adilcevaz, the formation disappears, the Adilcevaz limestone overlying unconformably the ophiolites of the Ahlat-Adilcevaz complex.

The same situation prevails in the southern part of the area. South of Oralbaşı Tepe, 7 km east of Ahlat, the Ahlat conglomerate suddenly disappears and the lowermost sandy part of the Adilcevaz limestone, unconformably overlies the oldest ophiolites of the Ahlat-Adilcevaz complex. The Ahlat conglomerate can be traced to the west, only as far as Nazik Lake, outside of the area under discussion, where it disappears under extensive basaltic lava flows of Nemrut volcano.

These coarse red beds indicate a continental sedimentation related to extensive uplifting, which has occurred after the deposition of the Ahlat-Adilcevaz complex.

No fossils have been found in the formation. Due to its stratigraphic position, its age is post-Maestrichtian - pre-Burdigalian. In the eastern extension of the Muş basin, 30 km southwest of Ahlat, normal marine sediments of Eocene-Oligocene age can be seen. In the opposite direction, 50 km east of Adilcevaz, marine Eocene sediments are present, in the western extension of the Van basin. A comparison of the stratigraphy of the area under discussion with the stratigraphy of the Muş region and Van region, as shown in Plate II, shows the possibility to accept the Ahlat conglomerate, as the continental time equivalent of Eocene and possibly Oligocene marine sediments of Muş and Van basins.

Adilcevaz limestone

The Adilcevaz limestone is transgressive over the Ahlat conglomerate and the ophiolites of the Ahlat-Adilcevaz complex. The formation presents a typical shelf deposition, which predominantly consists of normal marine and biostromal limestone.

The sediments are light-colored and show generally thick and/or massive bedding. Generally, an arenitic and pebbly limestone member, which marks the transgression, can be seen at the base of the formation.

A rich fossil content, both in micro and macrofossils, can be found throughout the formation.

The type locality of the Adilcevaz limestone is very close to the town of Adilcevaz, namely, the locality called Dikis mahallesi. At the type section (Plate III-6.k), the formation is 800 m thick and consists of, from top to bottom, the following:

5. 250 m of yellowish-gray, massive, partly dolomitic limestone, which contains Corals and mAphistegina lessonii d'Orb., Amphistegina sp., Elphidium, Rotalia, Textularia and Melobesiae.
4. 200 m of medium to thick-bedded, yellowish to gray detrital limestone, containing Aturia sp. gr. angustata (Conrad), Clypeaster, Schizaster, Turritella, Pecten, Flabellipecten burdigalensis (Lamarck), Chlamys and some Corals in individual forms.
3. 35 m of massive, light-colored, partly dolomitic limestone, containing Corals.
2. 300 m of gray and yellowish detrital limestone, forming beds up to 1 m thick, containing Conus, Chlamys cf. northamptoni (Mich.), Pecten and Miogypsina irregularis (Mich.), Miogypsina sp., Miogypsinoides sp., Amphistegina radiata (Fichtel & Moll), Amphistegina lessonii d'Orb., Operculina complanata (Defr.), Miliolidae and sections of Annelids. Intercalations of thick beds of light brown, coarse textured crystalline limestone.

1. 15 m of gray, medium bedded, sandy and pebbly limestone, which contains *Operculina complanata* (Defr.), Miogypsina sp., Miogypsinoides sp., Amphistegina radiata (Fichtell & Moll), Globigeriria bulloides d'Orb., Orbulina, Textularia and sections of Annelids. The unit overlies unconformably the Ahlat conglomerate.

The thickness of the formation gradually thins westwards. At Ziyaret Mountain, the maximum thickness is 500 m. To "the west of Aktaş., near the \vestern border of the area, the thickness is 150 m.

East of the town of Adilcevaz, the Adilcevaz limestone unconformably overlies ophiolites and dips under the recent basalt flows of the Süphan, volcano. Here, the formation consists mainly of biostromal limestones, from gray to buff in color. The bedding is very thick and/or massive. Intercalations of cherty limestone are present. The fossil content is represented by associations of colonial Corals (probably Heliastrea), Oysters of large size and Miogypsina, Operculina, Amphistegina, Miliolidae, Bryozoa and Melobesiae.

Limestones of similar type and containing similar fossil associations, outcrop northeast of Aygır Lake, between the hill named Tavşan Tepe and the Kadıköy village.

The fossils recognized in the Adilcevaz limestone, indicate a Burdigalian age,

It is easy to correlate the formation with the unnamed limestone sequence of Lower Miocene age of the Muş basin, to the west, on the basis of similarities in lithology and fossil content.

Correlation can also be drawn with the unnamed formation which consists of alternations of limestone and elastics, of Lower Miocene age, of the Van basin.

In these two adjacent basins, relatively arenitic carbonates represent the Aquitanian stage. As it has already been mentioned before, in the Ahlat-Adilcevaz area, nearly everywhere, the lowest part of the Adilcevaz limestone is also represented by arenitic carbonates. Therefore, it is possible that the lowermost part of the Adilcevaz limestone, may indicate the Aquitanian stage in the area.

Aktaş conglomerate

It is a polygenic, loosely cemented conglomerate. The type locality is to the north of Aktas. tepe, 12 km NNE of Ahlat. There, the formation overlies unconformably the Adilcevaz limestone. The maximum thickness of the formation is 200 m. It generally shows a local development, disappearing in the northeastern and northwestern part of the area.

No fossils have been found in this formation. Since it is conformably overlain by the Develik formation, of Middle-Upper Miocene age, its age may also be assumed as Middle Miocene.

Develik formation

It is an alternation of sandstones, shales and marls, which conformably overlie the Aktaş, conglomerate, when the latter is present. In the absence of Aktaş, conglomerate, it unconformably overlies the Adilcevaz limestone.

The formation is well exposed near Develik village, 18 km north of Ahlat, where its thickness can be estimated to be 800 m Due to frequent folding, a type section can not be given. The lowermost 300 m of the formation are cross-bedded sandstones (Photo 5). Near Dizdar village, the cross-bedded sandstones include several intercalations of clay. The clays contain Ostracods and Eponids, indicating a marine shallow water environment of deposition and a Middle Miocene age. Over the cross - bedded sandstones, lie conformably 400 m of sandstone, shale and marl alternations. These sediments contain tiny shells of Pelecypods and Gastropods, but none of them are diagnostic of age. The uppermost 100 m of the formation are sandy, conglomeratic and highly calcareous. The limestone bands bear shells of Dreissensia, indicating Upper Miocene - Lower Pliocene age. This part of the formation passes laterally into the base of the Çukurtarla limestone.

In the central-eastern part of the area, near Kağıtgir and northwest of Seydikar Mountain, there are some poorly exposed outcrops of sandy clays, overlying the Adilcevaz limestone. These sediments can be considered as the lower part of the Develik formation, in this part of the area.

The rock is characterized by the following Foraminifera : Globobulimina, Nonion, Valvulineria, Robulus, Bifarina, Siphonina, Bolivina, Discorbis ?, Cibicides and Globigerinides.

The association is indicative of a marine facies and of a Miocene age, probably Middle Miocene.

Çukurtarla limestone

It is a hard, dense, lacustrine limestone, which overlies and partly passes laterally into the Develik formation.

The unit can be best examined west of Çukurtarla village. Due to frequent folding, it is difficult to give a type section for the formation.

The formation becomes thicker to the west, where it is also more widely exposed. The authors believe that the formation, as with the Develik formation, can be better examined in the northeastern part of the Mus, basin, outside the area under discussion.

Quaternary deposits

The youngest sediments in the area, forming superficial deposits and considered Quaternary in age, have been subdivided and mapped as follows :

a. Travertine
b. Terrace deposits
c. New alluvium

a. Extensive outcrops of travertine, generally related to cold springs, are situated in the Adilcevaz valley and around the villages of Yolçatı, Yukarısüphan and Aşağısüphan. The deposits, ranging in color from gray to yellowish, are sometimes conglomeratic and attain a maximum thickness of 10-15 m.

In the Adilcevaz valley the travertine deposits cover the ophiolites, elsewhere, the late Cenozoic volcanics.

b. Terrace deposits or their remnants, made up of sand and gravel, sometimes poorly cemented, are preserved along the shore of Lake Van, namely south of Bahçedere village, around Patnos Mahallesi and between Adilcevaz and Yolçatı village.

Between Adilcevaz and Yolçatı, the boundary between terrace and travertine deposits, is rather gradational and not clearly distinct. Some outcrops along the road to Erciş, show alternations of sand and gravel, with pebbles of basaltic, andesitic and calcareous composition, sometimes partly cemented and sometimes cross-bedded. The top of the outcrops is often composed by some meters of conglomerates, having travertine as cementing material. Where the road to Erciş is crossing the creek Taşbaba, a bank of gravel 3 m thick, entirely composed of pebbles of pumice, is intercalated in the sand and gravel.

The maximum thickness of these alluvial,sediments, is about 20 m.

c. New alluvium are especially confined to the area of Lake Süte and along the shore of Lake Van. In the latter locality they generally form lacustrine deltas, the more typical one being preserved to the south of Bahçedere village.

V. LATE CENOZOIC VOLCANICS

Different kinds of lavas and pyroclastic rocks, generally considered as late Cenozoic in age (Altınlı, 1964), cover large portions, mainly in the eastern and northern parts of the studied area. These rocks are related to the activity of the Süphan volcano and to minor centers of activity in its surroundings.

Süphan volcano is situated about 20 km northeast of Adilcevaz. According to İ.E. Altınlı (1964), it is a strato volcano built up, mainly, of andesite and obsidian.

The volcanic rocks of the area have been mapped according to the following subdivisions :

a. andesite and rhyolite
b. basalt
c. cemented tuff
d. pumice
e. volcanic ashes

a. Andesite and rhyolite correspond to the oldest products of the late Cenozoic volcanism in the area.

Andesite forms the Nernek Mountain, southeast of Lake Aygır. The rock, intensively jointed, light brown to buff-colored, has the composition of a trachyandesite, with phenocrysts of biotite, andesine, sanidine and quartz, in a vitreous matrix. The andesite, or trachyandesite, is covered by pyroclastic deposits, mainly composed of volcanic ashes.

North of Lake Aygır there are masses of rhyolitic rocks, forming the southern slopes of the Süphan volcano. The petrology of the rock is essentially characterized by phenocrysts of quartz, albite, sanidine, biotite and pyroxene, set in a vitreous matrix with feldspatmicrolite.

ENE of Kadıköy village, the rhyolite covers the Adilcevaz limestone and is, in turn, covered by pyroclastic loose deposits.

b. Basalt is very extensive in the northern part of the area, where the lava flows form basaltic plateaus around the main cone of Süphan volcano. The lavas represent at least two main basaltic phases. The first one follows the andesitic-rhyolitic phase(s) and produces very extensive sheets of lava, sometimes considerably thick, covering a large portion of the northern part of the area, The lava extends in tongues also southwards, between Seydikar Mountain and Lake Aygır. The youngest flows, extending north of Yukarısüphan village, cover the volcanic ashes of the area around Lake Aygır.

The petrographic nature of the lavas, is basaltic-pyroxenetic. The rock often shows flow structure, columnar jointing and, at the surface of the lava sheets, vesicular structure. In the vicinities of Harmantepe village, the basalt contains frequent and important lenses of obsidian.

In the northern part of the area, the basalt covers the Develik formation; to the south it overlies the Adilcevaz limestone, while it is covered by volcanic ashes and other coarser ejectamenta.

c. Cemented tuff of ignimbritic type, probably contemporaneous with the andesitic-rhyolitic lavas, is largely exposed to the northeast of Ahlat, in the Uludere valley.

It is composed of altered and kaolinized vitreous matrix, together with occasional fragments of quartz, albite, orthoclase, sanidine and hornblende.

The cemented tuff unconformably overlies the Ahlat-Adilcevaz complex, Ahlat conglomerate, Adilcevaz limestone and Develik formation. To the northeast of Ahlat it is overlain by the pumice. Near Şekerova village, north of Lake Süte, a small outcrop of similar tuff is covered by the basalt.

d. The pumice is restricted to the east and north of Ahlat. It overlies all the other formations, including the cemented tuff. It is generally composed of unconsolidated aggregates of vitreous material.

e. The eastern part of the area is largely covered by pyroclastic loose deposits, mainly volcanic ashes, with associated lapilli, volcanic bombs and large and small fragments of andesite and obsidian. Sometimes the volcanic ashes show a cross lamination. In the volcanic ashes there are lenses or intercalations of pumiceous tuffs, tufaceous sands and agglomerates.

All these pyroclastic materials, or a large part of them, have been ejected by the explosion that formed the crater of Lake Aygır, now having the appearance of a characteristic maar (Photo 6). With the pyroclastics, particularly to the south of Nernek Mountain, are associated fresh-water sediments, composed of alternations of poorly cemented sandstones and well bedded marls and sands, the latter showing a cross-lamination.

VI. STRUCTURAL GEOLOGY

Regional features

In the regional tectonic framework, the area under discussion lies over the main southern axis of the alpine orogeny, namely the Toros - Zagros orogenic belt.

Another gross tectonic feature, which affected the area, has been known as the Van transversal high (Parejas, 1940). This positive area possibly existed during Eocene-Oligocene times and separated the Muş basin from the Van basin.

Folds

One fold system in the area, involves the Ahlat-Adilcevaz complex and trends NW-SE. The folds are strongly asymmetrical, very tight and present generally a disharmonic style. This folding is probably related to the Laramian orogeny and has been followed by a general uplift of the area. Extensive erosion of the uplifted area, supplied abundant material for the deposition of the Ahlat conglomerate on its flanks.

Another important structural feature of the area, is the Ahlat-Adilcevaz uplift. The core of the uplift is the Ahlat-Adilcevaz complex, while the rim rocks are formed by the Ahlat conglomerate and the Adilcevaz limestone. The trend of the axis of the uplift is NE-SW.

The youngest fold system is of late Tertiary age. It involves the Middle Miocene-Lower Pliocene formations of the northern part of the area. The general direction of the axis of this folding follows, more or less, the axis of the Ahlat-Adilcevaz uplift, that is NE-SW. The folds are open, symmetrical and of concentric type.

Faults

Both reverse and normal faulting is known in the area. Reverse faulting, probably related to Laramian tectonic phases, involves the units of the Ahlat-Adilcevaz complex and is observable in the southwestern part of the area.

One of the faults is located to the west of Oralbaşı Tepe, where the ophiolites are thrusted over the unit K_3 of the Ahlat-Adilcevaz complex. The fault line trends NE-SW.

Another fault, trending NNW-SSE, occurs to the east of Kırmalar Tepe. Ophiolites and the bedded chert unit are thrusted over the conglomerates of unit K_3.

Gravity faults follow, more or less, a N-S direction. They are located in the central southern part of the area. The more important ones occur north-northeast of Adilcevaz, near Kıztaşı village and near İpekçayır village. The youngest formation involved in this faulting is the Adilcevaz limestone, of Burdigalian age. This places the age of the faulting as post-Burdigalian.

The faults occurring near Adilcevaz caused the subsidence of the block of the Kafir Mountain, with a maximum vertical displacement of almost 200 m Near Kıztaşı and İpekçayır villages, the faulting probably has also horizontal displacement.

The strong late Cenozoic volcanic activity appears to be related to regional fissure zones, trending SW-NE, along which are aligned the Nemrut, Süphan, Tendürek and Ararat volcanoes (Altınlı, 1964).

Unconformities

In the area investigated, three main unconformities are present.

The first one exists between the Ahlat-Adilcevaz complex and the Ahlat conglomerate, and is an angular unconformity.

The second unconformity, which appear to be a disconformity, separates the Ahlat conglomerate from the Adilcevaz limestone. Its presence is indicated by an arenitic and pebbly member at the base of the transgressive Adilcevaz limestone, which oversteps on the older Ahlat conglomerate and ophiolites.

The third unconformity which also appears to be a disconformity, is situated between the Adilcevaz limestone and the overlying Aktaş conglomerate and Develik formation.

The tectonic features of the area are schematically shown in the Plate IV.

VII. HISTORICAL GEOLOGY

Rocks older than Upper Cretaceous are not exposed in the Ahlat-Adilcevaz area.

During the Upper Cretaceous, a geosyncline trough, trending NW-SE, was present in the area. Different types of sedimentary rocks, such as bedded cherts, limestones, pyroclastics, sandstones and conglomerates, were mingled with or cut through by ophiolites. Turbidity seems to have hindered organic life. On the other hand, in scattered areas with limestone deposition, abundant fossils are found. Owing to the unstable bottom conditions, ball and pillow structures developed during sandstone deposition. Wedging out and interfingering were common sedimentary features. Small patch reefs found favoring conditions in certain localities. In the deeper parts of the geosyncline, fine elastics and shales were deposited with subsidiary interference of ophiolites.

At the end of the Upper Cretaceous period, the area was uplifted, giving rise to the folds trending in a NW-SE direction. This orogenic activity resulted in regional folding, emergence and erosion. The withdrawal of the sea, the establishment of lagoonal and even continental conditions, produced in the emerged areas a conglomeratic red bed facies (Ahlat conglomerate).

During Eocene and Oligocene epoques, in the Muş basin, west of the Ahlat - Adilcevaz area, normal marine sedimentation took place. It is the authors' belief that the red bed sequence is a comprehensive continental formation occurring along the border of the Muş basin and grading southwestwards into a thick marine sedimentation of the Muş basin.

A regional transgression followed the deposition of the red bed sequence, and shallow neritic carbonates (Adilcevaz limestone), corresponding to stable shelf conditions, were deposited, during the Lower Miocene, in the area.

The later movements affected the area, which underwent local erosion, giving rise to the local deposition of the Aktaş conglomerate. During Middle - Upper Miocene, the area was under the effect of epeirogenic movements; sandy, marly and shaly sediments were deposited (Develik formation). During the Upper Miocene - Lower Pliocene times, the sea withdrew, causing large lakes and the deposition of lacustrine limestones (Çukurtarla limestipne). The latest movements caused intensive folding in the northern part of the area.

During late Cenozoic, intermittent volcanic activities, which continued until recent times, extruded andesites, basalts and tuffs.

VIII. SUMMARY AND CONCLUSIONS

The oldest rocks of the area, which form the Ahlat-Adilcevaz complex, are of Upper Cretaceous age. These rocks were shown by the earlier workers as formations of Miocene age. The Upper Cretaceous rocks are unconformably overlain by the Ahlat conglomerate, of possibly Eocene-Oligocerie age. These conglomerates are shown to thin out and disappear southwards as well as eastwards. Contrary to the earlier workers, who considered these conglomerates as the basal conglomerate of the Miocene marine series, they have been correlated with Eocene-Oligocene unnamed marine formations of the adjacent Muş and Van basins. The Ahlat conglomerate is considered of continental origin.

The Adilcevaz limestone, which consists mainly of normal marine and biostromal limestones, is transgressive over the Ahlat conglomerate and the Ahlat-Adilcevaz complex. The age of the formation is Lower Miocene.

The Aktaş conglomerate and the Develik formation, overlie unconformably the Adilcevaz limestone. The Develik formation consists of alternations of sandy, marly and shaly sediments, and it is conformably overlain by the Çukurtarla limestone, of lacustrine origin. These three formations range in age from Middle Miocene to Lower Pliocene.

The Quaternary deposits are represented by travertine, terrace deposits and new alluvium.

The Upper Cretaceous rocks form the core of the NE-SW trending Ahlat-Adilcevaz uplift. These rocks themselves have been folded along NW-SE trending axes. Both reverse and normal faults are present in the area.

During the Upper Cretaceous, a geosyncline trough, trending NW-SE, was present in the area. During Eocene-Oligocene times continental conditions of sedimentation prevailed. A regional marine transgression took place during the Lower Miocene. The sea withdrew from the area at the end of the Miocene epoque. During Upper Miocene-Lower Pliocene times, lacustrine environments prevailed in the area. During late Cenozoic, intermittent volcanic activities, which continued until recent times, extruded different kinds of lavas and pyroclastic rocks.

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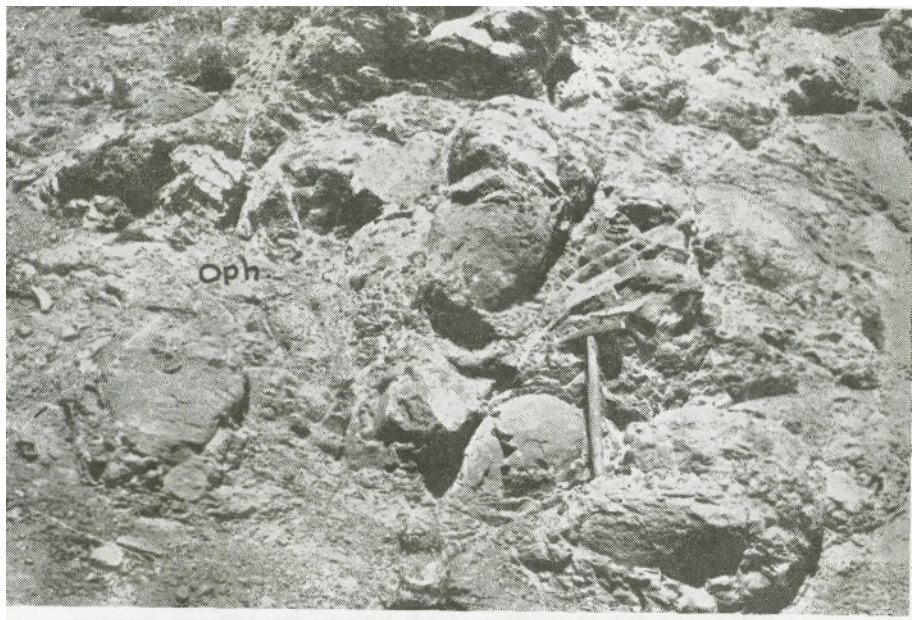


Photo 1 - Pillow structure in ophiolites **(oph) at Dargaban.**

Photo 2 - Pillow and ball structures in the unit K_4 of the Ahlat-Adilcevaz complex, near Başlıkaya Tepe.

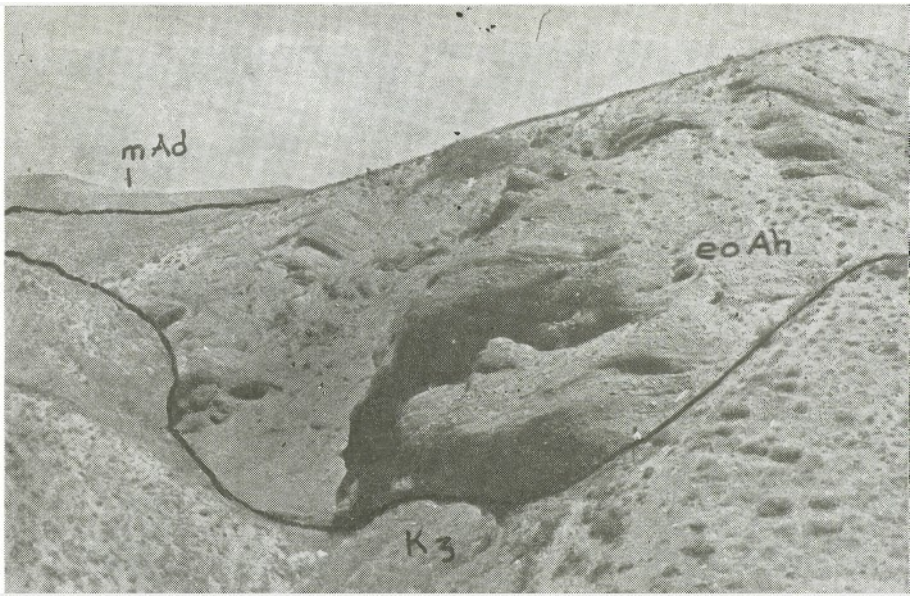


Photo 3 - Unconformity between the Ahlat conglomerate (eoAh) and the Ahlat-Adilcevaz complex (K_3), near Bahçedere village. mAd, indicates the Adilcevaz limestone.

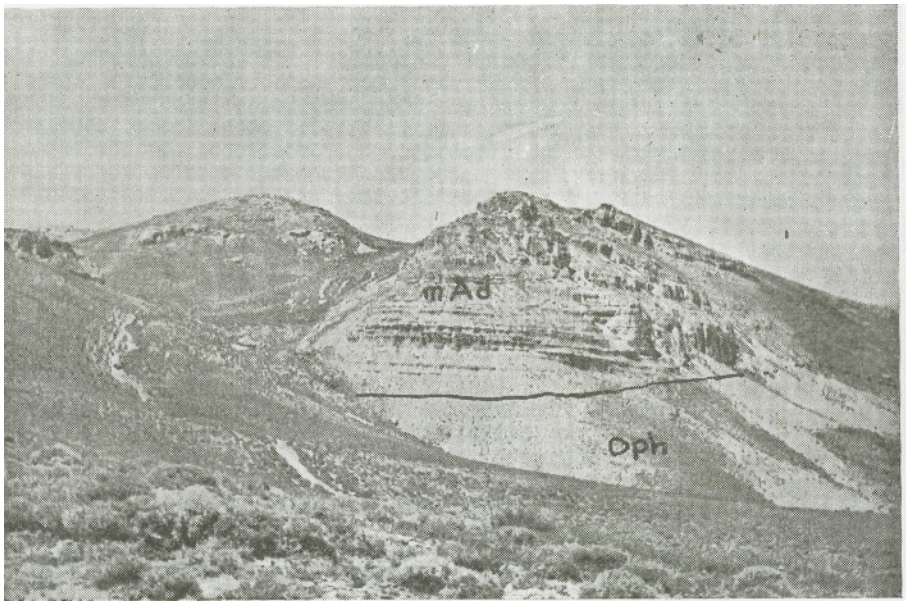


Photo 4 - The Adilcevaz limestone (mAd), overlying ophiolites (oph) to the north of Adilcevaz.

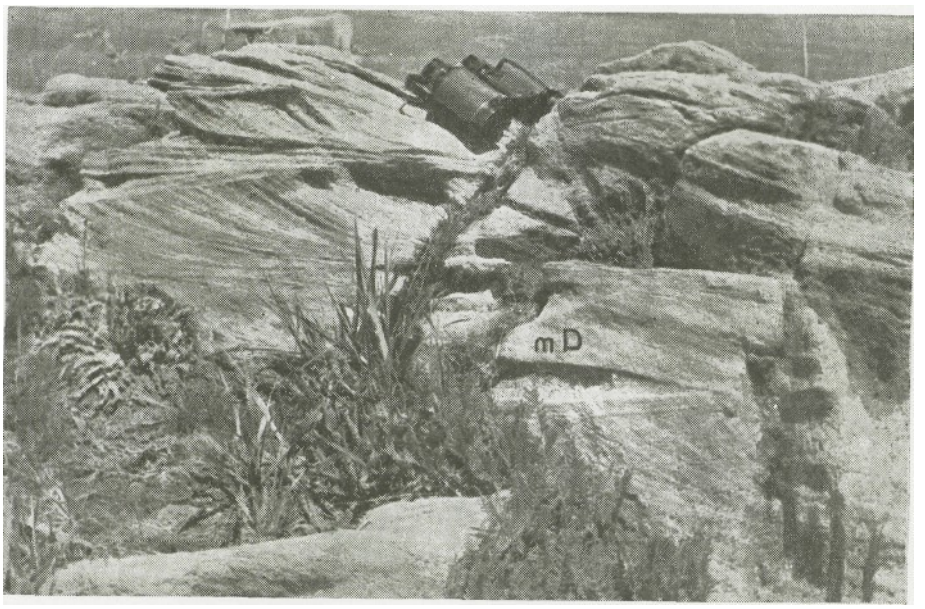


Photo 5 - Cross-bedded sandstones of the Develik formation (mD), near Dizdar.

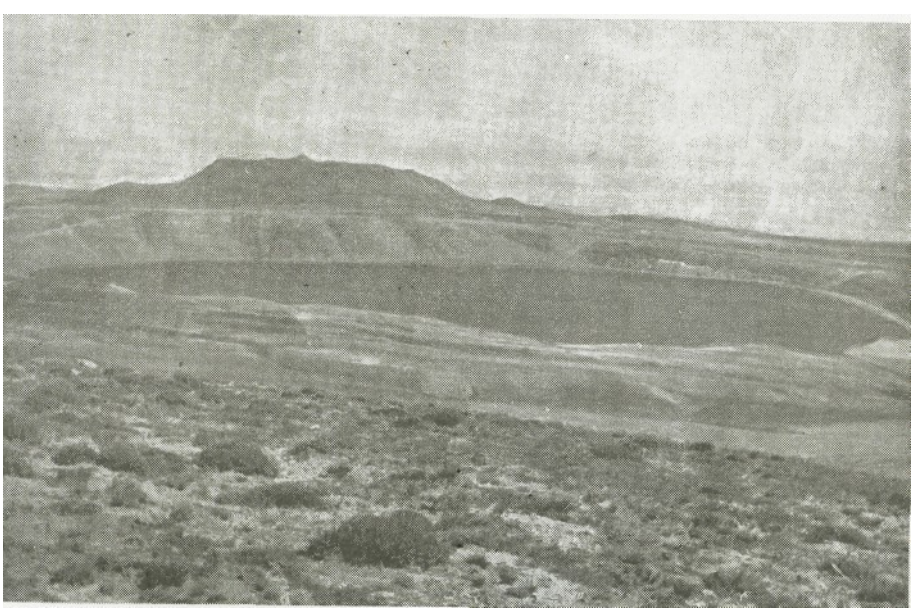
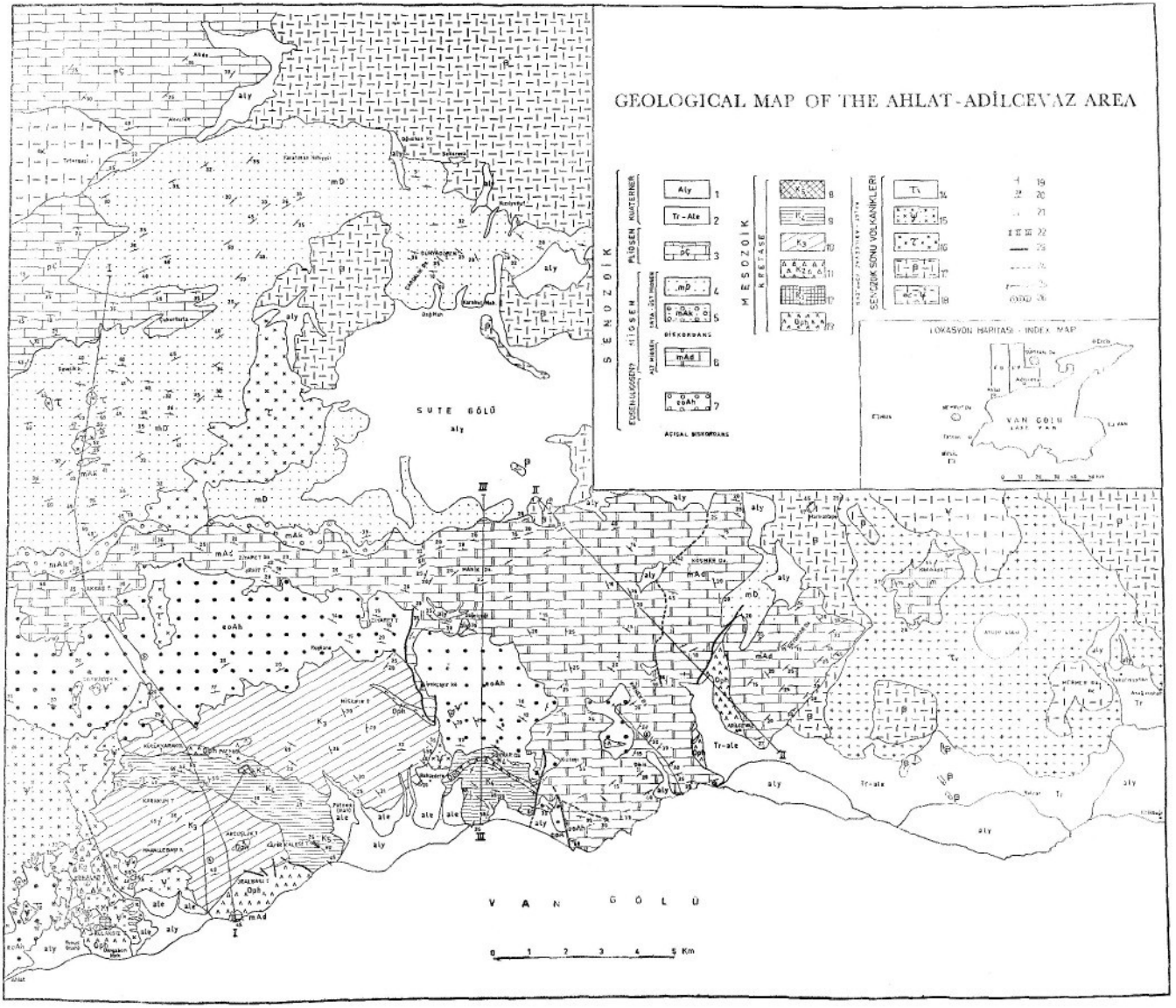
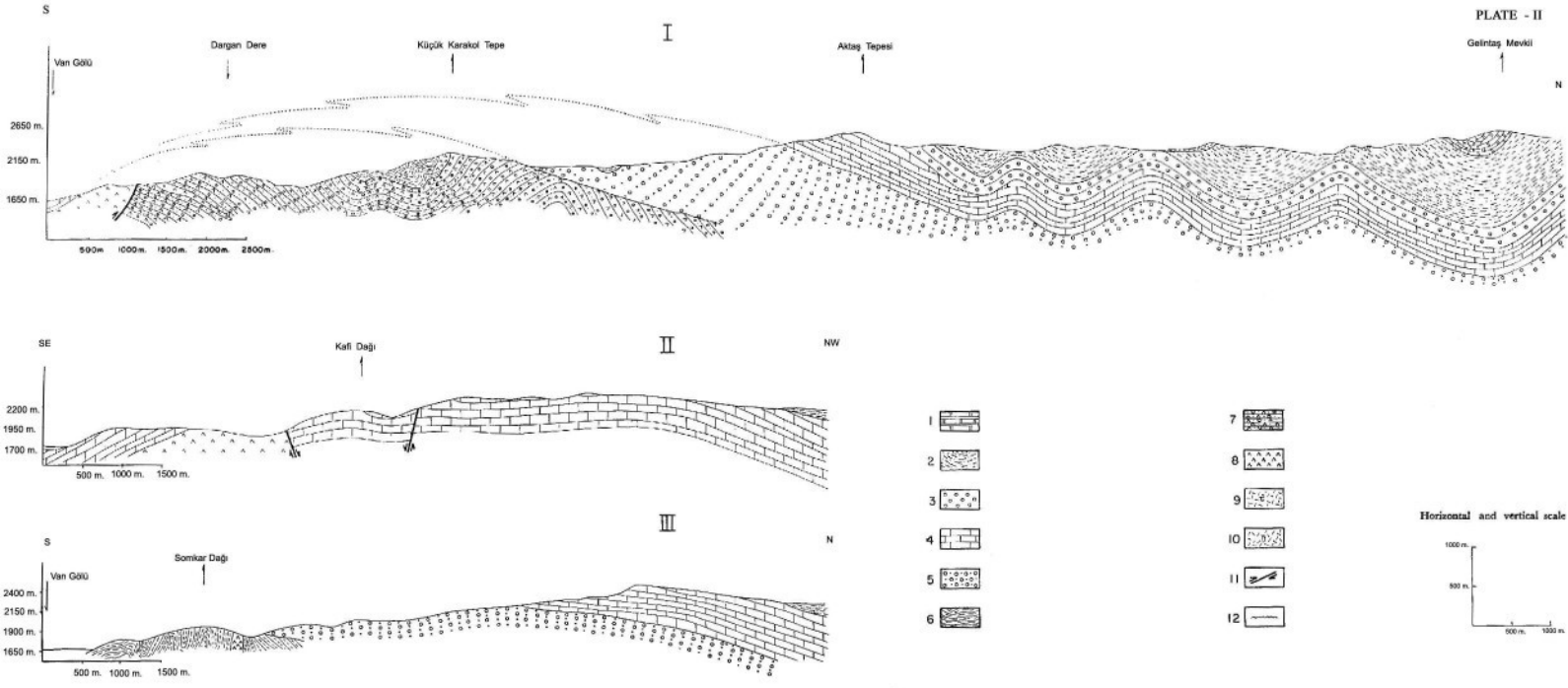


Photo 6 - The maar of Aygır Gölü.



1 - Alluvium; 2 - Travertine and old alluvium; 3 - Çukurtarla limestone; 4 - Develik formation; 5 - Aktaş conglomerate; 6 - Adilcevaz limestone; 7 - Ahlat conglomerate; 8 - Reefs; 9 - Alternation of fine clastics, marl and shaly limestone unit; 10 - Arenitic, pyroclastic and conglomeratic unit; 11 - Bedded chert unit; 12 - Limestone unit; 13 - Ophiolites; 14 - Volcanic ash; 15 - Sponge; 16 - Cemented tuff; 17 - Basalt; 18 - Andesite and rhyolite; 19 - Horizontal beds; 20 - Dip and strike of beds; 21 - Vertical beds; 22 - Numbers of cross-sections; 23 - Fault; 24 - Probable fault; 25 - Formation boundary; 26 - Type sections.

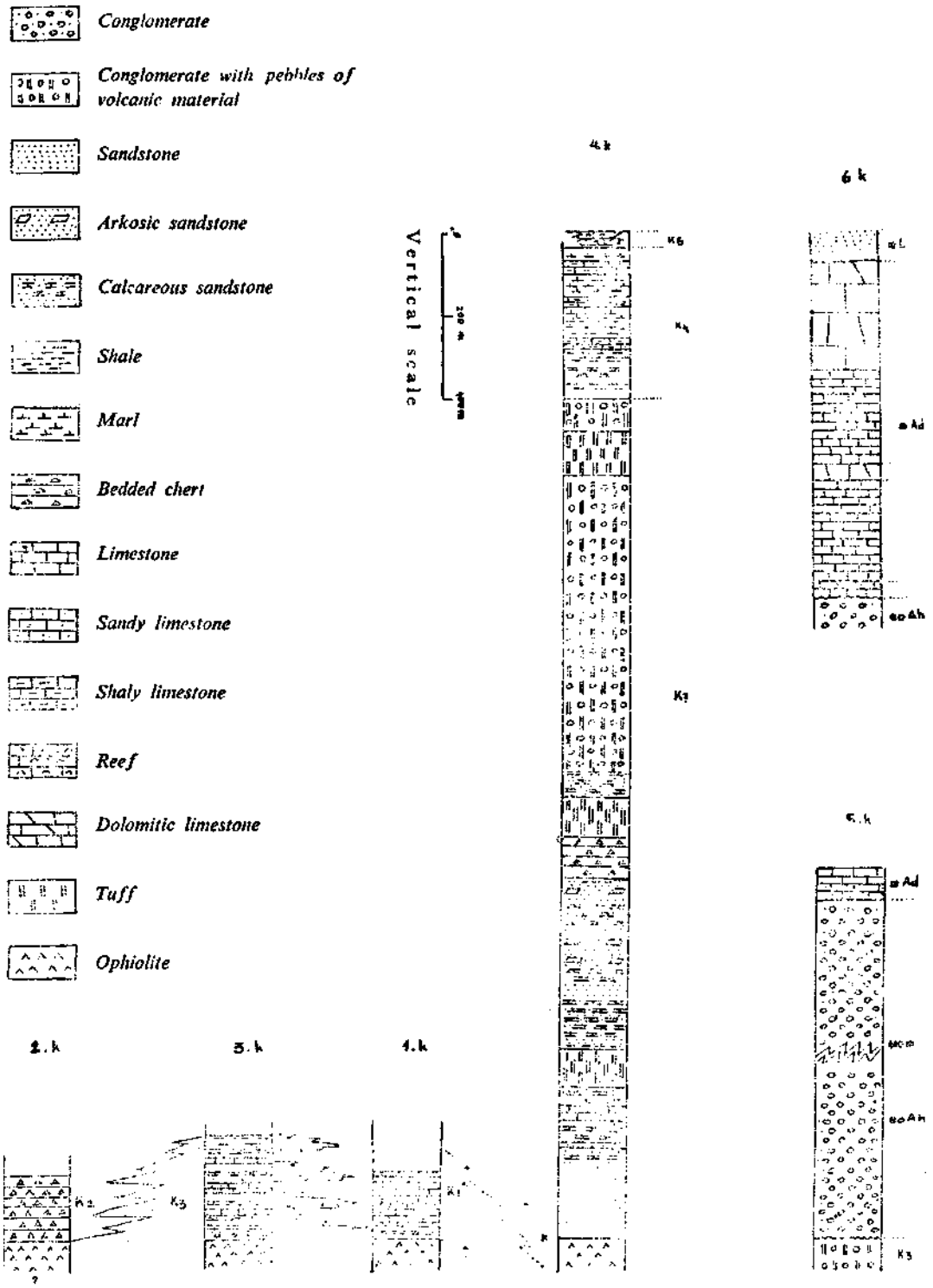
PLATE - II



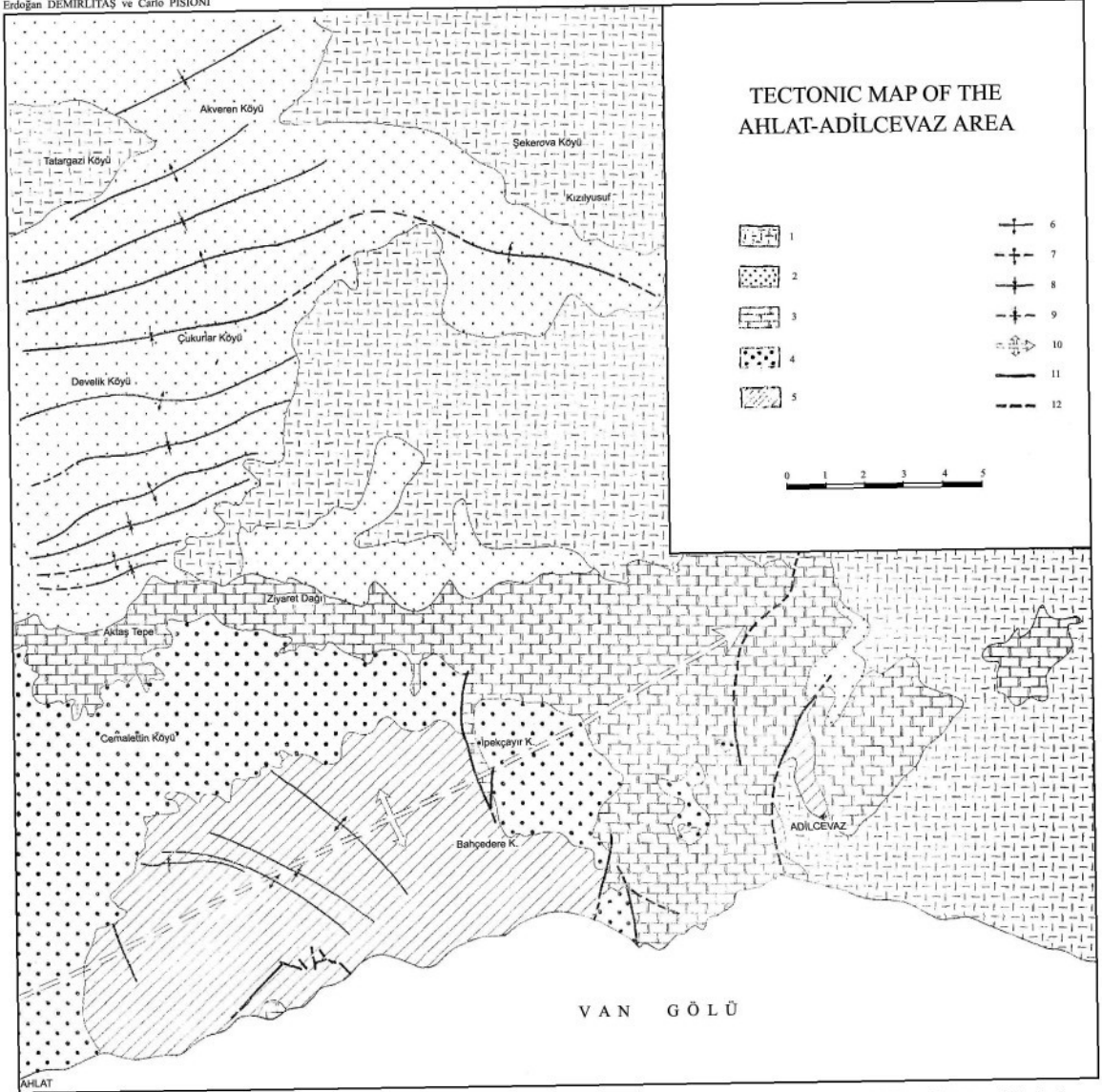
GEOLOGIC CROSS-SECTIONS OF THE AHLAT-ADİLCEVAZ AREA

1- Çukurtarla limestone (PÇ); 2- Develik formation (mD); 3- Aktaş conglomerate (mAk); 4- Adilcevaz limestone (mAd); 5- Ahlat conglomerate (aoAh); 6- The alteration of fine clastics, marl and shaly limestone unit of Ahlat-Adilcevaz complex (k4); 7- Arenitic, pyroclastic and conglomeratic unit of the Ahlat-Adilcevaz complex (k3); 8- Ophiolites of the Ahlat-Adilcevaz complex)oph); 9- Tuff; 10- Basalt; 11- Fault; 12- Angular unconformity

TYPE SECTIONS OF THE AHLAT - ADİLCEVAZ AREA



1.k - Kulaksız Tepe section
2.k - Kırmalar Tepe section
3.k - Tonus section
4.k - Başlıkaya sektion
5.k - Cemalettin-Ahlat section
6.k - Dikis-Adilcevaz section



1- Late Cenozoic volcanics and alluvium; 2- Middle- Upper Miocene and Lower Pliocene; 3- Lower Miocene; 4- Eocene-Oligocene (?); 5- Upper Cretaceus; 6- Axis of anticline; 7- Axis of probable anticline; 8- Axis of syncline 9- Axis of probable syncline; 10- Ahlat-Adilcevaz uplift; 11- Fault; 12- Probable fault

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