AGE RELATIONS OF MAGMATIC ACTIVITY AND OF METAMORPHIC PROCESSES IN THE NORTHWESTERN PART OF ANATOLIA - TURKEY

G. v. d. KAADEN

Mineral Research and Exploration Institute of Turkey

ABSTRACT.— The investigated and discussed areas are situated around the Kazdağ (Çanakkale Peninsula) and around the Uludağ (south of the town of Bursa) — Compare fig. 1.

History of mapping activity, older literature, geological setting, magmatic activity and age relations of magmatic activity and of metamorphic processes are discussed.

A pre-Variscan, the Variscan and the Alpine mountain - building period could be distinguished. Strong block faulting of late-Tertiary age affected the area. Each of the mountain-building periods is characterized by its own magmatic activity, degree of metamorphism and mineralization. Maps and sections are presented.

INTRODUCTION

Recent publications by Pınar and Lahn (1955) and by Holzer and Colin (1957) discussing age relations of metamorphism and of magmatic activity in the western part of Anatolia are in disagreement with publications by Philippson (1910/1918), Penck (1918), de Wijkerslooth (1941), Erk (1939/1942), Ketin (1947), Yalçınlar (1952) and Aygen (1956).

The former investigators postulate an alpine emplacement of peridotitic rocks and late-alpine granitic intrusions in this part of Turkey. The latter investigators assume a Variscan emplacement of peridotitic rocks and late-Paleozoic granitic intrusions.

The author, while studying the area around the Kazdağ complex and around the Uludağ complex in more detail during the years 1956-1957, was able to throw a more definite light on age relations.

Although metamorphism and magmatic activity are more complex than described by Philippson and de Wijkerslooth, their standpoint in general could be substantiated by more definite proofs.

The standpoint put forward by Pınar and Lahn and by Holzer and Colin has to be rejected.

FORMER INVESTIGATIONS WITHIN THE REGIONS DISCUSSED

The regions discussed—Kazdağ and Uludağ complexes—are included into small-scale maps published by Tchihatcheff (1869), Philippson (1918) and into the geological map of Turkey, (sheet of Istanbul, scale 1: 800,000) compiled by Egeran and Lahn (1942).

A more detailed map of the Kazdağ region was already given by Diller (1883) on a scale of about 1: 600,000. Age relations, according to the then known facts, were discussed by him.

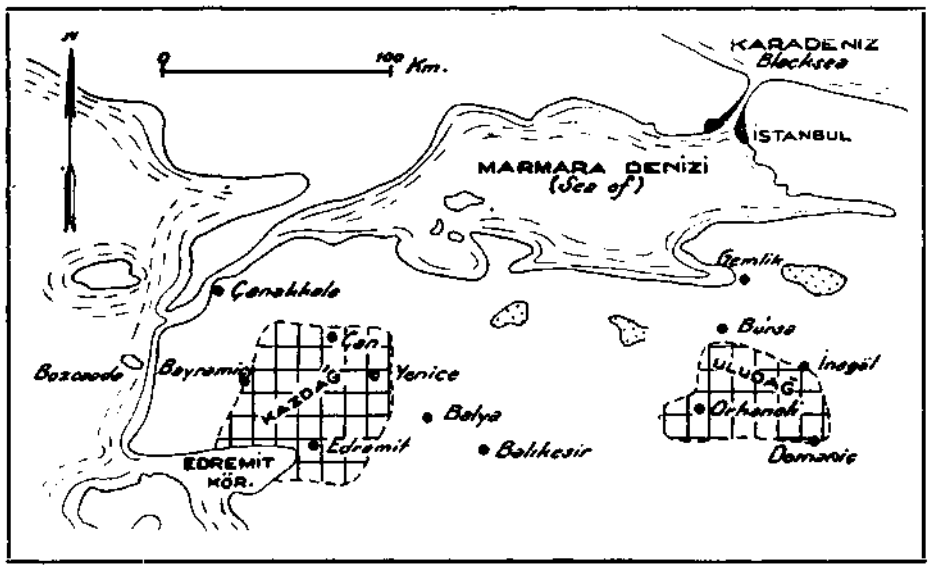


Fig. 1 - Location of investigated areas

The map given by Philippson on a scale 1: 300,000, with only slight modifications, is almost identical with the one published by Diller. The geological map compiled by Egeran and Lahn gives, however, an impaired picture of Diller's map, as dioritic rocks indicated on Diller's map, situated north of the Kazdağ complex, are not separated from serpentines on Lahn's map.

Philippson (1918) and Penck (1918) suggest a Paleozoic age for the serpentines and granitic intrusions in this part of Turkey.

Magmatic activity and metamorphic processes of western and central Anatolia were discussed by de Wijkerslooth (1941 and 1944). Age relations are properly discussed by him. He suggests a late-Paleozoic age of the granitic intrusions and an older Paleozoic age of the serpentines.

Of the Uludağ region a detailed map on a scale 1: 100,000 is given by Ketin (1947). He postulates a late-tectonic Variscan age of the granitic intrusions and stresses the older Paleozoic age of the serpentines south of the Uludağ range.

Bordering the investigated areas, publications: (including maps) by Ternek (1949), surroundings of Dardanelles; by Erguvanlı (1955 and 1957) west of Kazdağ complex; by Aygen (1956) surroundings of Balya; by Erk (1942) north of the Uludağ range, exist.

The publications by Ternek and Erguvanlı deal mostly with Tertiary tectonics, volcanic activity, and sedimentation. The publications by Aygen and Erk give also valuable information about Mesozoic sedimentation and alpine movements; both assume a pre-Triassic age of the granodioritic-granitic intrusions.

Between 1945-1954, geological mapping was carried out on a scale 1: 100,000 by different M.T.A. geologists (S. Türkünal, M. Tokay, V. Kovenko, N. Tolun, H. Geis) in the Kazdağ region and its immediate surroundings. With the exception of a short report given by

Geis (1953) no explanatory notes were given to the maps.

In 1955 the author carried out a general prospection in the Kazdağ region (v.d. Kaaden, 1956). During the summer of 1956, maps of the Kazdağ region were revised by a group of geologists (v.d. Meer Mohr, Ziya Barut, Sabit Yılmaz) under the supervision of the author. The results were compiled and laid down in reports by v.d. Kaaden (1957a) and v.d. Meer Mohr (1956).

During the summer of 1957, the region south of the Uludağ range was prospected and the maps partly revised by the author and Ziya Barut. The results of these investigations were laid down in a report by v. d. Kaaden (1958).

KAZDAĞ AND ULUDAĞ REGIONS AND IMMEDIATE SURROUNDINGS

GEOLOGICAL SETTING

(Compare Plate I and II and sections)

Pre - Variscan rocfys.

The oldest rocks of the region are situated in the Kazdağ mountain range with the highest peak reaching 1,767m. in the Kartalpınardüzü (Babadağ) and around the Uludağ batholith where they are for instance exposed west of the line Sabasultan-Kıranköy and near Süleymaniye köy.

These old crystalline cores form the backbones of the Kazdağ and Uludağ mountain regions.

These cores consist of a formation of regional metamorphosed rock complexes. The grade of metamorphism has a meso-kata zonal character. The cores have a dome-like structure, as they dip away in all directions under the younger formations. The study of these rocks—especially those of the Kazdağ, and to a less extent those of the Uludağ—enlarged by petrographic data, has served to clarify a number of relationships which had to be understood before the larger regional problems could be solved.

The Kazdağ complex consists of quartz-plagioclase gneisses with different amounts of biotite and hornblende, garnet bearing quartz - hornblende-plagioclase gneisses, diopside bearing plagioclase-hornblende schists, albite-chlorite-hornblende schists, biotite-albite-quartz schists, well-banded marbles and subordinate metamorphic iron formations of sedimentary origin (above Altınoluk), garnet rocks, olivine schists (Kartalpınardüzü), and more massive metamorphosed intrusives as tremolite bearing pyroxenites, orthogneisses and pegmatite gneisses. Interlayered with the gneisses are hornblende-schists, and sometimes marbles. In the upper part of the series, above Altınoluk, marbles are more predominant than in the eastern part. Alternating with the marbles are, especially, hornblende-schists and gneisses. The interlayering of different lithological types occur on a wide range of scales including interlayering of no more than a few cm. thick, and marble of more than 100 m. thick. This interlayering reflects the alternation in types of sediments deposited. The individual gneiss layers are thin and notably persistent along the strike.

The litological relationship must have been inherited from the stratigraphic layering of an old mixed series of geosynclinal sediments, such as feldspathic pelitic sediments, greywackes, arkoses, marls and limestones. The estimated thickness of the formation, as can be studied north of Zeytinli, amounts to at least 1,000 m.

The strike of the gneisses and schists changes between NNW-SSE to NNE-SSW. This general N-S strike direction snows deviations owing to younger tec-

tonic phenomena as shear zones, situated in the neighbourhood of the early - Paleozoic formations and the granodioritic intrusions in the north of the complex. The general N-S strike direction, as observed in the interior of the complex, is truncated by the NE-SW direction of the early-Paleozoic formations.

To obtain an impression of the grade of metamorphism, the mineral assemblage of the different rocks was studied. The index minerals are biotite, oligoclase and, to a less extent, zoisite, garnet, diopside in the gneisses, and actionolitic-hornblende, albite, epidote in the hornblende - schists and gneisses. Sphene is a common accessory constituent in the hornblende - schists and gneisses and apatite in the quartz - plagioclase gneisses. Movements during recrystrallization are indicated by the occurrence of rotated garnets. Internal folding within the different layers is a common feature. Locally, viz. north of Zeytinli köy, small-scale palingenesis of paragneisses is indicated by flat lenses, up to 5 cm. thick, of granodioritic material situated parallel to the schistosity of the gneiss layers.

The same characteristics described from the Kazdağ complex were also observed from the old crystalline cores of the Uludağ range. To the list of the minerals observed in the Kazdağ region, orthoclase, muscovite, and orthite can be attributed.

Intercalation of marbles with gneisses—as was described from the Kazdağ—was not observed in the Uludağ. Here the schistose and well - banded marbles are on top of the gneisses, but are in the summit region in overturned position, as was already pointed out by Ketin (1949). Metamorphosed intrusives are much less conspicuous than in the Kazdağ.

The general strike of the gneisses in the interior of the Uludağ range changes between NNW - SSE to NNE-SSW., although at the border zones of the complex and near the Uludağ batholith deviations were the rule.

The best exposures can be studied west of Kıran köy, the estimated thickness of the formation amounts to at least 1,000 m.

The age of the original sediments has not been determined definitely, but the high grade of regional metamorphism and the position in relation to the other formations, as for instance the truncation of the general strike by that of the early-Paleozoic formations, make the assumption of a pre-Variscan age (Caledonian?), at least for a part of the rocks, highly probable (compare Yalçınlar, 1952).

Paleozoic series.

Early - Paleozoic formations.

1. Around the Kazdağ (Plate 1 and fig. 2) the early-Paleozoic formations begin with epi - dynamometamorphic greenstones. From Zeytinli, the greenstones with thin intercalations of limestones and phyllitic rocks, could be followed along the eastern border of the pre-Variscan gneisses over more than 20 km. towards NNE. Along the western border they also lie on top of pre-Variscan rocks as can be studied NW of Dededağ. In the north, between Çal and Bardakçılar, south of Durcam tepe, the greenstones seem intercalated between phyllitic rocks. The greenstones represent volcanics and pyroclastics of spilitic character that have been meta morphosed. Sometimes the greenstones are strongly schistose and nearly always chloritized and epidotized. In succession to the greenstones a contorted strongly tectonized series of epi-metamorphic

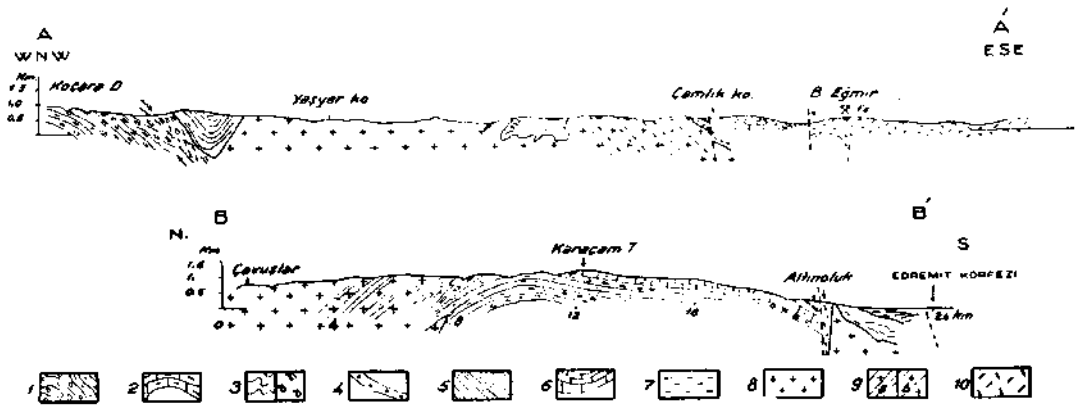


Fig. 2 - Sections AA' and BB' of Kazdağ region. (Compare Plate I)

1. *Gneisses and amphibolites of old crystalline core.*
2. *Banded marbles of old crystalline core.*
3. *a. Early-Paleozoic epidynamornelamorphic schists, contact-metamorphosed in batholitic aureoles, b. Early-Paleozoic greenstones.*
4. *Conglomerates and arkoses at base of Upper-Triassic strata containing pebbles of No. 3a and No. 8.*
5. *Upper-Triassic and Lower-Jurassic.*
6. *Upper-Jurassic limestones.*
7. *Upper-Miocene deposits.*
8. *Paleozoic granodiorites, subordinate granites and quartzdiorites.*
9. *a. Foliated granodiorites, south of Çavuşlu. b. Strongly diaphtoritic granodiorites WNW of Çamlık köy.*
10. *Tertiary andesites and dacites.*

phyllites,semi-phyllites,sericite-chloritc schists, greywacke-quartzites, arkoses, black graphitic shales and subordinate lenses of serpentine and of recrystallized limestones follows. The graphitic shales are i.a. exposed along the Karıncalıçeşme Çay, SW of Kalkım Lithologically the described epi-metamorphic series are the same as the Silurian Devonian formations described from the vicinity of Istanbul by Arabu (1935) and others. The graphitic shales resemble the graptolite-bearing black shales known from the Feki area (Prov. of Adana). For this reason, the author considers a Silurian-Devonian age for the epi-dynamometamorphic series described before, highly probable, although, owing to the high grade of cleavage folding, no fossils have as yet been found. The early-Paleozoic formations around the Kazdağ show a general NE-SW strike of the fold axes.

2. Moulded around the Uludağ complex (Plate II) lies a similar epi-dynamometamorphic series. It consists of phyllitic schists, greenschists, glaucophane - bearing greenschists, greywackes, greywacke-quartzites, recrystallized limestones, together with greenstones of spilitic origin and serpentinized peridotites with chromite mineralization. Greywackes, marbles and black semi - crystalline limestones probably belong to late-Paleozoic formations as the greywackes already contain clastic fragments of greenstones and marbles and also black semi - crystalline limestones are on top of the epi-dynamometamorphic series. The general strike of the Palaeozoic formations, though locally changed in the neighbourhood of the batholitic intrusions and the old cores, is WSW-ENE.

In both regions the epi-dynamometamorphic series represent pelitic and

psammitic sediments with intercalations of limestones and of ultra-basic igneous rocks, together with spilitic rocks, and are of geosynclinal character.

In both areas a contact-metamorphism has been superimposed on the epi-metamorphic series in the aureoles of granodioritic-granitic intrusions, under the formation of marbles, hornfelses, garnet-diopside rocks, skarns, and biotite schists.

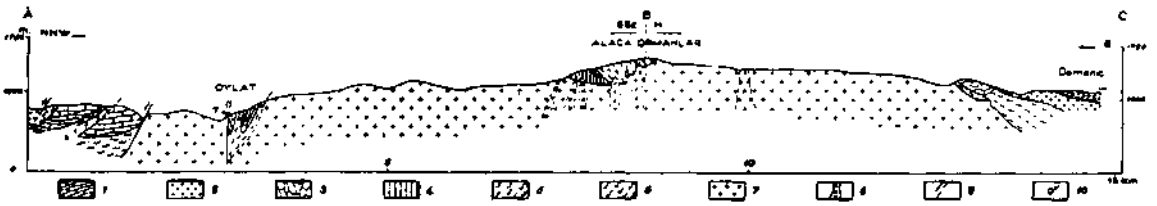


Fig. 3 - Section ABC east of Uludağ range, north of Domaniç. (Compare Plate II)

1. *Fresh- water limestones of Neogene age.*
2. *Clastic fades of Neogene.*
3. *Paleozoic marbles and semi-crystalline limestones.*
4. *Skarn rocks (tactite).*
5. *Contact-metamorphosed early-Paleozoic schists.*
6. *Epidynamometamorphic early-Paleozoic schists.*
7. *Paleozoic granodiorites.*
8. *Quartzdiorite porphyry.*
9. *Fault, showing relative movement.*
10. *Hot spring.*

Carboniferous and Permian.

Black semi-crystalline limestones with transitions to contact - metamorphosed marbles were observed by the author NW of Domaniç köy (Vil. Kütahya, Plate II). These limestones are cut by dikes of grariodiorite porphyrites. Black semi-crystalline limestones of the same feature, directly north of the Uludağ range, were described by Erk (1942). He attributes an early-Carboniferous age to these black limestones.

North of the Uludağ range, the black limestones are covered by clastic sediments which form the base of non-metamorphic fossiliferous Middle-Permian limestones. Granitic boulders were described by Erk (1942, p. 47) from a conglomerate intercalated in Permian limestones (Dışkaya dag north of Bursa). Permian is described in detail by Erk from the region directly north of the Uludağ range; the reader is referred to his paper. Direct observations on Permian, limestones were made by the author from the areas around the Kazdağ. These limestones are always overlying the early-Paleozoic rocks. The limestones are grey, somewhat tectonized and crossed by veinlets filled with calcite. Fossils are rare but north of Yk. Çavuş the following Permian fossils were found by the author:

Neoschwagerina craticulifera Schwager.
Schwagerina sp.
Verbeekina?
Geinitzina (Lunucamrnina).

These fossils, according to Cemal Öztemür (Report No. 33, 1956 of the Pal. Dept. of M.T.A. from 31.7.1956), indicate a Middle-Permian age for these limestones.

From the region of Balya, Permian limestones were already known (Philippson 1910). Only remnants of this Permian transgression are preserved within the area investigated. At the base of one of these erosion remnants — the Paşadağ, north of Edremit— a conglomerate, containing pebbles of early-Palaeozoic epi-dynamometamorphic schists, is exposed east of Karadağ obası.

Mesozoic Series.

Triassic formations
(Compare Plate I).

Triassic formations near Balya were already known by Bittner (1890) and Neumayr (1887). Recently they were described in more detail by Aygen (1956). New occurrences of Triassic formations became known by the author in different parts surrounding the Kazdağ. The erosion remnants of Triassic formations cover only a small part of the area. The best exposures are located NNE of İnönü köy, east of Edremit (compare fig. No. 2). Fossiliferous Triassic formations were discovered on top of Paleozoic formations. They consist of polymict pebble-conglomerates and medium - to coarsely - grained arkoses at the base, followed in normal succession by black sandy slates with thin intercalations of black limestones.

The conglomerates contain granitic and quartzitic pebbles and fragments of early-Palaeozoic schists, hornfelses and phyllites; the black slates are sandy and rich in flakes of mica.

The formation represents non-metamorphic clastic sediments deposited in shallow water marine environment. The lithological characteristics of the black slates are the same as described from the Triassic formations near Balya by Aygen (1956);

Locally the thin limestone layers contain abundant well-preserved brachiopods. In the black slates pelecypods as *Halobia, Daonella* and *Posidonomya* and gastropods as *Neritopsis* were found by Sabit Yılmaz and the author (Determinations by Necdet Karacabey and Mrs. Cahide Kırağlı). The brachiopodes resemble *Rhynchonella arpadica* Bittner and *Rhynchonella concordiae* Bittner, and Mrs. Kırağlı is of the opinion that an Upper Triassic age is highly probable.

This age determination is supported by the fact that in the hanging wall in normal stratigraphical column Liassic fossils were found. Arabu (1935, p. 126) describes brachiopods in Upper-Triassic limestones in the same lithological sequence from the vicinity of İstanbul.

The conglomerates at the base are older than Upper-Triassic and younger than Middle-Permian.

The total thickness of the Triassic formation NNE of İnönü köy is estimated to at least 500 m.

In different isolated spots the same arkoses, sometimes associated with black slates, are found on top of Paleozoic formations. The following occurrences were registered: east of Terzialanı, in the neighbourhood of Sasak, south of Aş.Karaaşık, east of Helvacı köy, north and south of Yenice, along the road Balya-Yenice, south of Pazar köy, SW of Armutcuk köy.

In these isolated spots fossils have not yet been found in the black slates and arkoses, but south of Terzialanı Liassic ammonites were found by the author in calcareous sandstones that were situated on top of these black shales.

In consequence of the same stratigraphical position and lithology, the author ascribes a Triassic age to these arkoses and black slates.

Directly north of the Uludağ region fossiliferous Upper-Triassic formations were described in detail by Erk (1942). According to Erk, the Triassic transgression came from the south. The Triassic conglomerates there contain pebbles of fossiliferous Permian limestones and of metamorphic schists.

Jurassic formations.

In close connection with the Triassic formations already mentioned, a formation of sandy slates and calcareous

sandstones is developed. This formation contains fossils of Lower and Middle Jurassic age. NNE of İnönü köy, *Pecten (variamussium)* aff. *pumilium* Lamarck were found by the author. According to Necdet Karacabey, who carried out the determination, this form is typical for Lias - Dogger.

South of Terzialanı, the following ammonites were found in calcareous sandstones. According to Mrs. Mukerrem Türkünal these ammonites are typical for Lias.

Atractites sp.
Rhocophyllites sp. (probable *limatus* Gemm).

Calcareous sandstones — with microfossils such as *Textularia, Rotalia Miliolidae* and *Frondicularia* — also became known from isolated spots near Yaykin köy. According to Dr. K. Turnovsky, who carried out the determinations, the occurrence of *Frondicularia* points towards Jurassic age of this formation (compare Oberhauser, 1954).

In the area NNE of İnönü köy and south of Pazar koy, Upper Jurassic formations are represented by thick-bedded, massive grey limestones. Characteristic for these limestones is the presence of belemnices and chert concretions. The belemnites are, however, badly preserved. At the base of these limestones, NNE of İnönü köy, belemnites were found together with Pecten belonging to Lower or Middle Jurassic. As these limestones are in normal sequence on top of Lower to Middle Jurassic beds, an Upper Jurassic age is highly probable.

North of the Uludağ range Lower and Middle Jurassic formations are lacking. Here an erosion period is proved by the presence of boulders of Permian limestones and Triassic sandstones in conglomerates, situated at the base of Upper-Jurassic (Malm) limestones. This same conglomerate (Erk, 1942) rests unconformably on a biotite-granite, near Dışkaya köy, and contains -pebbles of this granite.

East of the Uludağ range, near Söğüt, Liassic conglomerates rest unconformably on granodioritic rocks, as was observed by the author (1957b) and by Kupfahl (1954).

Cretaceous formations.

North of the Kazdağ range, in the surroundings of Aş. Çavuş and of Çal koy, Cretaceous formations are represented by spilitic rocks, with local intercalations of shales and reddish thin-bedded limestones, and by conglomeratic limestones in combination with thin-bedded limestones. A bed of macrofossils was found by the author in conglomeratic limestones on top of Jurassic calcareous sandstones near Yaykin. This bed contained brachiopods, belemnires of Cretaceous type and corals indicating reef facies. The material is, however, badly preserved and no exact age determination could be given.

The spilitic rocks and limestones were also found resting upon Paleozoic rocks. The conglomeratic limestones often contain clastic spilitic material. However, microfossils indicating Middle to Upper Cretaceous age were reported by Lebküchner (1956) and by Geis (1953) from limestones NW of Yk. Çavuş. According to Oberhauser (Report Pal. Dep. M.T.A. No. 1953/4), the limestones contained:

Globigerina cretacea typ.
Globotruncana cf. *lapparenti bulloides* Vogler
Vidalina sp.
Cormuspina sp.
Lenticulina sp.
Operculina sp.
Nodosaria sp.

According to the report by Oberhauser, the limestones were deposited in shallow-water marine environment. Near Yk. Çavuş the limestones are intercalated with, or on top of spilitic rocks. Erosion remnants of these limestones and conglomerates are overlying Liassic calcareous sandstones in discordant position east of Bardakçılar.

Erk (1942) describes Upper-Cretaceous sediments with conglomerates at their base situated on top of Upper-Jurassic limestones from the area directly north of the Uludağ range. These conglomerates contain detritic material of older Mesozoic (pre-Cretaceous) formations.

This picture of transgressions followed by long periods of upheaval and erosion is in full accordance with the observed facts around the Kazdağ complex. In both areas the Mesozoic formations are non-metamorphic.

Tertiary series-

Early Tertiary (Eocene) formations are reported outside the investigated areas by Erguvanlı (1957) and by Ternek (1949), from Bozcaada and north of the Çanakkale Boğazı (Strait of the Dardanelles) and by Erk (1942) from the north of the Uludağ range and south of Gemlik. These formations were not observed in the investigated regions. They consist of marine flysch that is in a transgressive position on top of older formations deposited in mainly E-W striking foredeeps. According to Erk they were subjected during Oligocene to alpine folding and small - scale overthrusting. These formations are non - metamorphic.

Late-Tertiary deposits cover considerable parts of the investigated region. Around the Kazdağ range they consist of slightly brackish-water sediments along the southern coastline and of fresh-water sediments inland. These sediments are built up of clastic material and have along the coastline the characteristics of a flysch facies. In the upper part this series is mixed with tuffaceous beds and sometimes covered

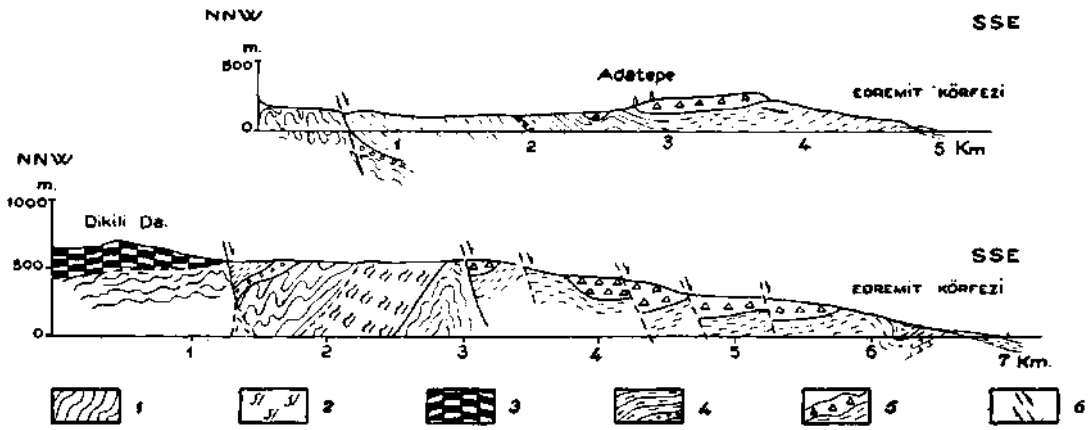


Fig. 4 - Sections west of Küçük Kuyu. (Compare Plate I)

1. *Epidynamometamorphic early-Paleozoic schists.*
2. *Early-Paleozoic greenstones.*
3. *Permian (?). Semi-crystalline limestones on top of (1).*
4. *Upper-Miocene deposits, (dark shales, sandstones; marls, tuffaceous shales, conglomerates at base).*
5. *Tuffites.*
6. *Faults, showing relative movements.*

by volcanic series consisting of pyroclastics and andesitic-dacitic lava flows. In the region of Çan, west of İnönü, Bayramgıç, and Öğmen, the sediments are partly deposited on top of older kaolipized andesites. The sediments consist of conglomerates, sandstones with plant remnants, occasional lignite beds, marls, which are locally gypsum-bearing, shales and to a less extent fresh-water limestones. The total thickness in the local basins is different, but may reach 500 m. close to the coastline. The conglomerates often contain pebbles of andesitic rocks of the older flows. Fossiliferous beds are rare, but imprints of leaves from *Myrcia, Tilia* and *Acer* have been found near Çan by Wedding (1957). Imprints of fishes became known to the author west of İnönü köy, by Lebküchner near Örencik and by Wedding near Gölcük in paper-thin laminated shales.

Tuffaceous beds containing fossils were found near Demirci by Sabit Yılmaz and near Öğmen by v.d. Meer Mohr. The material of Demirci has not yet been studied, but it seems to include Mactra, Hydrobia and Planorbis making an upper-Miocene age probable. Near Ezine Erguvanlı (1957) found fossils of upper - Miocene age in the same formations directly west of the investigated region. According to Wedding (1957) pollen-analyses were carried out by Dr. v. d. Brelie on lignite samples of the Çan area. Results suggest an upper-Miocene age. On account of the data available, the author considers an upper-Miocene age for these late-Tertiary formations as probable.

The late-Tertiary deposits around the Uludağ range were only superficially investigated. The deposits are predominantly built up of clastic material. Especially at the base of the deposits coarse conglomerates are common. Marls, sandstones, siltstones, but also tuffaceous beds built up the series. Occasionally lignite beds are observed. Fresh-water limestones are known in the upper part of the series in the surroundings of Domaniç (compare fig. 3).

The late. Tertiary deposits were subjected to strong block-faulting (compare also Pınar 1949). The movements of the blocks have created, in some cases, folds, which are secondary to the faulting, as for instance north of the bay of Edremit near Kü. Kuyu (Saxonic type of folding, compare fig. 4).

Magmatic activity.

Intrusives.

Granodioritic - Granitic rocks :

1. In Pre-Variscan Rocks.— Intrusive rocks are indicated by injection type orthogneisses and pegmatitic gneisses, as reported by v.d. Meer Mohr (1956), from the NW - corner of the Kazdağ gneiss complex, north of Uzunalan köy. These rocks have a granodioritic composition and are of minor importance. They show no clear contact zones and no mineralization. Towards the border there is only a gradual increase of dark minerals (mostly coarsely-grained hornblende), the foliation becomes more pronounced and develops into a real schistosity characteristic of all rocks belonging to this formation.

These rocks might be explained by local palingenesis of pre-Variscan gneisses: This would explain the lack of mineralization and of contact zones described previously.

As these rocks were difficult to trace in this densely-forested area and are of minor importance they have not been separated on the maps. Pyroxenites were observed northwest of Güre, but are of minor importance. Extrusive rocks and

pyroclastics are probably hidden in some of the albite-chlorite-hornblende schists.

In the Uludağ area aplitic concordant «injections» were observed, as for instance in the gneisses west of Kıran koy and the marbles SW of Kıran köy. These aplitic «injections» are foliated and sometimes garnet-bearing. They might be explained by assuming local palingenesis or they may represent metamorphosed tuffaceous beds, but proof is lacking.

The Uludağ batholith described by Ketin (1947) belongs to a late tectonic Paleozoic cycle, which will be described below.

2. In Paleozoic Formations.— The granodioritic-granitic intrusions in Paleozoic formations within the investigated areas are of major importance. The following separate bodies could be distinguished (compare Plate I-II) :

A. Kazdağ region :

1. Eybekdağ batholith, situated NE of Edremit.
2. Small batholith stocks, north of the Ovas of Kalkım and Yenice.
3. Small stock of porphyritic granodiorite near Kuşçayırı.
4. Çavuşlu-Müdanya batholith, NW of the Kazdağ.
5. Katrandağ batholith, SW of Bardakçılar.

B. Uludağ region :

1. Uludağ batholith including WNW -ESE extension south of the summit region.
2. Göynükbelen-Kuzbudaklar - Deliler batholith.
3. Tepeldağ-Boğazova batholiths, which are separated only by a narrow ridge of highly altered mesozonal Contact rocks and schists.
4. Gürgen yayla batholith, which is separated from the Boğazova batholith by a narrow ridge of marbles and highly altered mesozonal contact rocks and schists.
5. Batholith south of Orhaneli.

The style of foliation within these batholiths varies. The Çavuşlu Müdanya and the Katrandağ batholiths (No. 4-5 A), situated north of the Kazdağ range, show a rather pronounced foliation, parallel with the boundary between granodiorite and gneisses. In the interior of these batholiths the foliation is much less conspicuous.

The batholith south of Orhaneli (No. 5 B) shows along the border zone a rather pronounced N-S striking foliation.

The Çavuşlu-Müdanya and the Katrandağ batholiths have a more or less concordant shape towards the gneisses which form their footwall. The other batholiths and the smaller stocks mentioned above show sharp and cross-cutting contacts in Paleozoic schists or gneisses (Uludağ) and foliation is almost lacking. However, inclusions of wall rock near the contacts is a common feature in all batholiths. These xenoliths, in various states of reconstitution, are more or less parallel arranged towards the lineation of the foliated batholiths, and towards the wall rock of the non-foliated batholiths.

The batholiths, but especially the non-foliated batholiths, show well-developed contact aureoles. The low-grade schists within the aureoles have been altered to mesozonal contact rocks as biotite schists, garnet rocks, skarns, hornfelses and are locally mineralized (W, Mo, Fe, Zn, Cu, S, F,) by an aftermath related to the granitic-granodioritic intrusions.

Especially the roof pendants within the batholiths are strongly metamorphosed, as for instance the narrow ridge dividing the Tepeldağ-Boğazova batholith mentioned before (No. 3 B) and the Alaca-Ormanları ridge (No. 4 B) (compare fig. 3). The contact rnetamorphism is less conspicuous on the older higher-grade gneisses, as for instance Uludağ batholith (No. 1 B) and Çavuşlu-Müdanya and Katrandağ batholiths (No. 4-5 A).

The larger batholiths have a granodioritic composition, the smaller stocks have locally a more granitic composition. The granodiorites are mostly hornblende-biotite granodiorites with such variations as biotite-bearing granodiorites, hornblende granodiorites and biotite granodiorites. The parts of different composition pass gradually from one into another. Locally along the contacts, hornblende diorites as well as aplite-granites are observed.

From the rest-solutions ensued aplitic and lamprophyric dikes. Pegmatites are extremely rare and poorly developed.

Among these, only aplitic dikes are common as in the vicinity of the border zones and roofpendants of the non-foliated batholiths, and in the border zone of the small batholithic stocks north of the Ovas of Kalkım and Yenice. Lamprophyric dikes as vogesites became known from the surroundings of the contact zone north of Kalabak koy and west of Yaşyer köy (Eybekdağ batholith).

Field relations suggest an intrusive magmatic emplacement of these granodioritic-granitic rocks into folded Paleozoic epi-sediments and pre-Variscan gneisses.

A somewhat younger phase of intrusions, but belonging to the same cycle, produced quartz-diorite porphyrites in the Gürgen yayla batholith, north of Durabey köy. Dikes of granodioritic porphyrites occur in the western part of the marbles of the Uludağ (compare Ketin, 1947).

These porphyrites also cut the serpentines, epi-dynamometamorphic series and black semi-crystalline limestones in several places south of the Uludağ range.

. The observed foliation, the poorer mineralization and the poorer development of aplitic dikes of the Çavuşlu-Müdanya, Katrandağ and Orhaneli batholiths—in comparison with the non-foliated batholiths mentioned previously— might be partly explained by assuming different erosion levels. However, the foliated batholiths might also be syntectonic-intruded. The non-foliated batholiths belong to a late-tectonic phase of the Variscan mountain building period.

The east border of the Eybekdağ batholith and the south border of the Uludağ batholith were subjected to post-magmatic tectonic movements of alpine age. Here the granodiorites are strongly diaphtoritic. NNE of Çamlık köy (Eybekdağ) Triassic non-metamorphic sediments are infolded in these diaphtoritic rocks, and situated in a zone parallel towards the Triassic formations and the fault zone bordering Tertiary andesites (compare fig. 2).

The Uludağ range in the south is bordered by a fault zone of primary importance (wrench-fault ?), which might explain the observed diaphtorism.

Serpentinized peridotitic rocks of Paleozoic age

South and south-west of the Uludağ range serpentinized peridotitic rocks are wide-spread. They contain chromite deposits that were or still are in exploita-

tion. This area was investigated by Helke (1955), who stresses the presence of two main directions in which chromite concentrations are orientated, being the N-S and ENE-WSW directions respectively. The serpentines are strongly tectonized along the borders of the schists and in the neighbourhood of the granodioritic intrusions. At the base of the serpentine bodies, lenses of amphibolites and gneisses are observed.

The serpentines are older than the granodiorites because they are intruded by them. This phenomenon can be studied at the western and northern sides of the Göynükbelen-Kuzbudaklar-Deliler batholith (No. 2 B) in several places. Also dikes of quartz-diorite porphyrites cut the serpentines in the border zones.

South of the Kazdağ range, small lense-shaped bodies of strongly tectonized serpentines are infolded within early-Paleozoic schists. The largest of them lies south of Bardakçılar. Larger bodies of serpentinized peridotitic rocks are known from the region of Ezine as can be seen from the map presented by Erguvanlı (1957).

The serpentines are here in the same relationship to Paleozoic schists as describedpreviously.

The serpentines together with greenstones belong to the initial basic phase of the Variscan mountain building period.

Extrusives.

Greenstones of Paleozoic age and glaucophanized greenschists

Epi - dynamometamorphic volcanics and pyroclastics of the spilitic suite were found around the Kazdağ and south of the Uludağ range in several places. They were subjected to the same grade of regional metamorphism as the early-Paleozoic sediments. More rigid bodies of spilitic rocks were, however, less metamorphosed and could be recognized under the microscope as spilites. Although locally massive, they are mostly schistose. The rocks are characterized by small crystals of albite and augite in a cryptocrystalline ground-mass and they are mostly epidotized and chloritized and may contain quartz. In the Kazdağ region they are often slightly tremolitized. Sphene is there, a common accessory constituent.

In the Kazdağ region greenstones have been found between Zeytinli köy and the upper course of the Karınca çay, along the Köprü dere, in the contact-metamorphosed aureoles of the batholith intrusions to the north of Kalkım and north of Eğrikbağaçdağ, and east of -Çaldağ (south of Bayramgiç). Within the aureoles of the granitic batholithic intrusions north of Kalkım, the greenstones have been altered to amphibolites through contact-metamorphism. These amphibolites lack the foliation that is so characteristic of the amphibolites of pre-Variscan formations. The greenstones of the Kazdağ region are intercalated between early - Paleozoic formations or situated between pre-Variscan gneisses and early-Paleozoic formations (compare fig. 2).

In the Uludağ region the greenstones also occur in the neighbourhood of pre-Variscan rocks. Closely linked to the spilitic greenstones around the Uludağ range are glaucophanized greenschists and diabases. Near Teşvikiye köy, north of the Uludağ range, the spilitic rocks merge into olivine diabase and picrites.

The greenschists probably represent spilitic tuffs that have been metamorphosed. Glaucophanization was already mentioned by de Wijkerslooth (1941) from a zone of diabases and greywackes

along the Bursa road, north of Nilüfer çay. Glaucophane rocks were observed by the author in different localities, all located in the Uludağ area (compare plate II).

1. Between Hüseyinalan and Kirazlı koy; glaucophane-epidote schists, chlorite - epidote - glaucophane schists and glaucophane-bearing epidote-biotite schists. Microscopical studies showed that biotite is younger than glaucophane. These occurrences coincide with the zone of glaucophane rocks mentioned by de Wijkerslooth.
2. Directly south of Teşvikiye köy, situated in a strongly dynamo - metamorphic zone containing lenses of olivine-gabbro, picrite, olivine diabase and greywackes, glaucophane-epidote schists are intercalated with these rocks.
3. Four km. NW of Tiraz köy along the Bileylikyayla dere, in a narrow zone of schists between strongly tectonized serpentinized peridotitic rocks and black schistose limestones, epidote-glaucophane and quartz-rich chlorite-lawsonite = glaucophane schists were found.

The distribution of the glaucophanization, outside or in the outer borders of the contact aureoles of the batholiths, and the replacement of glaucophane by biotite, as was described under (1), shows that it is related to metamorphic processes that were pre-granodioritic intrusions. It confirms the opinion put forward by Schurmann (1956, p. 85) that the granitic-granodioritic intrusions destroyed previous glaucophanization.

The glaucophanization in the Uludağ area belongs to the Variscan mountain-building period.

Spilitic-keratophyric rocks of late - Mesozoic age (compare Plate I) :

North of the Kazdağ range spilitic rocks were found by the author west of Çavuş around Çalköy, southeast of Karakoca koy. Locally they are intercalated with thin beds of shales and with thin - bedded sometimes reddish limestones. Erosion remnants of Cretaceous limestones rest on top of these spilitic rocks. Again the spilitic rocks rest on top of Lower Jurassic calcareous sandstones. Pillow structures are a common feature and even agglomerates were observed. The spilitic rocks can be easily studied along the main road south of Çalköy. Microscopically sodium-keratophyric spilites and normal spilites could be distinguished. These rocks are often calcitized and chloritized and crossed by veinlets of albite. Ilmenite is a common accessory constituent.

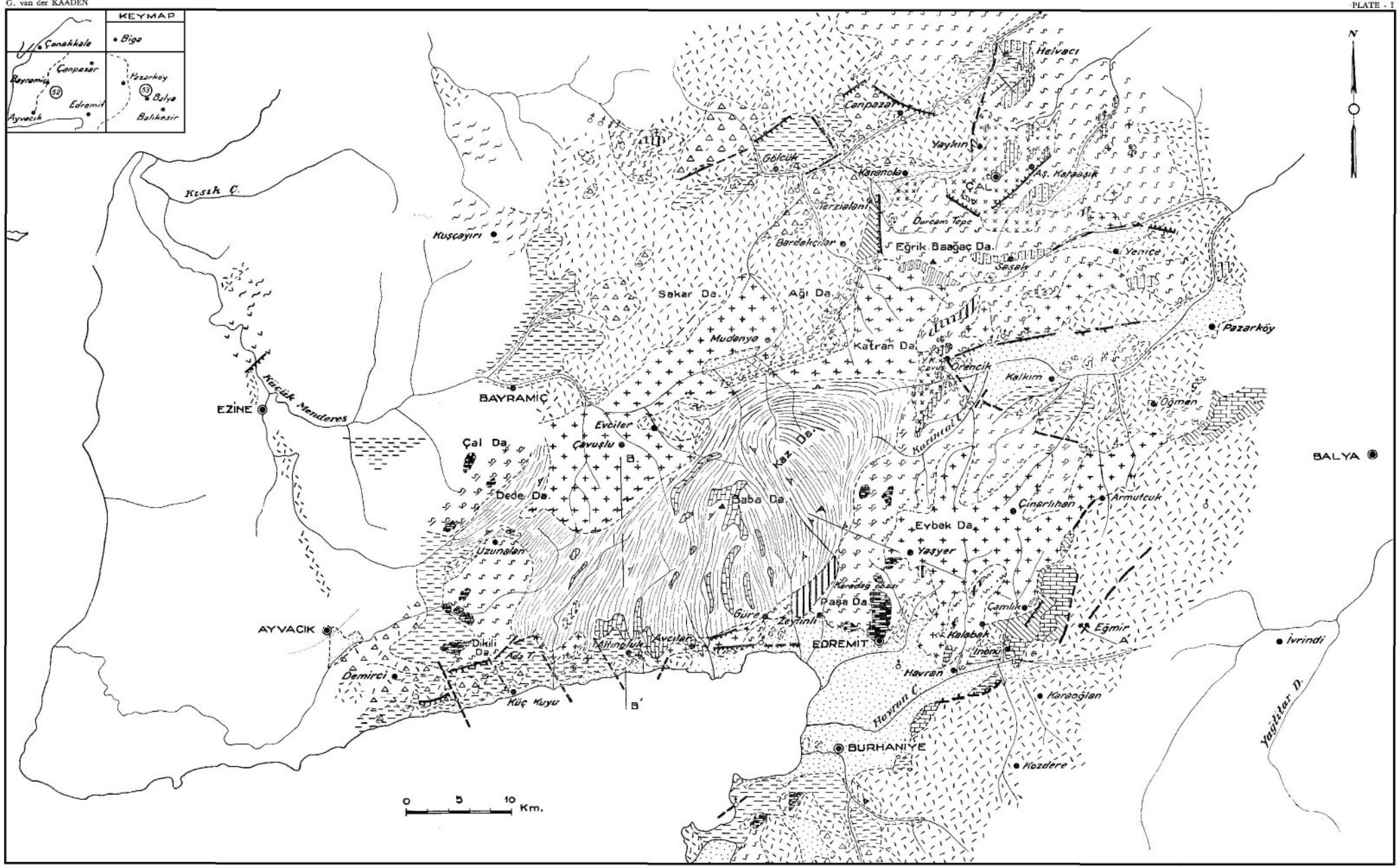
In strong contrast to the greenstones, the spilitic rocks, described above, have not been subjected to regional metamorphism.

North of the Uludağ Mesozoic volcanics are not known with certainty. An indication is given by Erk (1942), who describes some dikes of spilitic rocks situated north of the plain of Bursa, but is unable to fix their age. They are, however, post-Paleozoic and might belong to the Cretaceous cycle of spilitic rocks described from the Kazdağ region.

Both greenstones and spilitic rocks belong to an initial basic phase, but they are of Variscan and Alpine age respectively.

Tertiary volcanics and pyroclastics :

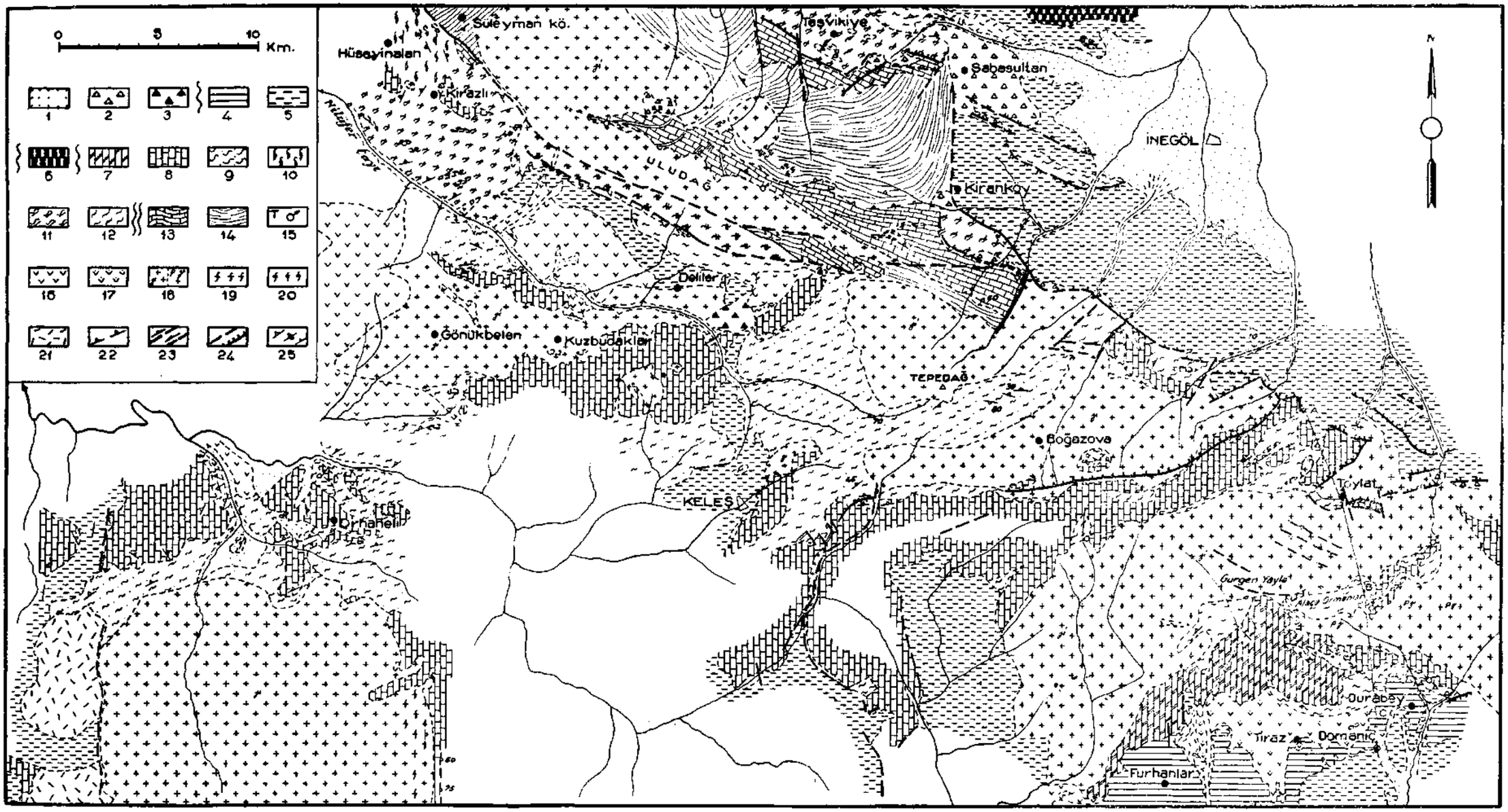
Different cycles of early - Tertiary (Eocene) volcanics and pyroclastics were



GEOLOGICAL MAP OF THE KAZDAĞ REGION AND IMMEDIATE SURROUNDINGS

(Compiled by v. d. Kaaden from fieldwork by v. d. Kaaden, v. d. Meer Mohr, Sabit Yılmaz, Ziya Barut, H. Wedding)

1. Alluvial deposits; 2. Upper-Miocene deposits; 3. Upper Cretaceous on top of rocks of the spilitic suite; 4. Upper-Jurassic limestones; 5. Lower-Jurassic and Triassic; 6. Triassic (?) (massive arkoses on top of Paleozoic formations); 7. Permian limestones; 8. Epi-dynamometamorphic greenstones; 9. Contact-metamorphosed early-Paleozoic formations; 10. Early-Paleozoic epi-dynamometamorphic formations; 11. Lenses of marble in early-Paleozoic schists; 12. Pre-Variscan crystalline complex (strongly foliated gneisses, amphibolites, schistose marbles); 13. Tertiary volcanic-agglomerates, mainly of andesitic composition; 14. Tertiary tuffs and tuffites, mainly of dacitic composition; 15. Tertiary andesites, older flows regional kaolinized, subordinate basalts, docites and rhyolites in younger flows; 16 a. Paleozoic granodiorites, subordinate gramites, quartzdiorites. 16 b. Paleozoic foliated granodiorites (south of Çavuşlu and Katrandağ batholith); 17. Serpentinized peridotites in early-Paleozoic schists; 18 a. Hot springs, warm springs and springs rich in mineral salts. 18 b. Cross-sections; 19. Fault, fault showing relative movement, supposed fault.



GEOLOGICAL MAP OF THE ULUDAĞ REGION AND SOUTHERN SURROUNDINGS

(Compiled by v. d. Kaaden from fieldwork by v. d. Kaaden and Ziya Barut, including parts of the map presented by İ. Ketin, 1947.)

1. Alluvial deposits; 2. Pleistocene debris; 3. Pleistocene granodioritic debris on top of Neogene; 4. Fresh-water limestones of Neogene age; 5. Clastic facies of Neogene; 6. Permian limestones; 7. Black Carboniferous (?) limestones; 8. Marbles on top of metamorphic Paleozoic schists; 9. Contact-metamorphosed early-Paleozoic formations; 10. Glaucophane-bearing greenschists; 11. Greenrocks of the spilitic suite; 12. Epi-dynamometamorphic early-Paleozoic schists; 13. Schistose marbles of the Uludağ range; 14. Pre-Variscan crystalline complex (gneisses, subordinate amphibolites); 15. Big springs, T=hot spring; 16. Serpentinized peridotites; 17. Radiolarian chert on top of serpentines; 18. Paleozoic granodiorites, subordinate granites, P=quartzdiorite porphyry; 19. Foliated granodiorites (Orhaneli batholith); 20. Diaphtoritic granodiorites (south of Uludağ range); 21. Tertiary volcanics (andesites, dacites, subordinate basalts; 22. Thrust plane, hachure on hanging wall; 23. Wrench fault (?); 24. Fault, supposed fault; 25. Strike and dip of schistosity and of strata.

described by Erk (1942) from marine flysch formations between Bursa and Gemlik, north of the Uludağ range. These rocks have in general an andesitic-dacitic composition. This period of strong volcanic activity was followed by a period of little volcanic activity during Oligocene. According to Erk, these Eocene volcanics, pyroclastics and flysh formations were subjected to alpine folding during Oligocene.

Similar observations were made by Ternek (1949) from the region north of the Dardanelles.

The volcanics and pyroclastics, situated in the investigated areas around the Kazdağ and the Uludağ, belong already to the post-tectonic volcanic phase, and are at least partly of late-Tertiary age. Related to these volcanics is a Pb, Zn, Ag, Cu, Sb, As and Ba mineralization.

These volcanics and pyroclastics cover large areas around the Kazdağ region. The apparent absence of early - Tertiary strata makes it difficult to decide when the eruptions began and no definite answer can be given as to the starting point of Tertiary volcanism in the region. At all events, the region around the Kazdağ witnessed a phase of strong andesitic volcanism, prior to the deposition of lignite-bearing Upper-Miocene beds.

These beds are situated on top of older volcanic rocks. The older andesites cut, however, through Paleozoic as well as Mesozoic strata and are therefore without doubt of Tertiary age.

These older flows are leached and kaolinized on a regional scale, which indicates an old erosion surface. In contrast to the older volcanics, the late-Tertiary volcanics are nearly not altered. Few exact data are available concerning the location of the older eruption centra, because they are strongly eroded and partly covered, but they seem to have NNE-SSW trends, as is indicated by the linear arrangement of andesitic ridges, viz. NE of the iron deposit Büyük Eğmir, NW of Mudanya on the Sakardağ.

Isolated eruption points are located viz. near Ağıdağ and in the eastern part of the Ova of Kalkım.

During the sedimentation of the Upper-Miocene deposits, volcanic activity is only indicated by the presence of tuffaceous beds interlayered between the strata. This period of relative inactiyity was followed by another cycle of anong volcanic activity.

Contemporaneous with the opening of new fissures, strong block faulting with predominant east-west and subordinate NE-SW trends dissected the area into «horsts» and «graben-like» depressions.

Along these fault zones are located—more or less isolated—eruption centra, as between Küçük Kuyu and Edremit, but also linear arrangement of andesitic ridges, as south of the line Burhaniye-Havran occurs. This new volcanic cycle had a somewhat more acidic composition. Besides andesites, dacitic rocks were formed together with andesitic agglomerates and more acidic tuffs. Good exposures of these thick-bedded tuffs with bombs and mud balls are found NE and NW of Küçük Kuyu, (compare fig. 3) of agglomerates NE of Ayvacık and in the surroundings of the Çan-Gölcük basin. Younger andesites are exposed viz. south of the plain Edremit-Havran where they are accumulated in sheets that are sometimes thin - bedded, as is the case between Yk. Karaoğlanlar köy and Kozdere köy.

Locally, flows and agglomerates alternate, showing that ejection of magma took place in several stages. As a

whole, the Tertiary volcanics show a rather limited differentiation series.

The Tertiary volcanics around the Kazdağ region mainly consist of biotite and hornblende-andesites. Of minor importance are augite and orthopyroxene andesites. Dacites, rhyolites, but also basalts were formed on a very small scale, in the post-Upper Miocene cycle together with large quantities of andesites and agglomerates. Dikes of basalt occur, viz. SW of Çanpazar in andesites and east of Bardakçılar in Jurassic strata; dacitic necks occur, viz. between Küçük Kuyu and Edremit; rhyolitic dikes occur north of Bardakçılar and SE of Çanpazar in andesitic rocks.

Also in the late-Tertiary deposits described by Erk (1942), north of the plain of Bursa, an andesitic character predominates. Around the Uludağ range dacitic lava flows and their pyroclastic sediments were observed west of İnegöl (Yıldız tepe), west of the Orhaneli batholith. Basaltic lawa flows are known NNE of Furhanlar köy (Vil. Kütahya).

SUMMARY

In the investigated and discussed areas around the Kazdağ and Uludağ complexes, four separate units—each characterized by its own geological development, magmatic activity and tectonics—could be distinguished. These units are :

1. Old crystalline cores of pre-Variscan (Caledonian?) origin. The old crystalline cores form the backbones of the Kazdağ and Uludağ mountain ranges, around which the other units are grouped. They are characterized by a meso - kata - zonal regional metamorphism and by the conformable relationship of the different lithological types, which was inherited from the stratigraphic layering of an old series of geosynclinal sediments of considerable thickness. The general N-S strike direction of these oldest rocks is truncated by the NE-SW to ENE-WSW strike direction of the early-Paleozoic formations.

Magmatic activity during the pre-Variscan mountain-building period is represented by granodioritic and by basic rocks, but their original features have been partly obliterated by the high grade of regional metamorphism to which they were subjected. The granodioritic rocks show no clear contact zones and no mineralization. Kata-zonal metamorphic iron ores above Altınoluk are of sedimentary origin.

2. Paleozoic formations which were subjected to the Variscan orogenesis.

Paleozoic formations are represented by early-Palaeozoic geosynclinal sediments of pelitic and psammitic composition and early - Carboniferous black limestones. Middle-Permian limestones are already in discordant position on top of folded and metamorphosed older Paleozoic formations.

Magmatic activity during the Variscan mountain-building period started with an outflow of spilitic lavas and the emplacement of peridotitic rocks (with chromite mineralization). The whole series was subjected to intense epi - dynamometamorphism which was certainly of pre-Permian age. The observed glaucophanization around the Uludağ originated during this period.

The formations were intruded by granodioritic batholiths, which superimposed a contact-metamorphism on the already epi-dynamometamorphosed series. Syntectonic intrusions are indicated by the presence of some strongly foliated batholiths. Late-tectonic batholiths were non-foliated and are still intrusive in early-Carboniferous black limestones. Related to these intrusions is a minera-

lization (W, Mo, Fe, Zn, Cu, S, F) of which an example has been described in detail by the author from the Uludağ (1958).

3. Mesozoic and early-Tertiary formations which were subjected to alpine folding.

The alpine mountain-building period in this part of Turkey is of a subcratogenic type, and no regional or contact metamorphism has affected the Mesozoic and early-Tertiary strata. They are non-metamorphic. Alpine movements (Cimerian phase of Stille) between Upper Triassic and Upper Jurassic were described by Aygen (1956) from Balya and resulted in small-scale upthrusting. According to Erk (1942), the alpine paroxysm culminated during Oligocene, in which the foredeep filled with Eocene flysch sediments north of the described area was folded. The deposition of Mesozoic and early-Tertiary sediments was often interrupted by regressions and periods of erosion. Middle - Permian conglomerates already contain pebbles of granites and metamorphic schists (see Erk, 1942). Pebble conglomerates of Triassic age (east of Kazdağ) and of Liassic age (near Söğüt east of the Uludağ range) contain pebbles of granodiorites, hornfelses and Paleozoic schists. Upper Triassic conglomerates north of Bursa. (Erk, 1942) are non-metamorphic and contain pebbles of metamorphic schists.

These observations prove the pre-Triassic age of the granodioritic intrusions and epi-dynamometamorphism in this region of Turkey.

Magmatic activity is restricted to the local putflow of spilitic-keratophyric lavas during Cretaceous time (north of the Kazdağ complex). These spilitic lavas are intercalated with limestones and are, in contrast to the Paleozoic greenstones, non-metamorphic.

In early - Tertiary time andesitic-dacitic submarine lavas and tuffs were reported by Erk (1942) and Ternek (1947).

4. Late-Tertiary sediments, volcanics and pyroclastics.

The apparent absence of early-Tertiary strata around the Kazdağ makes it difficult to decide when the eruptions began and no definite answer can be given as to the starting point of volcanism in this region. The volcanics and pyroclastics, situated in the investigated areas around the Kazdağ and the Uludağ belong, however, to the post-tectonic-volcanic phase and are at least partly of late-Tertiary age. The region around the Kazdağ witnessed a phase of strong andesitic volcanism prior to the deposition of lignite-bearing upper-Miocene beds. Related to these volcanics is a Pb, Zn, Ag, Cu, Sb, As, Fe and Ba mineralization.

Lignite-bearing Upper-Miocene beds are situated on top of these older volcanic rocks. The older volcanic rocks are leached and kaolinized on a regional scale, which indicates an old erosion surface. In contrast to the older volcanics, the late-Tertiary volcanics have not changed.

During the sedimentation of the Upper-Miocene deposits, volcanic activity is only indicated by the presence of tufiaceous beds interlayered between the strata. This period of relative inactivity is followed by another cycle of strong volcanic activity.

More or less contemporaneous with the opening of new fissures, strong block faulting, sometimes accompanied by Saxonic type of folding, dissected the area in «horsts» and «graben-like» depressions. As a whole, the Tertiary volcanics show a rather limited differentiation series.

The older Tertiary volcanics around the Kazdağ region mainly consist of biotite and hornblende-andesites. Of minor importance are augite and orthopyroxene andesites.

In the post-Upper-Miocene cycle, dacites, rhyolites but also basalts were extruded on a very small scale together with large quantities of andesites, agglomerates, and more acidic tuffs.

Manuscript received November 20, 1958.

REFERENCES

ARABU, M.N. (1934-1935) : Contributions a l'etude geologique des environs de la mer de Marmara. *Comptes Rendus des Seances. Inst. Geol. de Roumanie. Tome XXIII.*

AYGEN, T. (1956) : Balya Bölgesi jeolojisinin incelenmesi (Etude geologique de la region de Balya) *M.T.A. Ankara. Ser. D., No. 11.*

BITTNER, A. (1890) : Brachiopoden der Alpinen Trias. *Abhandl. d. K. K. geol. Reichsanstalt. Band 14. Wien.*

DILLER, J. S. (1883) : Notes on the geology of the Troad. *Quart. Journ. Geol. Soc. London. Vol. XXXIX.*

EGERAN, N. and LAHN, E. (1942) : Geological map İstanbul. 1 : 800,000. *M.T.A. Ankara.*

ERGUVANLI, K. (1955) : Etude geologique de l'Ile de Bozcaada, *Bull. Geol. de France. Tome 5. pp. 399-401.*

———(1957) : Outline of Geology of the Dardanelles. *Geol. Mag. Vol. XCIV. pp. 47-53.*

ERK, A. S. (1939) : Etude geologique de la region de Gemlik (vilayet Bursa) *Publ. Inst. Geol. Univ. İstanbul.*

———(1942) : Etude geologique de la region entre Gemlik et Bursa (Turquie). *M.T.A. Ankara Ser. B. No. 9.*

GEIS, H. (1953) : Geologischer Aufbau des nordlichen Kazdağ. *M.T.A. Ankara* (not printed).

HELKE, A. (1955) : Beobachtungen an türkischen Minerallagerstatten. *Neues Jahrb.f. Min. Band. 88.*

HOLZER, F. H. and COLIN, H. (1957) : Beitrage zur Ophiolitfrage in Anatolien (Türkei). *Jahrb. d. Geol. Bundesanst. Bd. 100. Wien.*

KAADEN, G. v. d. (1956) : Geologische und lagerstattenkundliche Forschungen im Raume von Edremit. *M.T.A. Ankara. Rep. No. 2400* (not printed).

———(1957a) : Report on geological fieldwork and mineral deposits within the Çanakkale-Biga - Edremit Peninsula region. *M.T.A. Ankara. Rep. No. 2661* (not printed).

———(1957b) : Report on the tungsten-antimony occurrence south of Dudaş (Vil. Bilecik-Kaza Söğüt). *M.T.A. Ankara, Rep. No. 2560* (not printed).

———(1958) : On the genesis and mineralization of the tungsten deposit Uludağ-Prov. of Bursa, Turkey. *M.T.A. Bull. No. 50. Ankara.*

———(1958) : On W-Zn-Cu prospection etc, on W (tungsten) prospection around the Uludağ range etc., on the geological setting and evolution of the region. *M.T.A. Ankara* (not printed).

KETİN, İ. (1947) : Uludağ masifinin tektoniği hakkında (Ueber die Tektonik des Uludağ-Massivs). *Bull. Geol. Soc. Turk. Vol. l.pp. 61-88.*

KUPFAHL, G. (1954) : Rapport über die geologischen Untersuchungen zur Kartierung der Blatter 55/2-55/4, Eskişehir, 56/1, 56/3 Sivrihisar. *M.T.A. Ankara Rap. No. 2247* (not printed).

LEBKÜCHNER, R. F. (1956) : Bericht über das Ergebnis der geologischen und lagerstattenkundlichen Untersuchungen im Braunkohlenhoffigen Gebiet von Örencik. (Vil. Çanakkale). *M.T.A. Ankara* (not printed).

MEER MOHR, H. E. G. v.d. (1956) : Report on the geological fieldwork in the area of Edremit. M.*T.A. Ankara* (not printed).

NEUMAYR, M. (1887) : Ueber Trias und Kohlenkalkversteinerungen aus dem westlichen Kleinasien. *Anz.d. Kais. Akad. d. Wiss. Wien.*

OBERHAUSER, R. (1954) : Ein Vorkommen von Involutina liassica (Jones) im Distrikt Eskişehir. *Bull. Geol. Soc. Turk. Vol. V. p. 204.*

PHILIPPSON, A. (1910) : Reisen und Forschun-en im westlichen Kleinasien. *1. Heft. Erganzungsheft No. 167. Petermanns Mitt.*

———(1918) : Kleinasien, Handbuch reg. Geologie. *Heidelberg.*

PENCK, W. (1918) : Die tektonischen Grundzüge Westkleinasiens, *Stuttgart.*

PINAR, N. (1949) : Les lignes sismiques du bassin egeen de l'Anatolie et les sources thermales. *İstanbul Üniv. Fen Fak. Mec. Ser. A. XIV.*

PINAR, N and LAHN, E. (1955) : Nouvelles considerations sur la tectonique de l'Anatolie (Turquie, Asie Mineure). *Bull. Soc. Geol. de France, Tome. 5. Fasc. 1-3. pp. 11-34.*

SCHÜRMANN, H.M.E. (1956) : Beitrage zur Glaukophanfrage (3). Geologie der Glaukophangesteine in Japan und in der Türkei. N*eues Jb. Mineral. Abh. 89. pp. 41-85.*

TERNEK, Z. (1949) : Geological study of the region of Kasan-Korudağ. *Fac. Sc. İstanbul.*

TCHIHATCHEFF, P. de (1866-1869) Asie Mineure, description physique de cette contree. 8 Vol. *Paris.*

WEDDING, H. (1957) : Bericht über eine Untersuchung des Braunkohlenvorkommens bei Can - Çanakkale. *M.T.A. Ankara* (not printed).

WIJKERSLOOTH, P. de (1941) : Einiges über den Magmatismus des jüngeren Palaeozoikums (des Varistikums) im Raume West-Zentral Anatoliens. *M.T.A. Mec. 4/25 Ankara.*

———(1944) : Notes explicatives de la carte geologique de la Turquie. *Feuille Istanbul M.T.A.*

YALÇINLAR, I. *(1952) :* Les lignes structurales dc la Turquie. Congres Geologique International, Section XIII. Alger.