GEOLOGY AROUND EZINE AND BOZCAADA THE AGE OF THE LIMESTONES AND SERPENTINES

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ABSTRACT. — A series consisting of marbles and various types of metamorphic schists of Paleozoic age, constitutes the oldest formations in the area of study. The average direction of schistosity of this series, which shows metamorphism to varying degrees, is generally NE-SW. They have been folded during the initial paroxysm of the Varistic tectonic phase. This series is overlain by fossiliferous Permian formations, which mainly consist of conglomerates, limestones, sandstones and flysch sediments intercalated with members of the ophiolitic series. The Permian formations have also been folded by the young Varistic tectonic phase. The general strike of the Permian strata is NE-SW. Intrusions of acid igneous rocks, as well as ophiolitic rocks, are regarded to belong to this period. In Bozcaada, this series is unconformably overlain by Eocene formations, consisting of conglomerates, limestones and flysch sediments. In this area the Pyrenean tectonic phase represents the most important effect of the Alpine orogeny. There is a well-defined unconformity between Eocene and Neogene strata. The sea completely left this area during the post-Eocene tectonic movements. Lacustrine environment during Neogene caused mainly the deposition of conglomerates, sandstones, clays, sands, marls and limestones. Though generally the bedding is horizontal, some high dips may be observed near lines of dislocation. Volcanic activity was extensive during Neogene times. Sometimes concentric zones of volcanics may be observed. The greatest volcanic activity took place in Pliocene. During Lower and Upper Pliocene times, when there was large-scale subsidence in the Aegean region, the area studied was included within a large closed basin. This area was invaded by the sea when, at the beginning of Pleistocene times, the Hazer Sea in the north joined the Mediterranean in the south. Marine Pleistocene fossils are found in many places around the Sea of Marmara, as well as around Dardanelles.

I. INTRODUCTION

The area studied covers the ground around Ezine and also includes Bozcaada, of the Province of Çanakkale, West Anatolia. The geological study of this area was carried out within the frame of geological revision of the maps to be included in the Ayvalık-İzmir sheets of the Geological Map of Turkey of 1:500 000 scale. Geologists, E. Tanören, M. Zaralıoğlu and E. Arpad helped with the field work. Dr. K. Markus and Dr. Ö. Öztunalı carried out the petrographical studies. Paleontological investigations were made by Dr. L. Erentöz and Dr. S. Erk. I would like to express my gratitude to my colleagues above and to Dr. C. Erentöz to whose encouragements in the field work I am indebted.

II. PHYSICAL FEATURES

The western section of the area is made up of plains of very low altitude, which extend far inland from the coast. The average height of this section of the area is around 50 meters above the sea level. Eastwards, the height above

sea level increases. The highest points in the area are Büyükkızıl Tepe (385 m) and Fığlı Dağı (296 m). The main stream passing through the area is Küçük Menderes. The western section is locally covered by forests. Çanakkale-İzmir national road passes through this area (Fig. 1).

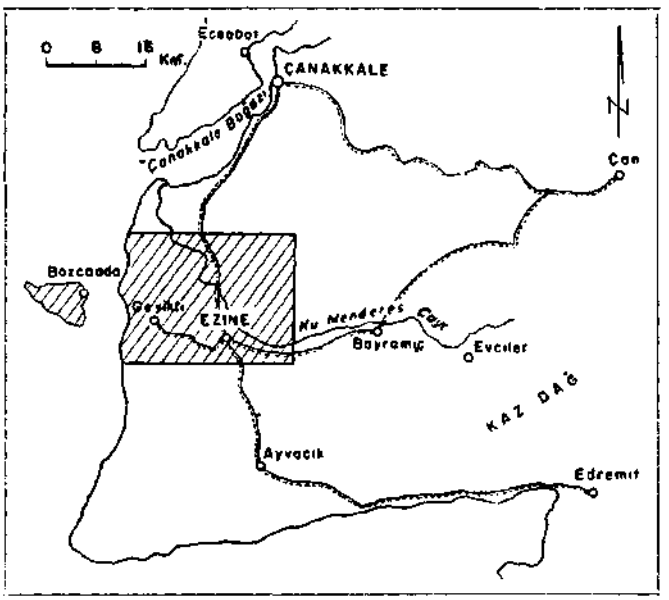


Fig. 1 - Map showing location of mapped area

III. PREVIOUS STUDIES

Previous geological studies of this area have been carried out by P. de Tchihatcheff, P. Spratt, A. Philippson, W. Penck, M. Akartuna, K. Erguvanlı and G. van der Kaaden. The first study of this area was made by Tchihatcheff, who pointed out the highly fossiliferous nature of the Tertiary rocks. Fossils of vertebrate fauna were found by Spratt around Erenköy, immediately to the north of our area of study. K. Erguvanlı, whose region of study included the present area, commented on the similarities between the lithology and fauna of the Neogene formations of this area, and the typical salt-water Miocene (Pontian-Sarmatian) sediments of the İstanbul region. G. van der Kaaden worked in the east and southeast of the area and established the existence of an unconformity between gneisses and the less metamorphosed strata, concluding to a Lower Paleozoic age for the serpentines. R. D. Schuiling regarded the crystalline rocks of Kaz Dağı of pre-Hercynian age. He found a clear connection between pre-Hercynian, Hercynian and Alpine tectonic phases and their respective (ultra) basic initial magmatic activities. M. Akartuna working in İmroz Island, NW of the present area, noted the existence of Oligocene formations, containing fresh-water sediments with plant remains, which conformably overlie the Eocene flysch sediments.

IV. STRATIGRAPHICAL SUCCESSION

The following units are found in the area studied : metamorphic rocks of Paleozoic age, Permian limestones and flysch, Eocene limestones and flysch, Tertiary lacustrine formations, alluvium, acid igneous rocks, ophiolitic rocks, lavas and tuffs (Fig. 2).

Paleozoic

Metamorphic series- — The mainly epi-metamorphic schists that cover large sections of the area of study, overlie, with a possible unconformity, the gneiss-amphibolite massif of Kaz Dağı. Some contact-metamorphic rocks, such as

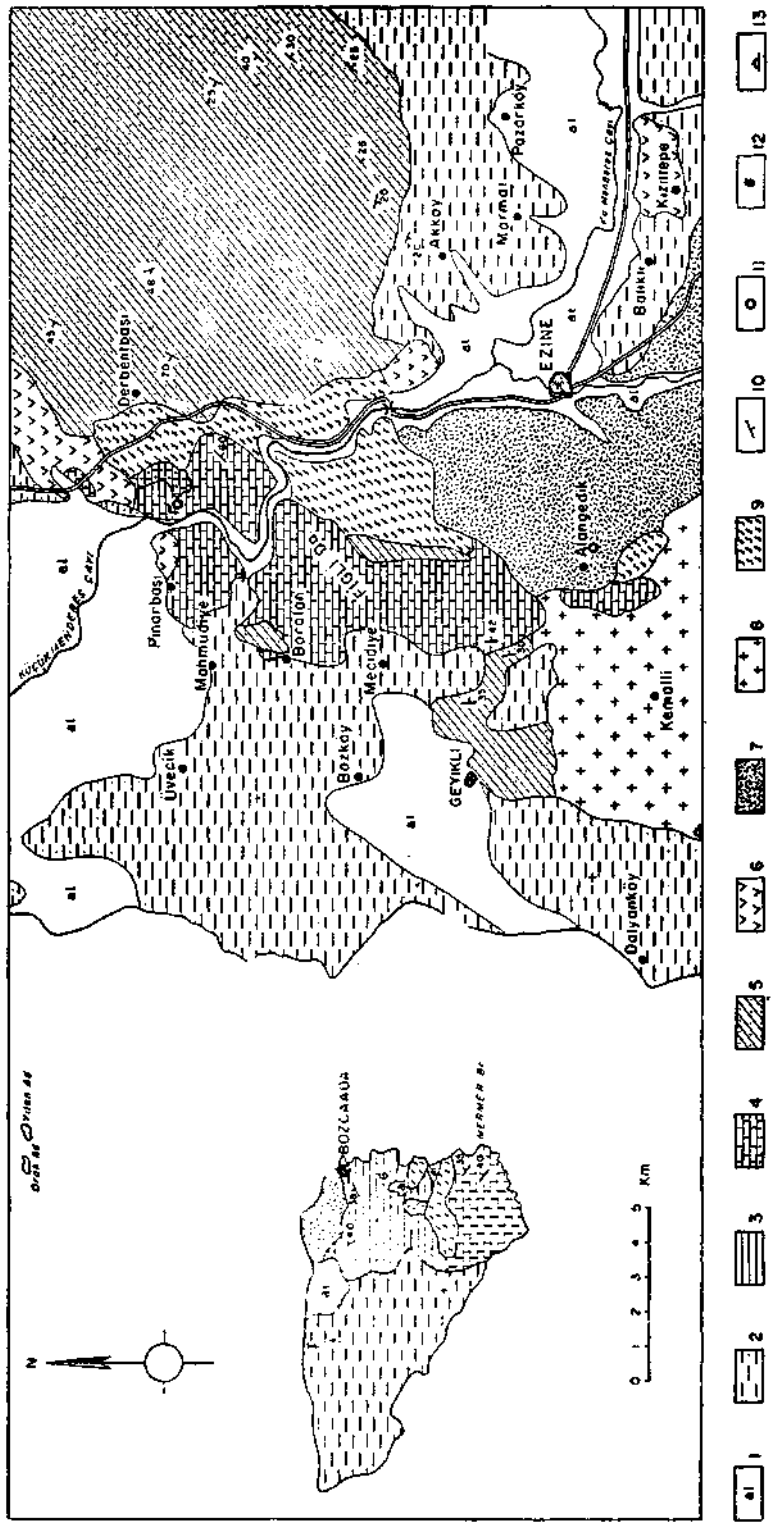


Fig. 2 - Geologic map of the area around Ezine and Bozcaada

1 - Alluvium; 2 - Conglomerate-sandstone-clay, sand-marl-limestone, silica-tuff (Neogene); 3 - Conglomerate-limestone, flysch (Eocene); 4 - Limestone, flysch (Permian); 5 - Sericite-schist, phyllade, quartzite, mica-schist (metamophic series); 6 - Basalt; 7 - Andesite; 8 - Granite; 9 - Serpentine; 10 - Strike and dip; 11 - Sample localities; 12 - Fossil bed; 13 - Hot spring.

amphibolite-schist, pyroxene hornfels, may be observed at the zones of contacts of large granodiorite intrusive bodies with surrounding country rocks. The schist series, which we named as the «Çamlıca massif», mainly consists of quartz-sericite schist, epidote-actinolite-albite schist, quartz-muscovite-chlorite-albite schist, schists with two micas, and quartz-muscovite schist. The constant average NE-SW strike of this series may locally show deviations due to orogenic movements and fracturing.

The distribution of this series indicates a widespread extension of the Paleozoic (Devonian-Carboniferous) geosyncline in this area. A thick sedimentary succession, accumulated by the continuous sinking of the gcosynclinal floor, was regionally metamorphosed by high temperature, stress and hydrostatic pressure. Intrusion of magma and the activities of some orogenic movements quickened metamorphism, causing the development of zones of high metamorphism at a number of localites. Depending on the degree of metamorphism reached at depth and surface, the beds appear to be a continuously concordant series in the area.

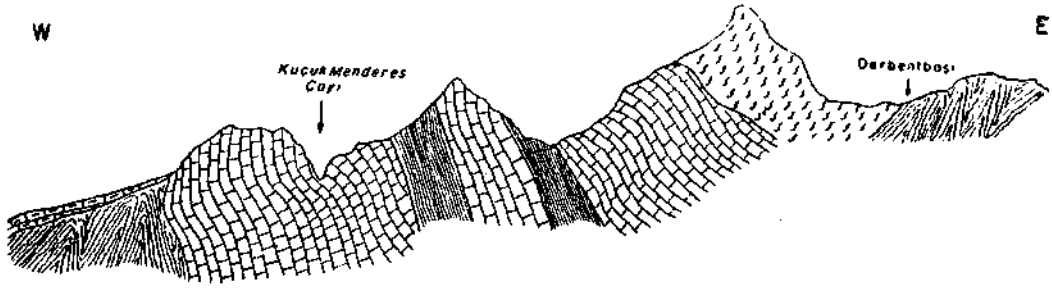


Fig. 3 - Section showing Permian, serpentines and schists in the area between north of Bozalan Köyü and Derbentbaşı

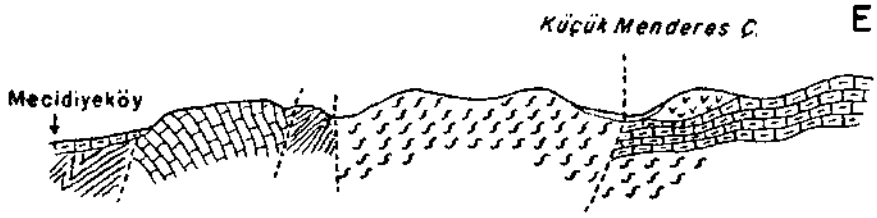
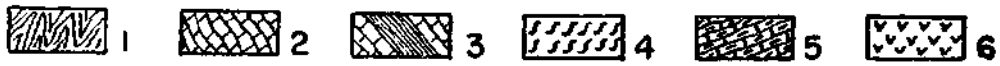


Fig. 4 - Geologic section of the area between Mecidiye Köy and north of Akköy



1 - Metamorphic series; 2 - Permian limestone; 3 - Permian flysch + ophiolite; 4 - Serpentine; 5 - Clastic series, Neogene; 6 - Basalt.

Permian

The oldest fossiliferous series in the area of study belong to Permian age. The Permian formations commence with a basal conglomerate, which unconformably overlies the metamorphic schists. Upwards they are followed, first by brown-colored hard sandstones, then by white, massive crystalline limestones, gen-

erally devoid of bedding, but sometimes containing thin bands of shales. These white limestones are followed by fossiliferous black limestones, which, in turn, are overlain by flysch sediments (marls, clays, limestones, sandstones), which contain intercalations of ophiolitic rocks.

Samples collected from the higher horizons of the limestones exposed along Küçük Menderes, north of Ezine, have been paleontologically analyzed by S. Erk, who found, as microfauna:

Glomospira

and as microflora:

Mizzia vclcbitana Schubert

which indicated an age of Middle Permian. A limestone of a similar character found in our area of study yielded:

Neoschwagerina cf. *craticulifera* Schwager
Glomospira
Hemigordius

which also indicates an age of Middle Permian.

Limestones of similar facies, overlying metamorphic schists, but isolated from each other, have also been regarded of Permian age.

White limestones underlying serpentines in the south of Bozcaada are also probably of Permian age.

Eocene

The Eocene formations are exposed in an area, approximately 4 km wide, extending from Kaza to Poyraz Harbor, east of Bozcaada. At Poyraz Harbor, they overlie serpentines and commence with a red-colored basal conglomerate, about 30 m thick. A gray-colored conglomerate, of approximately similar thickness overlies this formation, which, in turn, is overlain by brownish-white colored, abundantly fossiliferous limestones. The following results were obtained by S. Erk, who studied some samples of these limestones: This is a limestone with Alveolinas. This limestone, which is formed by numerous organic shell fragments set in a cryptocrystalline and opaque matrix, may also be described as zoogene or cochinoidal. It includes the following fauna of Lutetian age :

Nummulites sp.
Assilina spira de Roissy
Operculina
Alveolina sp.
Discocyclina sp.
Rotaliq trochidformis Lam.
Pararotalia
Pyrgo
Triloculina
Quinquoloculina
Textularia

The fossiliferous Lutetian limestones are overlain by the fossiliferous flysch sediments of the Eocene, consisting of conglomerates, sandstones, marls, clays, breccias and limestones. This flysch series, which extends to Kaza, is overlain by altered andesites around Göztepe in the north.

Neogene

Neogene formations cover extensive parts of the area studied. Though a large amount of information about the Neogene formations of this area has been given by the earlier workers —- Spratt, Tchihatcheff, Dillar, Calvert, Neumayr, Philippson and Erguvanlı — there appear some contradictions between their interpretations. A period of erosion commenced in the whole of the Çanakkale area, following the regression of the marine, conditions of the Eocene times. Lacustrine conditions set in probably during the Miocene (possibly Lower Miocene) times, which lasted till the end of Miocene. Once again, a marine sedimentation basin was developed during the Lower Pliocene times. (This description of events may generally be applied to the whole of the Aegean region.)

In the area studied, formations of Neogene age are usually found to be horizontal. They overlie the older formations with coarse basal conglomerates, which are upwards followed by sandstones, clays, marls, limestones, conglomerates, sands, tuffs and sandy limestones with beds of varying amounts of thickness. This series contains abundant fossils. An age of Lower Pliocene was given by L. Erentöz, on the basis of the following fauna:

Limnocardium (Euxinocardium) ochetophorum (Brusina)
Limnocardium decorum (Fuces)
Paradacna radiata (Stevanovic)
Ostracodes (abundant)
Ghara (rare)

These fossils were also compared with the Sarmatian forms, but have been, almost invariably, found to be related to the forms of Lower Pliocene.

Quaternary

The English, who previously studied the area north of the present area of study, recorded marine Quaternary sediments around the Sea of Marmara and the Dardanelles. According to him, subsequent to an opening of a canal between Mediterranean and the Sea of Marmara, the waters of the latter became sufficiently salty to enable the entry of the Lower Pleistocene fauna from the Mediterranean. On platforms around Çanakkale, none of which exceeds 15 meters in height above sea level, F. Calvert and M. Neumayr found many fossils, relatives of which still thrive at the present day in Mediterranean. In the western half of the area, large alluvial flats cover wide areas on both sides of Küçük Menderes. There are also important alluvial deposits north of Geyikli.

V. IGNEOUS ACTIVITIES

Ophiolitic series

Serpentines are the most extensive type of ophiolites in the area. Since the main purpose of this paper is connected with the serpentines, first we would

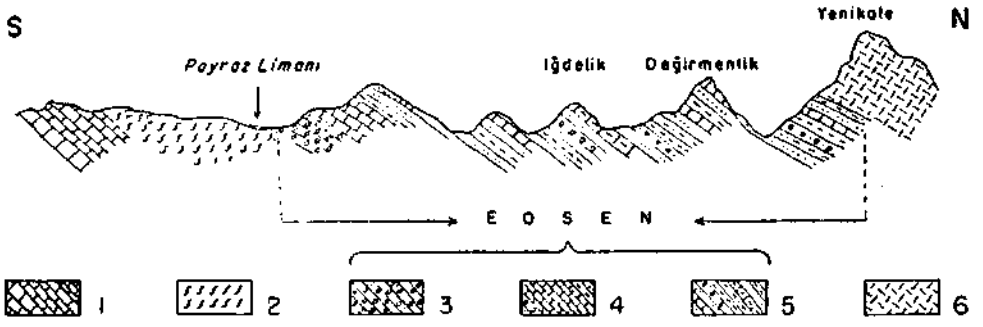


Fig. 5 - Geologic section of Bozcaada - Yenikale - west of Mermer Burnu

1 - Cristalline limestone (Permian); 2 - Serpentine; 3 - Eocene basal conglomerate (red at the bottom, gray-colored at the top); 4 - Brown-colored limestones rich in Nummulites; 5 - Flysch (conglomerate, sandstone-marl-clay-limestone); 6 - Andesite.

like to summarize the various ideas put forward about the age of serpentines up to the present :

According to the previous studies, there are three ophiolitic zones in the Aegean region :

1. Serpentines of Lower Paleozoic age. (These are emplaced between the pre-Paleozoic formations and the early Paleozoic formations.)
2. Serpentines of Permian age. (They are included in the magmatic region of the geosynclinal zones of young Varistic movements.)
3. Serpentines of Mesozoic (Upper Cretaceous) age.

1. Serpentines of Lower Paleozoic age.— These are recorded to consist of greenstones intercalated with the metamorphic schist series, and glaucophane schists which have been formed by the metamorphism of greenstones.

Some geologists claim that the much tectonized lenticular serpentine masses found within the early Paleozoic schists are of Lower Paleozoic age. Within the area of study, serpentine pebbles have been found nowhere in the Permian conglomerates, which unconformably overlie the metamorphic series, though there are serpentine exposures near by. This point is considered significant. The presence of the ophiolites within the schists may be discussed as follows : Beds of the metamorphic series constitute the base for the ophiolitic intrusions and extrusions. It is certain that the initial intrusive rocks, as well as the whole surrounding series, have been affected by the subsequent intensive orogenic movements. These orogenic movements, consisting largely of folding and imbrication, may have intensely affected large and small areas and geosynclinal depressions. These tectonic complications may result in the intermingling of the ophiolites with the old foundation formations. Therefore, it is our contention that the age of the serpentines should be determined only on the basis of relationship between the thick and large masses of ophiolites and the surrounding strata. Lenticular or smallish ophiolitic masses should not be considered as significant for age determination.

2. Ophiolites of Permian age-— According to Philippson, Paeckelmann and Wijkerslooth, the age of the Western Anatolian ophiolites is early Paleozoic.

Wijkerslooth mentions the existence of diabase within a series consisting of clayey shales, graywacke-sandstones and Fusulina-bearing limestones at top. He claims that ophiolites belong to the magmatic region of geosynclinal zones of young Varistic age.

In the present area of study, the serpentines are exposed in the north of Ezine, in a N-S extending belt, 10 km long and 2-4 km wide. They are also found in small exposures south of Poyraz Harbor on Bozcaada, and to the southwest of Bergaz.

The Permian limestones of Fığlı Dağı, upwards pass into sediments of the flysch facies. Serpentines, layers of which are found intercalating with these flysch beds, later dominate the higher sections of the series. In the south, contact between the limestones and serpentines is found to be of interfingering nature. On a sample taken from the granite-serpentine junction, SE of Bergaz, it may be clearly seen that granite has metamorphozed the serpentine. According to Öztunalı, who studied this sample, the serpentine, originally showing a scaly texture, has been brecciated and altered by contact-metamorphism. This is indicated by the alteration of metallic elements (Fe, Mn) parallel to the original scaly texture. Since such an alteration may only take place under thermodynamic conditions, it is evident that the serpentine was subjected to the contact-metamorphism of the granite. Thus, we conclude that the age of the serpentine must be older than the granite, hence Permian.

3. Serpentines of Mesozoic (Upper Cretaceous) age-— In the eastern sections of Western Anatolia, around Kütahya (Tavşanlı), the age of the ophiolites, which intercalate with the members of the Upper Cretaceous flysch, is quite clear. Therefore, it is our opinion that all the ophiolitic rocks of Aegean region can not possibly be of the same age. It is certain that, apart from ophiolites of an Upper Cretaceous age, there are some of Paleozoic age.

Acid intrusive rocks

The overall mineralogical composition of the small batholith at Bergaz, south of the area of study (and extending further south), is a granodiorite. Among the acid intrusions, locally there may be diorites, granites, porphyrites, pegmatites and aplites. Though the granites are generally fresh, near Bergaz they appear to have suffered a great deal of decomposition, forming wide sandy areas. Samples taken from the small batholith of Bergaz gave the following petrographical determinations :

South of Bergaz : porphyritic diorite,
Ezine, Üskütçü : diorite,
Yaylacık NW : granodiorite,
Ezine, Çamtepe : alkali granite.

Age of granitic rocks

The age of the granites of the area studied, as common to all granites in the Aegean region, is Hercynian, which has been previously established and accepted by many earlier workers. This age can be simply deduced from the fact that the Triassic-Jurassic sediments near or at contact with the granite have

not been metamorphozed, and also granite pebbles are found within the basal conglomerates of these formations. Since the granites have affected Lower Paleozoic and Permian limestones by contact-metamorphism, it may be concluded that these acid igneous rocks must belong to the Varistic orogenic phase.

VI. VOLCANIC ACTIVITY

The young effusive rocks of the area discussed are represented by andesites, dacites, basalts, tuffs and agglomerates. These belong to the post-tectonic phase and are mainly of Tertiary age. In the east of Ezine, much altered hornblende-andesites are found intermingled with tuffs and agglomerates. In Bozcaada, altered andesites are seen to overlie Eocene flysch sediments. At Kızıltepe and to the NE of Pınarbaşı, sediments of Neogene age are overlain by olivine-basalts, which in turn are overlain by laminated limestone beds. At many localities, especially to the north of the area, volcanic rocks and sediments of Neogene age are found interbedded.

VII. TECTONICS AND PALEOGEOGRAPHY

The area studied has suffered phases of Hercynian and Alpine orogenies. Rocks of the metamorphic series constitute the oldest tectonic unit of this area. The stratigraphically lowest portions of this metamorphic series are exposed on Kaz Dağı, SE of the area. G. van der Kaaden describes the isolated occurrences of gneiss-amphibolite series as separate domes, and claims that the overlying metamorphic rocks are unconformable over the former. In this case, the south of the area has probably suffered a Caledonian orogeny. (According to G. van der Kaaden, the gneisses are of pre-Paleozoic age.) The metamorphic rocks are rather intensely folded along NNE-SSW-oriented axes.

Metamorphic rocks of the arfa studied generally strike at NE-SW. This is the average direction of all Hercynian series of the Aegean region.

The metamorphic series has first been folded by the early Varistic phase. This was followed by marine invasion during the Permian. The average strike direction of Permian strata is also NE-SW. They generally dip SE at 40-70 degrees. Once again, towards the end of Permian, the area was uplifted above the sea level. This was followed by the intrusions of ophiolites and acid igneous rocks, No Triassic, Jurassic or Cretaceous strata have been seen within the studied area, though formations of these periods are known to exist in the neighbouring areas. The Permian strata is overlain by the basal conglomerates of marine Eocene. Following the Laramian orogenic phase, during the Lutetian, the area was once again covered by the sea. With the Post-Eocene tectonic movements the sea was completely withdrawn, which was followed by the most intensive tectonic phase (Pyrenean phase) of the Alpine orogeny.

Probably during the Miocene, the area was covered by lakes. The presence of the Attic tectonic phase may be regarded to occur within the Pliocene. Marine Quaternary sediments are found to the north of our area of study. The subsidence of the Aegean region (therefore of our area) commenced in the Pliocene. The seas to the north and south were connected during the Pleistocene.

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