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GEOLOGY, STRUCTURAL FEATURES AND SULPHIDE AND MANGANESE OCCURRENCES OF THE HOPA-ARHAVİ AREA (NE TURKEY)

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ABSTRACT — The area investigated is situated in the well-known mining district of Hopa-Murgul-Artvin. It is built of volcanic-sedimentary, effusive and intrusive rocks. The age of rocks ranges from Senonian to Quaternary. The basic volcanic-sedimentary series have been studied and subdivided in detail. Microfauna points to the Santonian-Campanian-Maestrichtian stage. Acid volcanic-sedimentary complex overlies the basic series. This complex is characterized by rhythmical alternations of different facies, which vertically and laterally thin out passing into homotaxial facies of tuffaceous, argillaceous and marly sandstones whose age ranges from Maestrichtian to Lutetian. Intrusive rocks are built of diorite and gabbro, granodiorite and quartz diorite and biotite granite. They were most likely formed in Oligocene-Miocene period. Reactivated volcanism in Tertiary produced augite-hornblende andesite and augite-diabase and basalt, mostly in the form of veins and sills. Geotectonically the region under investigation belongs to the Pontid-Adjaro-Trialete tectonic unit. All rocks of this geotectonic unit were formed in the eugeosyncline whose petrological character is volcanic-sedimentary. Tectonically, faults are predominant although the plicative forms are noticed, whose folds axes have ENE-WSW strike, in general. Mineral occurrences are divided into pyrite, manganese and skarn type according to their composition and genesis.

INTRODUCTION

Investigations in the Black-Sea region of NE Turkey in the Hopa-Arhavi territory were performed by a team of the Yugoslav geologists: S.Hristov, D. Koprivica, D. Lazic, S.Markov, V.Stanic and V.Stevanovic. During the field investigation in 1970, 85 sq. km were explored and mapped in the scale of 1:10,000 (D. Koprivica *et al,* 1971).

Microscopic determination of rock samples was carried out by D. Pesic and polished section studies by S. Talic, Yugoslav experts. Other analyses were performed by specialists of the M.T.A. Institute: S.Topçu - geochemical analyses, Y.Alarslan - chemical analyses, O. Orhun and A. Doğu - DTA analyses, Y.Pekmen and İ.Çakmak - micropaleontological analyses.

The Hopa-Arhavi territory is situated on the Black-Sea coast and stretches 12 km southwards. The terrain ascends from 0 to 1,500 m and is crossed by several creeks and brooks. In its major part, it is densely covered with Rhododendrons which made the work very difficult.

Main references for the Hopa-Arhavi region were written by A.Struve (1902 - a short report on the Peronit rnine); E.Zimmer (1937, 1938 - occurrence of Cu, Zn, Pb and Mn minerals); V.Kovenko (1941 - a report on a visit to the old mines). The most complete is the paper of A. Kraeff (1963) which covers the north part of the territory here described. Besides, here are well known old mines of: Peronit, Sivrikaya, Kutonit and a number of slag findings which bear evidence of flourishing activity.

LITHOSTRATIGRAPHICAL DESCRIPTION1

Dacitic breccias and tuffs

These rocks have small extension in the described region. They are placed between Peronit and Arhavi along an old and a new road. Smaller parts underlie sands and sandy limestones and also homotaxial facies (tuffaceous, clayey and marly sandstones and limestones). The rocks mentioned could be distinguished from rhyodacites and their tuffs by intensive green color and they are very cataclazed and silicified. Dacitic pyroclastic rocks are of submarine effusive character with intensively developed sedimentary components. Their texture is crystallolithoclastic and granular. The rock is composed of quartz and feldspar fragments in tuffaceous mass. The groundmass is crystalline-granular with bedded or ribbon structure. Almost everywhere chloritization and serialization are present and due to these changes the color varies from gray-green to grayish white. Dacitic breccias and tuffs by their lithological habitus and superposition of facies in the Hopa-Murgul region are similar to the dacitic tuffs and microbreccias near Artvin (D. Koprivica et al, 1973). When compared, they would belong to the Lower Senonian.

Basic volcanic-sedimentary series

This series has a large extension in the Black-Sea region. Former investigators have treated it differently. T. Gattinger and others (1962) take it as volcanics of basic composition and consider it to have started from Cenomanian. St. Bojadzijev (1967) states that in the eastern part of the Balkans similar volcanic activity started from the Upper Cenomanian. A. Azizbekov and A. Dzocenidze (1970) give us information that the Upper Cretaceous volcanism of the spilitic-diabase composition, with porphyric rocks and accompanied by quartz carbonate sediments is developed in the Pontid region as well. Regarding that diabases and basalts are mostly intensively spilitized and trachyandesite albitized (keratophyre), A. Kraeff (1963) in the Hopa-Murgul territory presents this series as «spilitic series II» and considers it to be younger than «albite dacites I» and «albite dacites II». A. Kraeff concludes that the scries could in places reach the thickness of 1000 m. The «spilitic series II», we treated, after our recent investigations, as *basic volcanic-sedimentary series* being older than «albite dacites II» (in this paper: *rhyodacite, dacile and their pyroclastites)*. S. Buser (1970) — in the vicinity of Murgul — describes it as albite-trachytic agglomerates distinguishing basalts in their lower part. J. Stern (1971) — in the Murgul region — identifies the distinguished members in this series which correspond to the basic volcanic-sedimentary series from the region of Hopa-Arhavi.

According to the development of geosynclinal magmatism in the described region, this series of rocks could correspond to the initial magmatism. These are diabases and basalts, andesites and trachyandesites (diabase-spilitic keratophyre association). The whole extrusive activity here is of submarine origin. Lithological differences in the basic volcanic-sedimentary series enabled us to distinguish two formations: (1) diabase and basalt (predominantly spilitic) and their pyroclastites; (2) andesite and trachyandesite (keratophyre) and their pyroclastites.

Diabase and basalt (spilitic predominantly) and their pyroclaslites. — This formation builds the major part of the area described. It was discovered along the Black-Sea coast (Hopa-Arhavi) and in the Kise Deresi and the İsina Deresi river valleys. Diabases and basalts in places show distinct pillow texture (Fig. 1). Then combined spherulites and breccia produce agglomerates and in the absence of spherulites they look like genuine breccias.

The rock color depends on their freshness and varies from green to gray and red-violet. The members described above are characteristic by alternations of tuffaceous sandstones (Fig. 2) and limestone beds and lenses.

The presence of sedimentary formations points to occasional submarine effusive rock interruptions and the existence of relatively calm intervals when the sediments (limestones) containing microfauna fossils formed, and in which the following forms and genera have been determined: *Globotruncana lapparenti tricarinata, Globotruncana* sp., *Gümbelina* sp., *Globigerina* sp., *Textularia* sp. The microfauna established points to the Lower Santonian-Lower Maestrichtian age. Spilitization prevails in diabase and basalt formation but there are parts of rocks where this process is not evident. It is difficult to confirm the origin of spilitic characteristics in these rocks, but water saturation and sodium concentration during differentiation and contamination in the geosynclinal basin probably played part in this. Apparent unconformity may be detected between basalt flows of different types (Fig. 3).

Such correlations may be observed in cuttings of more recent profiles (rivers and roads). On ridges and on slopes these rocks are disintegrated to such an extent that original rock can hardly be recognized. In such cases only amygdaloidal texture skeleton can be noticed. While mapping in the Pazar region we noticed the same characteristics of spilitized diabases and basalts (D. Koprivica *et al.* 1971a).

Diabases show ophitic texture combined with amygdaloidal. Rare phenocrysts are plagioclase. The groundmass consists of ophitic plagioclases (labradorite-albite) with fine grains of augite and biotite flakes. Its accessory constituent is an opaque mineral.

Basalts have identical mineralogical composition to diabases but differ in texture. They have holocrystalline-porphyritic texture combined with amygdaloidal or ophitic amygdaloidal one. Basalt with leucite was found very rarely only. Basalts and diabases are characterized by numerous amygdules filled with calcite, chlorite, quartz, zeolite and rarely with actinolite, epidote, prehnite, scapolite and limonite (Fig. 4).

In younger levels of diabase-basaltic pyroclastites, the Mn mineralizations often occur. These are minor submarine exhalation deposits with quartz and Fe in increased quantities. An ancient zinc and copper mine is known in this formation near Kutonit.

Andesite, trachyandesite (keratophyre) and their pyroclastites. — This formation was located in the S part of the map on both banks of the Çifteköprü Deresi (river). It was not possible to define the relation to diabase basaltic formation, therefore gradual passage was assumed. In places it is tectonically separated from diabases and basalts. In its upper part it gradually passes into genuine sedimentary breccia formation with beds of tuffaceous sandstones and sandy limestones. Judging by its outcrops this formation laterally and vertically passes into diabases and basalts. Andesites and trachyandesites are final members in the diabase-spilite-keratophyre association. They differ from diabase and basalt in distinct porphyritic texture in spite of numerous amygdules. Agglomerates and flow breccias are characteristic for this formation. Layers and intercalations of tuffaceous sandstones are represented less than in diabases and basalts, and limestones have not been noticed. The rock is mostly gray and gray-green in color. According to numerous petrographic analyses, this formation is built of two equally distributed varieties: andesites and trachyandesites (keratophyre). The transitional type of andesite-basalt (and very subordinate trachyte) exists in a small extent. Andesites have holocrystalline-prophyritic texture. Phenocrysts are plagioclases (andesine, rarely oligoclase). Fe-Mg minerals are usually chlerritized, carbonatized and limonitized. The groundmass is built of tiny feldspar crystals. An accessory constituent is an opaque mineral (hematite). The groundmass is intensively argillitized, silicified, rarely chloritized, carbonatized and limonitized.

Trachyandesites (keratophyres) have holocrystalline-porphyritic texture which is rarely combined with fluidal and amygdaloidal textures. Mineralogical composition is generally identical to andesites, i.e. with phenocrysts of plagioclase, K-feldspar and altered Fe-Mg minerals. The groundmass is made of microlites and fine albite crystals, sporadically limonitized and with distinct fluidity in which the above-mentioned constituents are parallel. Numerous amygdules are filled with quartz, calcite, chlorite, zeolite, epidote and quite subordinately albite (Fig. 5). Rock is intensively albitized and rarely sericitized, epidotized, and has distinct alterations like in andesite.

The age of this formation corresponds to the upper levels of diabase and basalt.

Acid volcanic-sedimentary complex

The members of this complex overlie basic volcanic-sedimentary series. At the bottom of this complex predominate diverse facies, they thin out vertically and laterally and grade into homotaxial facies of tuffaceous, clayey and marly sandstones. The following members have been distinguished: (1) sandstone, sandy limestone and breccia; (2) clayey tuffs and tuffaceous sandstones; (3)rhyodacite, dacite and their tuffs; (4) red and gray limestones; (5) andesite; (6) tuffaceous, argillaceous and marly sandstones with limestone intercalations.

1. *Sandstone, sandy limestone and breccia.* — This formation is found in the Kise Deresi area, south from the villages of Kise and Peronit, in the Balıklı Deresi (river), NE of Kutonit and in the Mağara locality. The formation of sandstones, sandy limestones and breccia is concordant to basic volcanic-sedimentary series underlying the former. This formation is heterogeneous and changes frequently, and this is particularly evident in the Yolgeçen Köy locality. Breccia is developed mostly in Yolge9en and Gürgençlik, where mostly andesites and trachyandesites (keratophyres) are encountered. Sandstones and limestones have distinct bedding. This is seen in microscopic scale. Sandstones are of clayish carbonate type. They are fine-and medium-grained. Grain size is 0.1 - 0.05 mm. Rock is built of relatively uniform grains of feldspar, quartz, biotite flakes and sometimes pyrite cubes. Cementing mass is composed of clay, calcite with chlorite and tuffaceous substance. These sandstones are often built of irregularly shaped grains, which points to the fact that material has not been transported too far. Limestones in the form of intercalations and layers are often sandy with abundant Fe substance. The texture is fine-grained. Rock is composed of calcite mass and rare grains of feldspar, quartz and metallic minerals. It is almost a rule that these limestones contain microfauna remnants. The microfauna established in the gray limestone beds in Pancöl Köy and Suğeren is: *Globotruncana lapparenti tricarinata, Globotruncana lapparenti lapparenti, Globotruncana area, Gümbelina* sp., *Globigerina* sp., *Textularia* sp. It may be concluded that these sediments belong to the interval between the Upper Campanian and Maestrichtian.

2. Argillaceous tuffs and tuffaceous sandstones. — This formation is located in the Peronit-Sivrikaya area. Its origin is closely associated with rhyodacitic effusion and related tuffs. It is very difficult to establish the correlation and boundary between this formation in the Sivrikaya-Peronit area and rhyodacites and their tuffs, since one part of their boundary passes gradually and the main part of it is tectonic, the basic volcanic-sedimentary series is tectonically separated or underlies this series.

Our observations in the Hopa-Arhavi area brought us new information which fundamentally changes the present opinion on stratigraphic correlations in this region. Considering that the Zn, Cu known ore deposits in the Peronit-Sivrikaya localities lie in this formation, it is very important to determine its character and place in the stratigraphic column.

According to the field observation and laboratory analyses this formation is sedimentary with high quantity of pyroclastic material. Pelitic tuffs are composed of 0.05 mm particles with banded texture and often parallel feldspar microlites. The rock consists of fine albite grains, very fine hematite-limonite grains and irregular quartz grains. The rock is intensively silicified, argillitized and pyritized. Transitions from tuffites to tuffaceous sandstones are particularly distinct. Some petrographic analyses show direct origin of this material from dacitic and rhyodacitic tuffs with distinct crystallolithoclastic texture. Such compositon points to successive direct eruption of volcanic material into the basin where the particles mixed and were deposited together with sedimentary material. Due to this we have distinct varieties: *argillaceous tuffs* with predominant pyroclastic materials and *tiiffaceous sandstones,* where pyroclastic particles are mixed with sedimentary material. These rocks are mostly gray-violet.

Intercalations and beds of argillaceous limestones containing microfauna relicts point to relatively calm intervals in volcanic activity, when all conditions existed for limestone formation and existence of live organisms — microfauna. The following species were determined in the Peronit-Sivrikaya limestones: *Globotruncana lapparenti tricarinata, Globotruncana lapparenti lapparenti, Globotruncana* sp., *Globigerina* sp., *Giimbelina* sp., *Textularia* sp. On the basis of microfauna the age could not be precisely determined but according to the formation superposition it is to be believed that these beds belong to Maestrichtian. Limestones near the Peronit mine contain recrystallized microfauna as well as expressed cataclasis and schistosity.

There are two main strikes of structures in the described formation: the first NE-SW and the other NNW-SSE. In the Sivrikaya, the dominant fault strikes 70°. It is manifested by highly silicified and pyritized tectonic breccia and on both sides of this fault silicification and argillitization are intense. Hydrothermal alterations are developed all over the area of Peronit-Sivrikaya (Fig. 6), such as kaolinization, silicification and pyritization with Zn, Cu sulphides.

3. Rhyodacite, dacite and their tuffs. — These effusive rocks are widespread in the investigated area. They strike NE-SW in the Kavak-Peronit area extending about 8 km with an average width of 1.5-2 km. They overlie basic volcanic-sedimentary series in the form of veins or minor bodies. Toward southeast the boundary of these rhyodacites and dacites with basic-volcanic-sedimentary series is tectonic. In the northwestern part the boundary is very much indented and minor or larger irregularly shaped rhyodacite and dacite masses overlie the basic series in the form of erosional tectonic residuals. Rhyodacite veins were found in argillaceous tuffs and tuffaceous sandstones. During the field work, distinguishing of dacites and rhyodacites from their tuffs was not possible, since they were simultaneous volcanic products of successive extrusions in submarine environment. This is confirmed by the presence of the lateral facies of argillaceous tuffs and tuffaceous sandstones. Almost as a rule, field observation displays intensive hydrothermal alterations of rocks. They are manifested by strong argillitization (kaolinite and montmorillonite, seldom illite), silicification and chloritization. Occasionally strong pyritization was also observed. As the surface manifestation of alteration there is frequent intense limonitization. The color of these rocks varies from violet to gray and very often to yellow and white.

By age, rhyodacites could correspond to the Laramian orogenic stage. This is Confirmed by their correlations with adjacent formations. Aceording to the tectonic features of boundaries mostly with spilitic diabases and basalts, their strike and the whole system of longitudinal faults in rhyodacitic mass, it may be assumed that NE-SW structures controlled their flow. The Sivri Tepe, as it looks today is a characteristic volcanic neck (Fig. 7). The peak dominates the area and looks like a breach. On the southern side a narrow diabase zone is inserted between a fault and a rhyodacitic body of the Sivri Tepe.

Rhyodacitic texture is holocrystalline-porphyritic and less frequently microphyric, sometimes with felsitic texture of the groundmass and very rarely fluidal. Phenocrysts are partly «clouded» plagioclases (albite and oligoclase) accompanied by K-feldspar. Quartz is most frequently bipyramidal in form, corroded quartz phenocrysts are noticed along the rims (Fig. 8). In places microperthite intergrowths are noticed. Biotite is rare and is chloritized and limonitized in the groundmass. The groundmass is composed of feldspar locally showing granophyric intergrowths with quartz, partly albitized (sometimes even up to 80 %). Quartz can be found as a secondary mineral as well. Accessory minerals always occur in the form of metallic powder, with rare relatively coarse grains of hematite, magnetite and pyrite. Secondary minerals are: chlorite, albite, quartz, calcite and limonite.

Dacites also have holocrystalline-porphyritic texture and their composition is identical to rhyodacites. In the hydrothermally altered parts beside kaolinization, pyritization, silicification and chloritization, also prehnitization, saussuritization and serialization were recognized.

Tuffs have fine-grained crystalloclastic texture. They are composed of partly altered K-feldspar and corroded quartz grains. The rock is often argillitized (bleached). The cement consists of tuffogenous-argillaceous substance with chlorite and metallic minerals powder. It is sometimes considerably silicified.

4. Reddish and gray limestones. — This limestone facies is relatively less widespread in the investigated area but important for stratigraphic superposition. They crop out as elongated zone on the right bank of the Kise Deresi and in a small area to the north of Ulukent. They overlie sandstones, sandy limestones and breccia or directly basic volcanic-sedimentary series. They thin out laterally and pass into homotaxial facies (tuffogenous argillaceous and marly sandstones with limestone intercalations). Bedding always has the dip angle of 20-60°C. They constitute an integral part of the Ulukent-Pınarlı syncline. Very often sandstones, gray and red limestones and marls alternate. Limestones are composed of fine-grained calcite with very rare grains of quartz, feldspar and biotite. They contain abundant microfauna relicts among which the following species have been determined: *Globotruncana lapparenti, Globotruncana* sp., *Rotalia* cf. *trahidioformis, Globigerina* sp., *Siderolites* sp., Algae and Bryozoa, *Gümbelina* sp., *Ostracoda* sp. Macrofauna has not been found. Based upon the established microfauna and superposition of sedimentary formations these limestones represent a bench mark for the transitional stage of the Upper Cretaceous-Paleocene (in the opinion of İ. Çakmak).

5. *Andesites.* — SSE of Çamlı Köy crop out andesites which form the Ciha Tepe and continue westwards to the ridge over the Peronit. They intersect the bottom parts of sedimentary series and overlie them. At the south end they are tectonically divided from the basic volcanic series. Andesite of the Ciha Tepe is in a sharp contact with surrounding sandstones intersecting them at an angle of 62° and 78°. In addition to this, the Ciha Tepe with its peak indicates a center of volcanic activity and the peak itself looks like a barren neck or dike. Steep walls dipping 80° to 90° have distinct columnar jointing structure also indicating a barren neck (Fig. 9).

This andesite lies in the zone of Peronit-Kavak in which suitable canals have probably been used by rhyodacitic flows. Andesite probably represents a later stage of rhyodacitic effusions. A. Kraeff (1963) identified them with «albite dacites» (now rhyodacite and dacite) and the surrounding tuffaceous argillaceous sandstones with dacitic tuffs. An andesite vein with intense zeolitization was found — the same in composition as the peak of the Ciha Tepe — on the road between Aşağı Şahinler-Ulukent. Macroscopically rock corresponds to andesite with visible feldspar phenocrysts. In the central part of the Ciha Tepe there are white bands and lenticular concentration of zeolite, 1-2 cm long. Central parts are characterized by trachyandesitic composition as well. Rock color varies from grayish-green to yellow and rarely violet.

The texture is porphyritic (in fresher parts the texture is clearly holocrysralline-porphyritic) with fine-grained groundmass. Rock is composed of microlites of plagioclase varying in length from 0.1-0.3 mm. In places phenocrysts are up to 90 % calcitized even. Biotite occurs as flakes between feldspar grains and is usually chloritized. Secondary quartz occurs in form of impregnations. The groundmass is composed predominantly of argillaceous and silicic substance; primary composition is frequently hardly visible due to intense argillization of feldspar. Intensive rock alteration is represented by argillization, zeolitization, calcitization, silicification, chloritization and limonitization.

6. Tuffaceous, argillaceous and marly sandstones with limestone intercalations. — Sediments of this series occupy the second place in abundance in the investigated area. They have been preserved in the eastern part in a syncline, with the strike of ESE-WNW, in the Ulukent-Pınarlı area. They build brachysyncline whose axis A has the strike of 64° gently dipping towards ENE (see PI. I- contour diagram D_4ss). The second part of these sediments is separated south from Kavak, between the villages of Yolgeçen and Güvercinlik (along the Mağara reef). Wherever intact by erosion these sediments build inverse relief. They overlie sandstones, sandy limestones and breccia as well as red and gray marly limestones and at places, where the preceding members thin out, they directly overlie basic volcanic-sedimentary series. This type of sedimentation gives to it the character of a homotaxial facies (from the Upper Senonian to the Middle Eocene). Though tuffaceous, argillaceous and marly sandstones alternate rhythmically, this facies is gradually enriched by finer-grained sediments and in upper parts argillaceous and marly sediments predominate. Limestone intercalations and beds are frequently developed and they thin out laterally. Particularly distinguished is the rhythmical alternation of sandy limestones and marls.

Tuffaceous and argillaceous sandstones have pelitic texture and rarely granular or fine-grained. In the pelitic texture particles are up to 0.05 mm in size and in the granular texture from 0.1-0.2 mm. The major groundmass is fine-grained and argillaceous (less than 0.01 mm) and this component accounts for about 80 per cent. Calcite sometimes accounts for up to 20 per cent. Rocks also contain quartz grains in the content up to 5 per cent, and altered feldspar grains together with rare grains of metallic mineral. Cement is argillaceous-carbonaceous and is very rare when the rock mass is well sorted and packed. Numerous calcite veins stretch along fractures.

Along the geological structures in the Güvercinli Köy and Balıklı Köy areas minor occurrences of compact and brecciated limestones with fragments and outlines of rudistid fauna were discovered. This indicates quite subordinate presence of reefs in this facies which is more developed in the Murgul region. The following microfauna forms were found in the homotaxial facies limestone intercalations: *Globotruncana* cf. *lapparenti lapparenti, Globotruncana globigerinoides, Globotruncana area, Gümbelina* sp., *Globigerina* sp., *Lentictilata* sp., *Nummulites guettardi, Nummulites subaticicus,* Operculina, Discocyclina. Nummulites were determined by Y. Pekmen in the uppermost part of marly sediments and they determined the age of the Lower Lutetian. This sedimentary series exists as a homotaxial facies from the Maestrichtian to the Lutetian stage. This ends up sedimentary geosynclinal cycle in the area investigated. Some pyritization of these sediments was noticed as being syngenetic with the rock formation.

In the Mağara region — at the contact of these sediments with granodiorites and quartz diorites — are discovered hornfels and skarn formations which shall be described later.

Intrusive rocks

In the investigated area frequent occurrences of granitoid rocks, intermediate and less frequently basic intrusives were discovered. The following members were distinguished: (1) diorite and gabbro, (2) granodiorite and quartz diorite, (3) biotite granite. These rocks often contain microdioritic, microgranodioritic, microquartzdioritip and micrograniti c differentiates and facies.

Intrusive rocks were formed in Tertiary after the Middle Eocene, most likely' in the Oligocene-Miocene interval, according to Magakljan *et al.* (1962). In the Caucasus Minor the intrusion of magmatic rocks took place in three main phases: (1) gabbro, (2) monzonite, (3) porphyroid granites and granodiorites. The above-mentioned authors applied the K-Ar method for determining absolute age and obtained the following results: for monzonite 35-40 million years (Oligocene), for granites and granodiorites 18-25 million years (Miocene). Intrusive rocks in the investigated area are probably synorogenic with the Savic orogenic stage (Oligocene-Miocene) and the mentioned members of intrusive sequence would correspond to that age.

1. *Diorite and gabbro.* — In the SW part of the investigated area, south of the Yolgeçen village and in the profile of the Lome Deresi river, diorite and gabbro occurrences were found. Also some minor masses of these rocks were observed at Kutonit, south of Kavak and Gürgençlik. By its macroscopic habit diorites are very similar to granodiorites and range from coarse- to fine-grained rock types. Gabbro ranges from granular to pegmatitic structure with augite crystals even over 1 cm long. The occurrence of these rocks in granodioritic and quartzdioritic complex allows different interpretations. Probably some minor intrusions of younger gabbro or, on the other side, a hybrid magma was formed as a result of assimilation processes during granitoid magma penetration through surrounding basic rocks and incorporating them in its own mass. The second interpretation is confirmed by the presence of a granodiorite hybrid rocks transitional to gabbro-diorite to the west of the old Kutonit mine.

Diorite and gabbro are gray-green. Texture of diorite is granular. The rock is formed of andesine crystals and some K-feldspar. Colored constituents are most frequently augite, less frequently hypersthene, hornblende and biotite. The main accessory constituent is a metallic mineral.

Gabbro has hypidiomorphic-granular texture as well. The rock is composed mostly of automorphic to hypidiomorphic plagioclase grains (labradorite and seldom bytownite and andesine). Augite and quite subordinate biotite occur as irregular grains. The accessory mineral is a metallic one.

2. Granodiorite and quartz diorite. — In the Lome Deresi profile, south of the Yolge9en village, a large mass of granodiorite and quartz diorite was distinguished at the contact zone with sediments along the Mağara ridge. Minor masses in form of veins and sills are numerous NE from the Yolge9en, in the area of Gürgençlik-Dereüstü-Kutonit-Peronit. Their presence was confirmed in the whole basic volcanic-sedimentary series and in the whole sedimentary complex. Field observation of granodiorites and quartz diorites west of Mağara showed numerous faults and fractures in them. These fractures are always accompanied by intensive pyritization. Major rock parts are sterile concerning pyritization.

According to the dark minerals composition, the granodiorite could correspond to augite-biotite type with hornblende. Its texture is most frequently granular (hypidiomorphic-granular, rarely combined with microgranophyric). The rock is composed of plagioclases and to a small extent of K-feldspar, which are partially intergrown in a granophyric way with quartz. Augite and hornblende occur as grains and biotite as flakes. Quartz forms irregular grains and makes 5-25 per cent of modal components. Accessory constituents are metallic minerals and rarely apatite, sphene and zircon. The alteration is represented by intense argillization (kaolin) and chloritization, accompanied by sericitization.

Hornblende-augite quartz diorite has hypidiomorphic granular texture. The rock is composed of elongate plagioclase crystals (andesine, less frequently oligoclase) and quite rarely K-feldspar. Main dark minerals are hornblende and augite, rarely biotite (Fig. 10). Quartz content varies. Accessory constituents are metallic minerals and rarely apatite. Rock is pyritized, silicified and frequently chloritized as well. The presence of quartz microdiorite variety with identical mineral composition has been noticed.

3. Biotite granite. — Southeast of Gürgençlik, two minor biotite granite masses are distinguished. The major part of these granites could be traced only along the ridge because of inaccessibility. Contact with limestones and tuffaceous sandstones is not evident, but covered with humus and rhododendrons. Sandstones in the vicinity of the contact with granite are silicified. Spheroidal weathering is distinct in these granites (spheroids of 4-5 m^3). Disintegration is concordant with surfaces of spheroidal boulders.

Biotite granite is whitish-gray. Hypidiomorphic-granular texture combined with granophyric is characteristic for biotite microgranite. The rock is composed of K-feldspar grains (orthoclase), less of plagioclase and biotite flakes. Quartz is less present forming irregular grains and intergrowth with feldspar (granophyre). Accessory mineral is metallic. Alteration is evident and represented by chloritization and epidotization.

Hornfelses and skarn

These formations are developed on the west slope of the Mağara along the contact between granodiorites and quartz diorites and tuffaceous and argillaceous sandstones. These rock occurrences could only be partially observed due to inaccessibility. Garnetite-type skarn occurs frequently as well (Fig. 11).

The rock is composed of garnet grains and crystals of various size (with partial limonitization along the rim) and some quartz in interstices. A skarn-type magnetite ore deposit with garnet, hematite, quartz and chlorite was detected. Hornfelses crop out frequently strongly silicified, sericitized, biotitized and mineralized with sulphides. There are some augite-scapolitic varieties of skarn formation being also mineralized. Amphybolites were found in the skarn zone and they are most probably the product *of* contact metamorphism too.

Augite-hornblende andesite and pyroclastites

Two formations were distinguished in the augite-hornblende andesite and they are separately described as: (1) augite hornblende andesitic pyroclastites and (2) augite-hornblende andesite.

1. Augite hornblende andesitic pyroclastites. — This formation was detected and mapped on the east-southeast part of the investigated area. They are preserved in the central portion of the Ulukent-Pınarlı syncline. The mapped unit is a pyroclastic formation in which breccias, agglomerates and tuffs alternate in the presence of andesite flows. Breccias and agglomerates contain lumps and blocks of andesite of different size. Large blocks often exceed 5-20 m^3. Tuffaceous sandstones occur as thin beds and lenses. All this indicates that material was deposited in a basin.

Pyroclastites are composed of fragments of augite hornblende andesite with varieties, hornblende biotite andesite and rarely, hornblende andesite and augite andesite. Pyroclastic texture is crystallolithoclastic. In some parts there are occurrences of andesitic flow breccia. Augite dacite tuff is occurring only as a differentiation product of andesite lava flows being more acid in some bordering parts.

2. *Augite-hornblende andesite.* — These effusives crop out on a relatively small area but very often occur in the form of minor bodies —- most frequently in the form of sills and veins over the investigated area. They are concentrated mostly in the area of Güvercinli Köy - Balıklı Köy - Ulukent and in the Mağara area.

Compared with similar rocks on the Caucasus Minor they may be of Pliocene age (Azizbekov *et* al., 1965).

In addition to augite-hornblende andesite, the augite biotite (Fig. 12) and augite andesite varieties also occur. Their texture is holocrystalline-porphyritic and their groundless is subophitic granular. Phenocrysts are plagioclases (andesine 65-50 % An) argillitized, albitized and less frequently sericitized and calcitized. Fe-Mg mineral constituents, augite, hornblende and biotite are chloritized intensively. The groundmass is composed of tiny oligoclase and andesine crystals which form ophitic aggregates and are partly albitized. There are some amygdules filled with chlorite and calcite as well. Silicification and epidotization are distinct. The accessory constituent is a metallic mineral. Andesite-basalt rock intermediate and rare differentiates of the normal andesitic rock in the mass of augite-biotite basalt were noticed. Infrequent dacite outcrops in minor sills were stated too. This may be the acidization phenomena of the same andesites.

Augite diabase and basalt

These are the youngest effusive rocks in the investigated area. They occur in the form of numerous veins and sills and rarely minor bodies, cutting all the other formations in the mapped area. They represent the latest product of the final tertiary magmatism. These veins are sometimes accompanied by weak pyritization. In a section on the new Arhavi-Çamlı Köy road a vein of young diabases cutting dacitic breccia and tuffs and containing their enclaves was discovered (Fig. 13).

Diabases have distinct ophitic texture. Transitional diabase-basalt rocks are detected as well. (Fig. 14).

In these rocks plagioclase sometimes is represented by albite containing 5-8 % An. There are also amygdules filled with calcite. Basalt texture varies from holocrystalline-porphyritic combined with ophitic groundmass and less frequently with fluidal orientation of microlites. Phenocrysts are plagioclases (labradorite, partly albite) and augite with some biotite. The groundmass is composed of ophitically intergrown plagioclases with some chlorite, epidote, quartz and calcite. An accessory constituent is a metallic mineral. Alterations are represented by calcitization, albitization, chloritization, silicification and argillitization. Albitization is very characteristic even for such a young diabase-basalt. This phenomenon was established in veins younger than basic volcanic-sedimentary series. These rocks, by age belong to Neogene and their extrusions may have lasted until Quaternary.

Quaternary formations

These rocks are the youngest in this area.

Talus deposits lie on the SE slope of the Ciha Tepe and are generally built of andesite lumps and blocks even over 10-20 m^3 in size.

Alluvium is formed along the Musazade Deresi River (Arhavi-Kavak-Şenköy). A river terrace of gravel and sands still being formed nowadays.

TECTONICS AND MAGMATISM

The investigated area belongs to the Pontid-Adjaro-Trialete geotectonic unit. According to numerous studies by Soviet geologists of recent date (G.I. Magakljan, 1960; G.S. Dzocenitze, G.A. Tvarcrelidze, 1968; G.M. Zaridze, 1968 et al.), geotectonic and metallogenetic units on the Caucasus Minor have been classified. They continue without interruption westwards in the region of the Black Sea and Anatolia plain. Thus, the Adjaro-Trialete system continues into the Pontid geotectonic unit whose west end extension sinks under the Black Sea. S. Pejatovic (1971) treats this unit as the Black Sea-Adjaro-Trialete zone.

In the Black Sea region intense submarine initial volcanism was developing during Senonian. The first magmatic cycle produced dacite and rhyodacite acid differentiates, discovered over a large area near Artvin and Murgul (D. Koprivica *et al.,* 1973). The second, younger cycle has created a magmatic range of diabase-spilite-keratophyric association with gradual acidization.

The Laramian orogenic stage has probably left trace in this area as well, in the form of plicative structures which are surely followed by longitudinal faults. These labile zones were most likely used by younger rhyodacitic and dacitic effusions. Simultaneously with these volcanics, argillaceous tuffs and tuffaceous sandstones were formed (Sivrikaya-Peronit). After the rhyodacitic and andesitic effusions, an eugeosyncline still remains with flysch sediments forming in it. The rhythmical character of sedimentation displays in lithological alternations of sandstones, limestones and marls. The flysch-type sediments reflect the restless nature of the basin and orogenic movements. The sedimentary cycle ends in the Middle Eocene (Lutetian). The period from Middle Eocene to Oligocene may be assumed to be an emergence — the continental stage (there are no marine sediments younger than Lutetian).

Most likely the Savic orogenic stage reflected itself upon this part of the area, as in the whole Alpine geosyncline and the Caucasus. Probably during the Savic orogenesis the Hopa-Murgul synclinorium was formed. The present relief is inverse and there are younger sediments preserved along the synclines building the ridges in topography. The Ulukent-Pınarlı syncline is in the mapped area, its axis striking 64° (Plate I- diagram $D4_{ss}$) and plunging towards ENE. On the Mağara ridge identical sediments form the residual of another syncline, its strike being NNW-SSE. These structures are brachysynclinal in form. Similar information is also obtained on the Murgul region according to the results of the Yugoslav geological teams: S. Buser (1970) and I. Stern (1971). The general strike of folding axis is ENE-WSW. However, it is evident that structures with the NNW-SSE strike occur also. This proves that plicative structures were formed in two periods. Such forming of folds was affected by basic volcanic series, less plastic than the upper sedimentary series. Pyroclastic material of augile-hornblende andesite most likely filled a large lake-type basin during Neogene.

Oligo-Miocene period is very important due to intense intrusions. Differentiations of diorite and gabbro and granitoid rocks (granodiorites, quartz diorites, their micro varieties and biotite granite) were formed in this period. This magmatism may be considered as synorogenic, a product of the Savic orogenic stage. Granodiorites and quartz diorites introduced contact-metamorphic changes in the sediments of the Mağara region. Magmatic activity continued with augite hornblende andesites. They used labile zones along the existing structures and newly formed faults- during Pliocene. The final volcanism ends with diabase-basalts in the period Pliocene to Quaternary. These rocks occur as numerous veins, sills and minor outcrops over the whole area and through all formations.

Faults

There are three types of faults noticed in the investigated area related to the strike of regional structures and formations: longitudinal, transversal and diagonal. In the diabase-basalt formation in the area of Arhavi-Kavak-Aşağı Şahinler-Kise, a fault contour diagram was made (Plate I - diagram $D1_f$). This diagram generally shows three fault systems of vertical character. The first system is longitudinal, striking 60°. The other two are diagonal, striking 30° and 115°.

The fault contour diagram in argillaceous tuffs and tuffaceous sandstones formation in the Sivrikaya-Peronit area (Plate I - diagram $D2_f$) in general shows three systems of fault strikes. The most distinguished system has two maxima: transversal type, striking 335° and diagonal, striking 310°. The next two systems are characterized by diagonal, strike 30° and approximately longitudinal strike 80°. These structures are accompanied by intensive hydrothermal alterations manifested by strong silicification, pyritization and argillitization.

The fault contour diagram in rhyodacites and dacites in the Kavak-Peronit area (Plate I - diagram $D3_f$) shows that the main fault system is approximate to the longitudinal strike of 48° and the second has the longitudinal strike of 70°. Faults in rhyodacites are followed by frequent kaolinization and silicification while pyritization is restricted to certain parts. These processes are post-volcanic, and hydrothermal actions may originate from the final stage of this volcanism or be caused by additional influence of granitoid magma.

In granodiorites and quartz diorites (west from Mağara) the fault contour diagram (Plate I - diagram D5f) shows that the main fault system has the strike of 336° and the second less pronounced strikes 105°. Further from fractures pyritization diminishes or disappears completely.

In andesite-trachyandesite (keratophyre) formation in the Güneşli Köy-Dereüstü-Gürgençlik area, the fault system has the strike of NNW-SSE, then there are faults striking approximately E-W and in the Şenköy-Güneşli Köy area the faults strike NE-SW.

Based on the existing structures on the geological map, it may be noticed that the number of faults is not identical in all formations. They are most abundant in the rhyodacite and dacite area (Kavak-Peronit), then in some areas of volcanic-sedimentary series, and the least in diabase-basalt (spilitic) formation.

On the basis of the above, a conclusion may be made that three fault systems predominate. The first system, striking ENE-WSW, contains longitudinal faults, approximately parallel with the strike of geological formations. The second fault system, diagonal in type strikes NNE-SSW. The third fault system, transversal, strikes NW-SE approximately and is manifested by argillaceous tuffs and tuffaceous sandstones and by granodiorites and quartz diorites. Geological map shows that the third fault system is somewhat younger than the preceeding two, since it intersects them.

MINERAL OCCURRENCES

Different mineral occurrences have been found in the investigated area. The most important are pyrite-type sulphide occurrences characteristic for the Pontid-Adjaro-Trialete zone. According to V. Vujanovic (1974), three genetical grups of deposits exist in the Black-Sea region: volcanic-sedimentary-hydrotermal, hydrotermal and skarn-hydrotermal deposits. V. Smirnov (1970) in his study of stratified ore deposits, takes, as their primary characteristic, that they depend upon the stratification of volcanic-sedimentary and sedimentary deposits. The author thinks that we did not gain such experience when we worked in the Hopa-Arhavi area. According to F. Sopko (1971), the Adjaro-Trialete zone in the Caucasus-Minor area is characterized by iron ore deposits of skarn-magnetite type and vein-like polymetallic deposits. Then he stated that such polymetallic deposits usually lie in volcanic rocks near syenite-diorite massif. These data can be compared with our field investigations. Further, in the description of sulphide-polymetallio ore and mineral occurrences in the investigated area we give priority to hydrothermal type of creation. By different composition, type and genesis they may be subdivided into: pyritic, skarn and manganese occurrences. From the aspect of economy pyrite type occurrences are worth attention.

Pyrite-type mineral occurrences

These deposits strike NNE-SSW. They lie in tuffs and tuffaceous sandstones, rhyodacites and in the upper part of the basic volcanic-sedimentary series or at its contact with rhyodacites. Further, they are subdivided into: zinc-copper-pyrite and pure pyrite occurrences.

Zinc-copper-pyrite occurrences lie in the localities of Peronit, Sivrikaya and Kutonit. The first two are associated with tuffs and tuffaceous sandstones of rhyodacitic origin and the Kutonit ore deposits lie in the upper part of spilitic diabases and basalts. Pure pyrite mineralizations occur in acidic or basic formations but mostly in the acidic ones.

The Peronit ore occurrence is situated at a distance of about 1 km from the coast. It lies SW of Çamlıköy and may be reached after 1.5 km along a rural road branching from the Hopa-Arhavi road.

Geological location: Ore deposits lie in the volcanic-sedimentary formation composed of argillaceous tuffs and tuffaceous sandstones (rhyodacitic and dacitic origin). Tectonic breccia are very much silicified, pyritized and limonitized in the gossan area. Ore deposits are situated inside the altered rocks at the crossing of two fault systems striking 335° and 80°. Impression is gained that longitudinal structures striking E-W and NE-SW are broken by a NNW-SSE transversal strike. SSE from collapsed galleries, at the contact with the gossan, there is a mineral spring surrounded by argillitized and pyritized rock. Pyrite also regularly occurs in hydrothermally altered breccia. North of old galleries, about 400 m deep in rhyodacites, the azurite mineralization occurs as minor impregnations striking 300°.

Investigations by A. Struve (1902) explain the results of ancient mining workings: «Two tunnels intersected several hydrothermal veins rich in sphalerite, galena and copper minerals». E. Zimmer (1937) on the basis of ore remains, identified the type of ore deposit same as in Kutonit. In his report V. Kovenko (1941) concludes that the «Peronit» ore deposit is similar to vein-type deposit and could correspond to impregnation type, since mineralization is not represented by massive copper pyrite. A. Kraeff (1963) proved that sphalerite and chalcopyrite mineralizations are present here. There are inclusions of tetrahedrite, galena, pyrite, chalcopyrite, covellite and bornite in sphalerite.

Polished section studies of samples from the waste in front of collapsed galleries, have shown that ore deposit bears pyrite, chalcopyrite and sphalerite. Pyrite is older ore mineral and is replaced by chalcopyrite, sphalerite and quartz. Younger ore associations occur in irregular veins through pyritic mineralization showing metasomatic characteristics. The ore groundmass is mostly built of sphalerite and the following minerals have also been identified: tennantite, chalcopyrite, enargite, galena and pyrite.

The chemical analysis on the ore samples has given the following results: Cu 5.025 %, Zn 35.35 %, Pb 0.53 %. The analysis resulted in the following assay: sphalerite 53.7 %, chalcopyrite 14.5 % galena 0.6 %. An analysis was also made on very kaolinized samples rich in pyrite (near the mineral spring) but it did not give positive results.

The Sivrikaya ore occurrence lies SW of the Peronit mineral occurrence at the distance of about 1.5 km and east of Arhavi at a distance of 4 km. Access is possible along a rural road branching from the Arhavi-Hopa main road.

Ore deposits lie in the volcanic-sedimentary formation, which is built of argillaceous tuffs and tuffaceous sandstones containing rhyodacitic veins and sills. The deposit is hydrothermal and controlled by main faults striking 70°. South of deposits a fault strikes 80°, being a boundary towards rhyodacites. Open and easy to observe is mineralized tectonic breccia striking 70°, about 20-30 m wide and about 200 m long. These breccia are strongly cemented with hydrolhermal quartz and pyrite. Pyrite occurs as veins, 1-2 mm thick and is mostly idiomorphic. Infrequent occurrences of barite were found and the magnifying glass sometimes shows chalcopyrite. These breccias have a network pattern with irregular angular forms of prismatic cells (Fig. 15). Mineralization is of stockwork type. Further from the breccia zone on both sides kaolinization and silicification are encountered in the form of zonal gradual transitions. NE and south of this structure (along the brook) collapsed old mines are situated. In front of the collapsed entrances into adits there are still today hand-picked pieces of pyrite, copper, zinc sulphide ores. The major par of the ore deposit area is covered by gossan (silicified and limonitized breccia). At the points where the gossan is lacking, argillitization is particularly evident.

Observations of the preceding investigators on this locality are worth mentioning here. E. Zimmer (1937) states that mineralization on Sivrikaya is of the same type as in Kutonit and Peronit. V. Kovenko (1941) thinks that Sivrikaya represents a continuation of peronitic mineralization A. Kraeff (1963) concludes that pyrite, copper, zinc mineralizations on Sivrikaya are of minor economic importance.

Breccia ore samples show that pyrite grains are disseminated throughout the rock. These fragments are cemented with quartz containing pyrite and chalcopyrite. Chalcopyrite is always in quartz which cements the rock fragments. A breccia sample assays: 3.71 % Cu, 0.52 Zn. The second analysis of ore samples taken from the collapsed mining shaft assayed: 3.66 % Cu, 7.93 % Zn.

The Kutonit ore occurrence. — Old mines in Kutonit ore deposits are north of the Şenköy-Arhavi road by about 1.5km. Among the existing old ore mines four galleries are sunk in full and two of them are partly accessible. Kutonit ore deposit lies in diabase-basalt spilitic formation. Certain rock fragments at the pit entrances are almost fully silicified. Minor remnants of rhyodacitic tuffs are preserved along the fault. Augite-biotite granodiorite was found in waste. This feature points to its origin from granite apical part.

Faults have the strike of W-E and rarely NE-SW. Granodiorite in waste material, as well as minor granodioritic bodies discovered in the immediate vicinity, lead us to the conclusion on possible genetic association of these ore deposits with the intrusive. Ore deposit may have been formed near apical parts of a large granodioritic intrusive.

E. Zimmer (1937) states that Cu, Zn ores are of good quality, but prospects for economically justified reserves are low and mineralization varies a lot. V. Kovenko (1941) indicates that investigations of deeper strata are necessary.

Ore consists of pyrite, chalcopyrite and sphalerite. Chalcopyrite rarely intergrows in sphalerite. Calcite was noticed beside quartz. There are lumps of ore whose groundmass is built of sphalerite occurring together with: tennantite, bornite, chalcopyrite and galena. These minerals fill little cracks in equal quantities. This type of occurrence points to two generations in mineral formation. Bornite is a secondary mineral and occurs around chalcopyritic grains. Chemical analyses of ore samples taken from gallery entrances assayed as follows: Assay I - 0.82 % Cu, 10.03 % Zn; Assay II - sample with chalcopyrite: 24.06 % Cu, 3.76 % Zn, 0.31 % Pb; Assay III - sample with sphalerite: 56.57 % Zn, 2.60 % Cu, 1.35 % Pb, which converted into minerals would give the following assay: sphalerite 84.4 %, chalcopyrite 7.5 %, galena 1.5 %.

The Güneşli Köy mineral occurrence. — NE of Güneşli Köy along a brook a fault striking 350° is evident. At the same time this structure acts as a boundary between spilitic diabases and basalts and andesite and trachyandesire. Faults striking NW-SE and NE-SW are diagonal to this structure. Bedrock is often altered inasmuch as to prevent microscopic identification. Strong silicification, kaolinization and pyritization are evident. Along the fault the granodiorites crop out in the form of veins and minor bodies.

Chemical and geochemical analyses have not given satisfactory results as regards the elements investigated except for one sample assaying: 7.80 % Zn and 1.40 % Cu. Ore deposit lies in breccia andesites (andesite-trachyandesitic formation) which are intensively silicified, argillitized and pyritized with macroscopically visible malachite. In this ore deposit there are two vertical faults striking 215° and 115° and in the area of their intersection hydrothermal mineralization of Zn and Cu is evident. This ore occurrence is even more interesting because it lies at the same level as the old «Kutonit» mine southward, and at the distance of about 2 km.

South of Güneşli Köy, about 1 km on the right side of Çifteköprü Deresi lies a vein dipping 55/33°, 12 cm thick and traced for about 1 m. Pyritic and chalcopyritic mineralization is evident on both sides of this ore vein at the depth of about 2-3 cm. The central vein section is built of garnetite, silicified, epidotized, argillitized and limonitized. The analysis shows high content of magnetite and less of pyrite. Chemical analysis resulted in 1 % Cu rnd 0.5 % Zn. Being small, the vein itself has no economic value, but jointly with the whole mineralized zone of Güneşli Köy it proves the fact that the «Kutonit» old mine is not a solitary case of Zn-Cu sulphide occurrence in the basic volcanic-sedimentary series.

The Konaklı mineral occurrence. — Northeast of Kavak, at the distance of about 1.6 km there is a pyrite ore deposit with minor quantities of Zn and Cu. It is associated with highly silicified basalts at their contact with rhyodacites. Pyrite mineralization starts at the fault striking 130° and may be traced up to the end of the next fault, whose strike is 45°. Ore deposit lies along the brook and between the two waterfalls. Magnifying glass detected chalcopyrite in addition to pyrite.

In an ore sample, mineralization manifested itself in veins and along cracks. Sphalerite, pyrite and chalcopyrite were found. Chalcopyrite occurs in sphalerite. Pyrite often replaces sphalerite. The chemical analysis assays: 0.4 % Cu and 0.35 % Zn.

This mineralization is interesting inasmuch as towards ENE pyritization in breccia rhyodacites increases along the faults which strike 60°, all the way to the old collapsed mining shaft of «kordelite». At this point an ore deposit in breccia rhyodacites about 10 m wide is situated. It is manifested by intense pyritization, silicification and limonitization. The chemical analysis assayed: 0.25 % Cu and 0.2 Zn.

The Yukarı Pınarlı mineral occurrence lies south from Pınarlı Köy. It is at a distance of 0.5 km from a rural road. It lies in a formation of agglomerates and breccia of augite-hornblende andesite. The site investigations established a kaolinized zone along the left bank of the brook. Very silicified parts are accompanied by uniform pyritization. However, under magnifying glass chalcopyrite was discovered in some samples. These hydrothermal alterations follow the structure striking 305° and impression is gained that the altered zone gently dips towards 215/30° (?).

In the ore sample, breccia with pyritic cement was found. The chemical analysis of one sample gave: 0.53 % Cu and 5.09 % Zn. According to the outcrops this mineral occurrence is not economically important but its importance lies in the fact that it lies in Neogene pyroclastites of augite hornblende andesite and that it is created by hydrothermal solutions along the structure described. This indicates the existence of very young mineralization.

Skarn occurrences

The Mağara mineral occurence. — On the west slope of the Mağara ridge, at the altitude of about 1,000 m there is a skarn-type Zn- and Cu-bearing mineralization. This mineral occurrence could be only observed on minor outcrops because Rhododendrons made access impossible. According to mineralized breccia this ore deposit has the strike of 135°. North of this observation point by about 10-15 m, there is a limestone outcrop dipping 270/23°. In this limestone, amphibole crystals were found indicating contact-metamorphic influence of granitoid magma. The ore analysis showed that mineralization consists of massive impregnation. It assays: 0.4 % Cu and 7.4 % Zn.

West of Gürgençlik Köy in microquartz diorite a large number of cracks striking 140° and pyrite-bearing-were discovered. One sample assayed: 1.3 % Zn only.

Magnetite mineral occurrence: In contact-metamorphic zone of skarn and hornfels there is an indication of two magnetite occurrences with some garnet. Ore samples have high specific density indicating higher content of Fe (magnetite). The first mineralization follows a fault dipping 110/76°. An ore analysis indicated high magnetite quantity and some chalcopyrite and pyrite. The chemical analysis resulted in 62.1 % Fe accompanied by 0.12 % Cu and 0.3 % Zn.

Southeast of the first mineralization, at the distance of about 300 m, there is another skarn mineralization of the same type and an ore analysis thereof showed richness in magnetite with pseudomorph martite accompanied by pyrite and garnet. The chemical analysis gave 41.6 % Fe and 0.1 % Zn.

Such results indicate a typical skarn-type ore deposit which is not economically worth for Cu and Zn.

Manganese mineral occurrences

All manganese occurrences generally lie in the upper part of the basic volcanic-sedimentary series or along the boundary with tuffaceous argillaceous and marly sediments and rhyodacites. An old manganese mine near Peronit lies in argillaceous tuffs and tuffaceous sandstones. Genetically all manganese occurrences may be considered as a product of submarine exhalation. They occur as minor intercalations, lenses and veins. Chemical analyses of samples collected, indicate a high Mn percentage but according to their outcrops, prospects for economical reserves are low.

The Pancoli Köy mineral occurrence, — On the right bank of the Kise Deresi there are two Mn ore outcrops. Mineralization lies in opalized diabase-basalts in form of thin beds dipping 50/50, and probably thinning out in lenses. The occurrence is 20 cm thick and occurs in lenticular thickenings up to 50 cm. Pyrite was also discovered. The ore sample analysis shows the psilomelane as gel. Cryptocrystalline pyrolusite develops from gels or their haloes. The groundmass contains plenty of fine limonite matter, which colored the rock red. The chemical analysis assayed: 42.56 % Mn.

The Peronit mineral occurrences. — West of Çamlı Köy at a distance of about 1 km above the old Hopa-Arhavi road four Mn occurrences were discovered. They lie in a row along a fault striking 300°, which is at the same time a boundary between rhyodacites and opalized diabase-basalt. The Mn-bearing rock is of tuffaceous origin. It is very much silicified with intense hematitization and limonitization. Two occurrences are associated with Mn impregnated quartzites. Ore analyses have shown that Mn is associated with jasper and in the form of gel with siliceous rock. Preliminary examinations suggest that these occurrences are minor ones. Two chemical analyses have given the following assay values: 8.24 % Mn and 21. 83 % Mn.

North of the occurrences described above there is a solitary Mn deposit. Its mineralization lies in amygdaloidal albitized and silicified basalt. The chemical analysis assayed: 35.58 % Mn. Ore deposit was discovered in an old shaft striking 270°.

The ancient Mn mine «Peronit» is situated SW of Çamlı Köy, left from the Peronit Deresi. Ore deposit lies in tuffaceous sandstones of rhyodacitic and dacitic origin. The rock around the shaft entrance is built of silicified and limonitized pelitic tuff.

In this ore A. Struve (1902) discovered pyrolusite. E. Zimmer (1938), when he visited manganese ore deposit of the Hopa-Vise, gave the following chemical analysis results for Mn in Peronit: 31.37 % Mn, 14.05 % SiO_2; second assay: 44.3 % Mn and 16.09 % SiO_2. V. Kovenko (1941) suggested that investigations should be continued, due to good ore quality and accessibility. A. Kraeff (1963) considers these ores to be the products of submarine exhalations.

An ore analysis helped to determine the minerals of psilomelane and pyrolusite. Psilomelane occurs in the form of relicts which served to develop pyrolusite laths. An assay of ore in front of the tunnel entrance is 43.63 % Mn.

The Kise mineral occurrence. — At the distance of 0.6 km SW of the Kise a Mn occurrence is located. It lies at the boundary between spilitic diabase-basalt and sandstones. Mn occurrence was discovered in an ancient adit striking 270°, now inaccessible. It assays 15.62 % of manganese.

The Kutonit mineral occurrence. — West of the «Kutonit» Zn and Cu mine at the distance of about 0.5 km lies a manganese occurrence. Manganese lies in spilitic diabase-basalts. Manganese ores were discovered at two outcrops in the brook. The first outcrop in form ot a vein or layer (on the right bank) strikes 250°. The ore body is about 1 m thick. Upstream at the distance of about 4-5 m about 20 cm thin ore bed occurs and dips 150/55°. In the manganese ore there is plenty of quartz and Fe matter. It assays 45.8 % Mn.

The Yukarı Şahinler mineral occurrences. — At the distance of 1 km NW of Ulukent there are Mn occurrences. They lie in spilitic diabase-basalts. The first Mn occurrence was detected in an old adit, striking 340°. It is a massive manganese ore deposit assaying 42.42 % Mn.

The second Mn occurrence lies SE from the first at the mouth of a brook. Mineralization occurs in the form of thin veins up to 5 cm. The strike is 150°. Manganese occurrence is accompanied by intense silicification, carbonatization and limonitization. It assays 47.13 % Mn.

The third occurrence in the form of an ore vein is situated under the Hilmi Durmuş hill. The Mn vein is 5-10 cm thick. The strike is 300°. In an ore sample Fe and Mn minerals occur in the form of gel. It assays: 45.58 % Mn.

The ancient mines of Peronit, Sivrikaya and Kutonit are characterized by Zn, Cu sulphide mineralizations which regularly have higher or smaller amount of pyrite. During our investigations a high number of pyritic mineral occurrences were established but description refers only to those in which the presence of Zn and Cu was confirmed (Güneşli Köy, Konaklı and Yukarı Pınarlı). All sulphide ore and mineral occurrences are of hydrothermal origin. Sivrikaya and Peronit show a distinct stockwork-type of mineralization. The Kutonit mine belongs to vein-type polymetallic Zn, Cu, Pb sulphide ore deposits. All sulphide ore and mineral occurrences are controlled by faults. An open question remains whether the sole bearers of mineral solutions are rhyodacites or granodiorites have taken part in it as well (Kutonit, Güneşli Köy).

Skarn-type mineral occurrences result from the contact influence of granodiorites upon surrounding rocks. They contain mostly magnetite and pyrite and are of minor economic importance.

All manganese occurrences are products of submarine exhalations. There are minor outcrops, assaying a high manganese percentage but their prospects are low.

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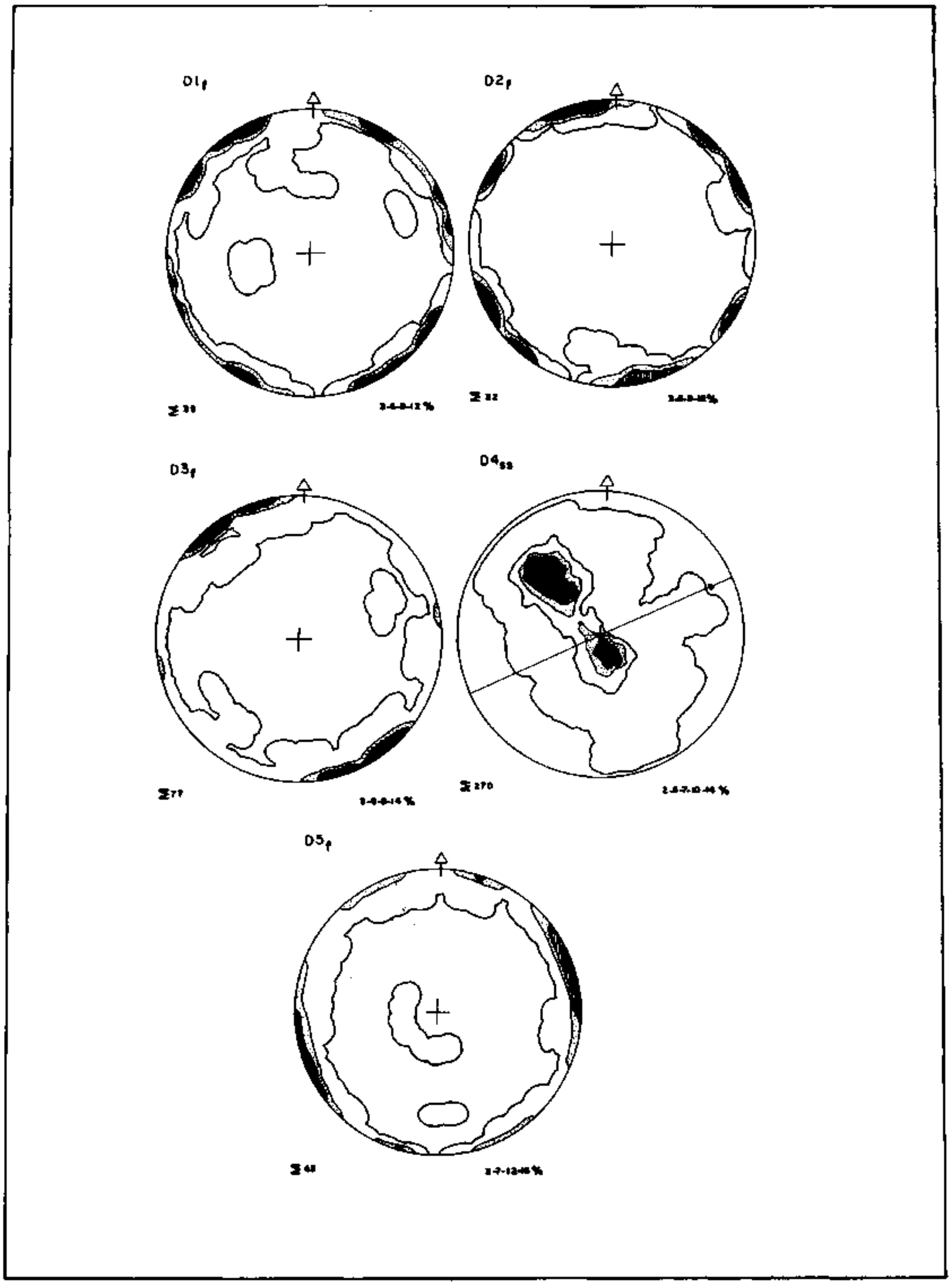
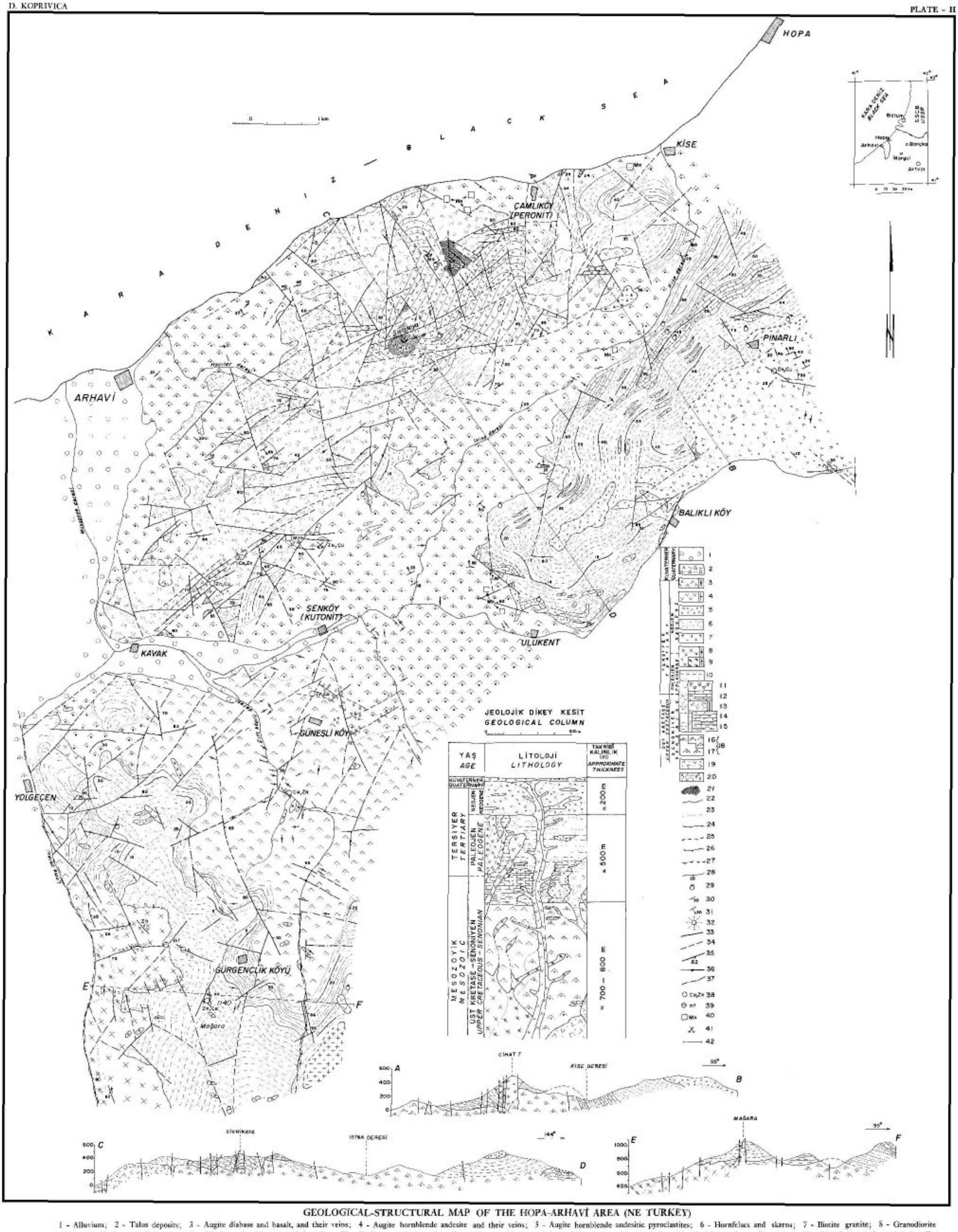


D. KOPRIVICA

CONTOUR DIAGRAMS*

D1f - Fault contour diagram in spilitic diabase-basalt in the area Arhavi-Kavak-Kutonit-Kise.
D2f - Fault contour diagram in the formation of argillaceous tuffs and tuffaceous sandstone in the area Sivrikaya-Peronit.
D3f - Fault contour diagram in rhyodacite and dacite in the area Kavak-Peronit.
D4ss - Dip of layers contour diagram in syncline sediments in the area Ulukent-Pınarlı.
D5f - Fault contour diagram in granodiorite and quartz diorite west of Mağara.

* Schmidt's polar network in equivalent projection was used for the contour diagrams construction. (References: M. Dimitrijevic & R. Petrovic, 1965.)



GEOLOGICAL-STRUCTURAL MAP OF THE HOPA-ARHAVİ AREA (NE TURKEY)

1 - Alluvium; 2 - Talus deposits; 3 - Augite diabase and basalt, and their veins; 4 - Augite hornblende andesite and their veins; 5 - Augite hornblende andesitic pyroclastites; 6 - Hornfelses and skarns; 7 - Biotite granite; 8 - Granodiorite and quartz diorite, and their veins; 9 - Diorite and gabbro, and their veins; 10 - Tuffaceous, clayey and marly sandstones with intercalations of limestones; 11 - Andesite; 12 - Reddish and gray limestones; 13 - Rhyodacite, dacite and their tuffs; rhyodacitic veins; 14 - Clayey tuffs and tuffaceous sandstones; 15 - Sandstone, sandy limestone and breccias; 16 - Andesite, trachyandesite (keratophyre) and their pyroclastites; 17 - Diabase and basalt (predominantly spilitized) and their pyroclasts; 18 - Basic volcanogenous sedimentary series; 19 - Dacitic breccias and tuffs; 20 - Pyritization; 21 - Gossan; 22 - Boundary of conformable formations; 23 - Transitional boundary; 24 - Boundary of intrusive; 25 - Inferred boundary of intrusive; 26 - Boundary of volcanic extrusions; 27 - Inferred boundary of volcanic extrusions; 28 - Trace of average bedding and dip; 29 - Microfauna locality; 30 - Strike and dip of bedding; 31 - Strike and dip of lava flow; 32 - Probable volcanic center; 33 - Fault of unknown nature; 34 - Inferred fault; 35 - Dip of fault plane; 36 - Vertical fault; 37 - Possible fault (as located from aerial photographs); 38 - Copper and zinc occurrences; 39 - Magnetite occurrences; 40 - Manganese occurrences; 41 - Old workings; 42 - Geological cross section.

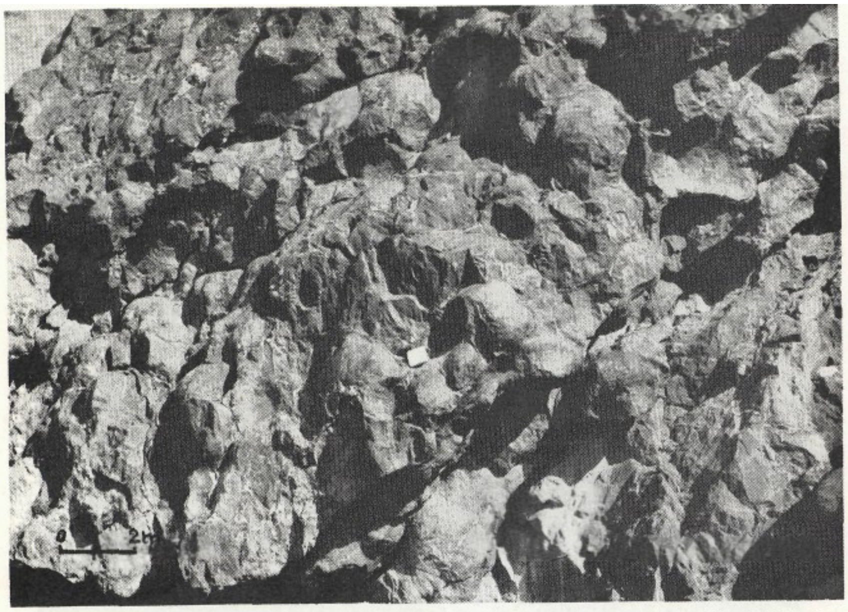


Fig. 1 - Spilitic diabase - pillow texture with narrow veins of calcite and zeolite. Within the profile of the new Hopa-Arhavi road (near the tunnel). Photo taken by: D. Koprivica.

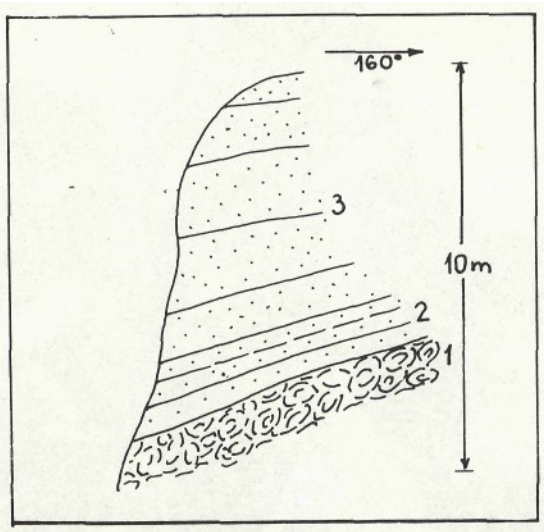


Fig. 2 - The Çamlıköy-Arhavi road profile.
1 - Diabase-basalt with pillow texture;
2 - Fine layers of tuffaceous sandstones;
3 - Thick-bedded tuffaceous sandstones.

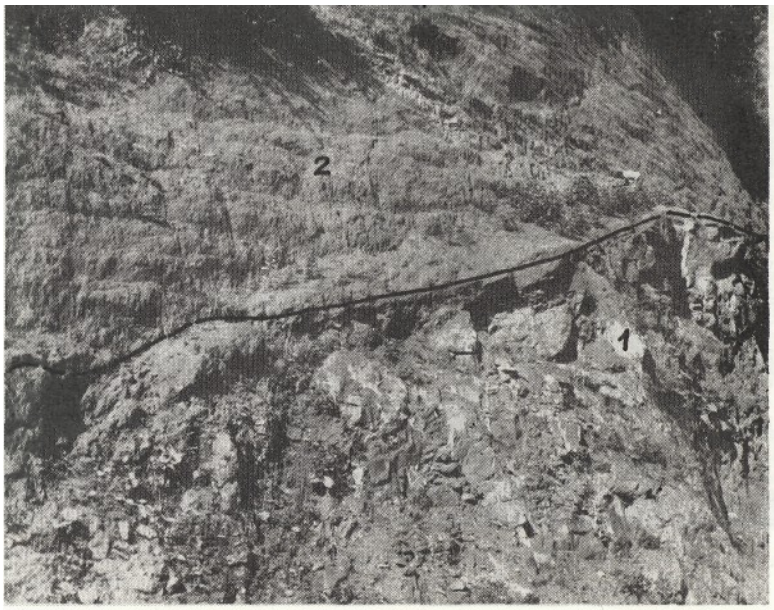


Fig. 3 - Basalts in the Çamlıköy-Arhavi road profile. 1 - Amygdaloidal-spilitic basalt; 2 - Olivine-pyroxene basalt. Photo taken by: D. Koprivica.

Fig. 4 - Basalt, amygdaloidal, albite with much opaque mineral powder. N//; 140 ×. Photo taken by: D. Pesic.

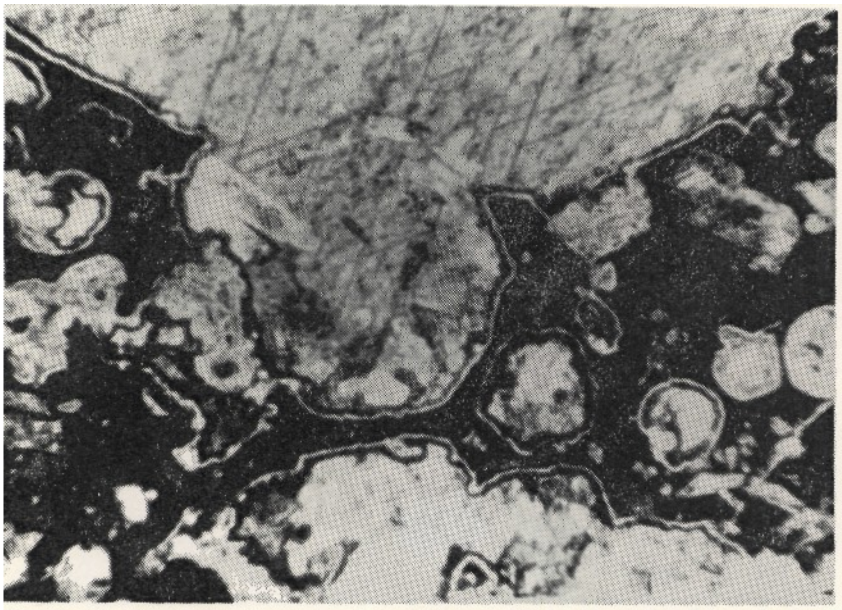


Fig. 5 - Trachyandesite (keratophyre) amygdules are filled with calcite, albite and quartz. N//; 45 ×. Photo taken by: D. Pesic.

Fig. 6 - Hydrothermally altered tuffs, south of the old mine of «Peronit» near the mineral spring. Photo taken by: D. Koprivica.

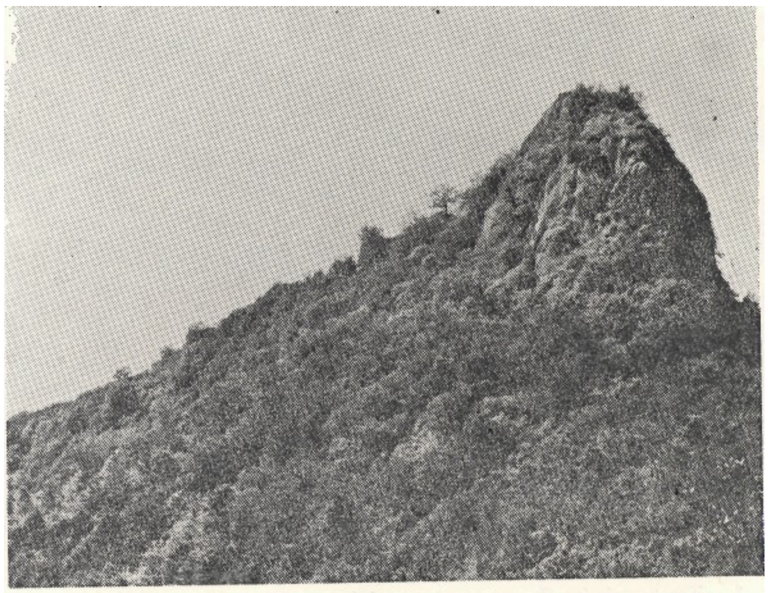


Fig. 7 - Sivri Tepe, a view from the east. Photo taken by: D. Koprivica.

Fig. 8 - Rhyodacite, partly chloritized (corroded quartz and feldspar phenocrysts are visible). N//; 140 ×. Phote taken by: D. Pesic.

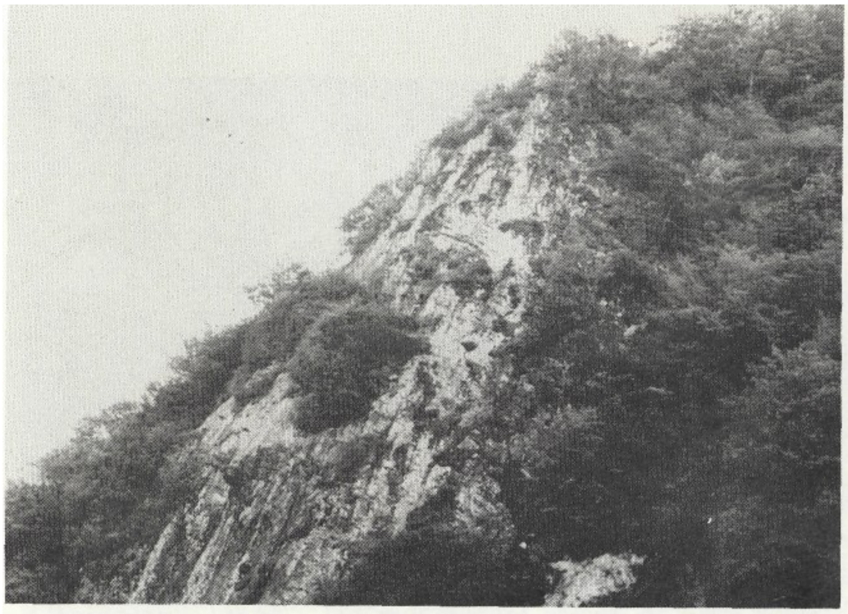


Fig. 9 - Ciha Tepe, a view from the north; visible distinct columnar jointing structure. Photo taken by: D. Koprivica.

Fig. 10 - Amphibole-biotite quartz diorite; N +; 140 ×. Plagioclase, quartz and hornblende crystals (grains) can be seen. Photo taken by: D. Pesic.

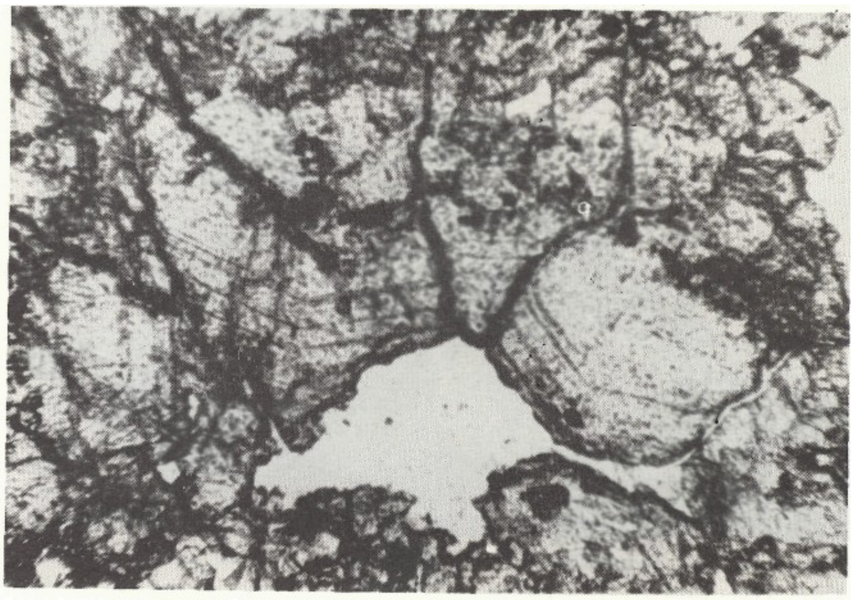


Fig. 11 - Garnetite skarn: grains and garnet crystals. N//; 140×. Photo taken by: D. Pesic.

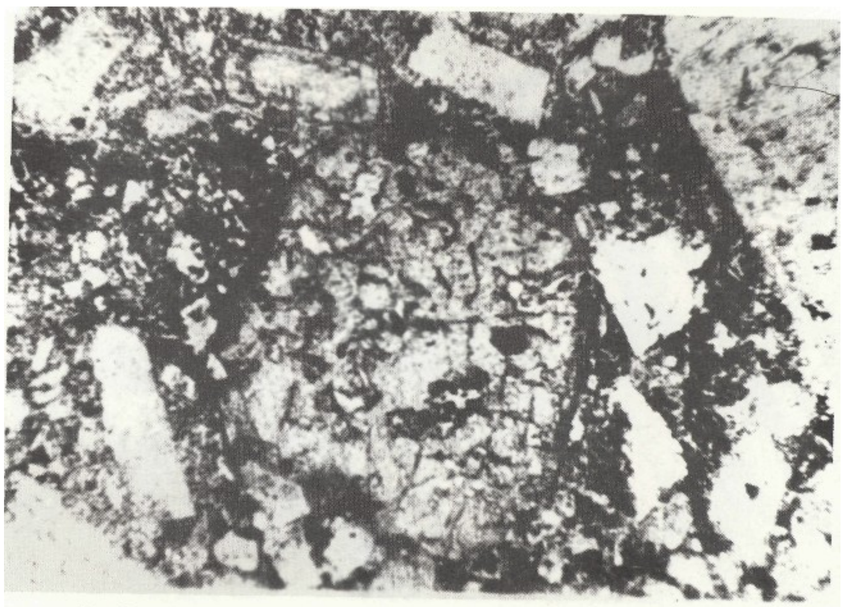


Fig. 12 - Augite, andesite: plagioclase and augite phenocrysts. N//; 140 ×. Photo taken by: D. Pesic.

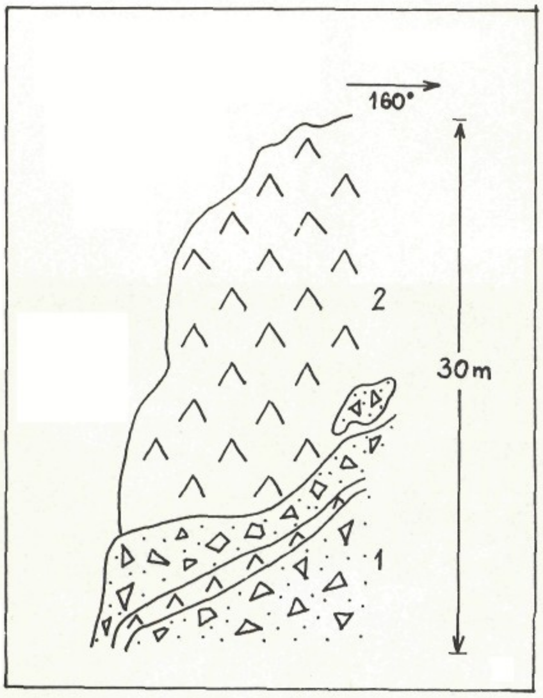


Fig. 13 - A cross section on the Arhavi-Çamlıköy road.
1 - Dacitic breccia and tuffs; 2 - Augite diabase.

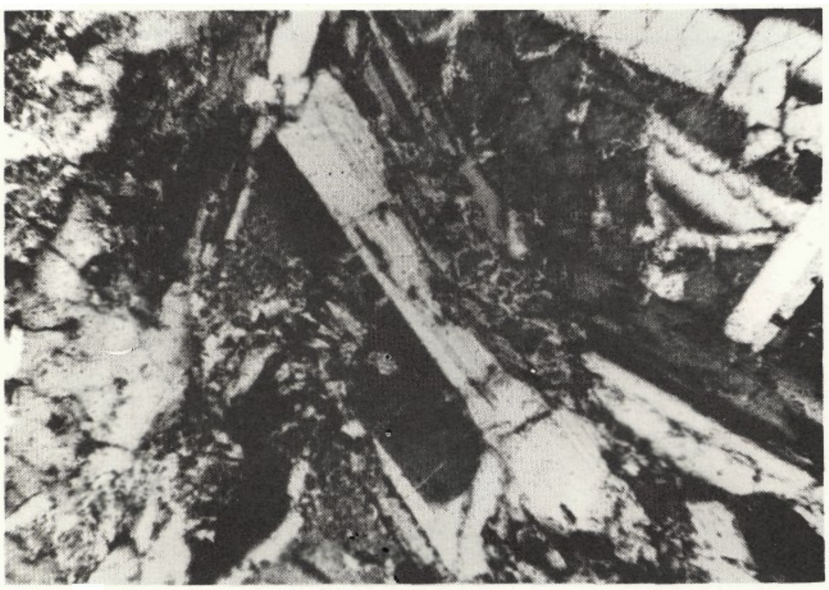


Fig. 14 - Diabase-basalt, plagioclases and augite crystals, in **ophitic intergrowth.**
N +; 140 ×. Photo taken by: D. Pesic.

Fig. 15 - Tectonic breccia cemented with hydrothermal quartz and pyrite. Sivrikaya locality.
Photo taken by: D. Koprivica.