GEOLOGIC-STRUCTURAL FEATURES AND THE SULPHIDE DEPOSITS IN THE AREA WEST OF THE ŞAVŞAT (NE TURKEY)

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ABSTRACT. — The area under investigation belongs to the Pontid-Adjaro-Trialete tectonic unit. In the evolution (Upper Cretaceous-Tertiary) all formations of this geotectonic unit were formed in the eugeosynclie. These formatictos are basic-carbonatic as regards their chemical-mineralogical character with the tendency of periodic acidity, while petroiogically they are volcanic-sedimentary.

In the area of Şavşat generally have developed andesitic rock facies. The Artvin Paleozoic barrier had a significant role in separating the facies of Hopa, Artvin and of Şavşat. An important member of the volcanic-sedimentary series the amygdaloidal andesite is in form of slightly prominent and irregular brachyanticline, its longer axis striking NW-SE. All other mapped units, in general, strike ESE.

The Trialete folding phase in the Lutetian-Priabonian interval encompassed all parts of the Pontid-Adjaro-Trialete geosyncline. The fault tectonics is very much pronounced with three fault systems.

The majority of fault structures served as suitable routes for hydrothermal solutions which led to intensive pyritization and sulphide polymetallic (Cu, Zn, Pb) mineralization. Some of these fault structures were reactivated in the Tertiary and new ones created with andesites, diabases and basalts injected alongwith.

INTRODUCTION

The geological investigations in the course of summer 1972 were carried out in the region of Dereiçi NNW of Şavşat (NE Turkey) by a Turkish-Yugoslav team of geologists: Mustafa Demirkan, Dragan Koprivica, Djordje Klajn, Dr. Tiosav. Novovic, Desimir Puric, and Vladimir Stevanovic. This time, 40 sq. km were explored and mapped in the scale of 1:10,000 and sulphide ore occurrences were treated separately. This author has interpreted field and laboratory data giving their synthesis in this paper (Koprivica *et al.,* 1973). Due to the small scale of the geolegical map, pyritization, silicification and argillization are not shown. Other informations from the original map are contained in the geological one.

Laboratory analyses were carried out in the laboratories of the M.T.A. Institute. Petrographic samples were determined by Dragan Pesic and Jane Jancevski. Microscopic analysis of ores were done by Dr. Güner Aslaner and Dusan Kleut. Geochemical analysis by Vasa Ocokolic and chemical ones by Ekrem Ceyhun. Micropaleontobgical fossil fauna were determined by Ibrahim Çakmak and Fahrettin Armağan. DTA analyses by Sami Can.

The existing geological knowledge of the investigated area is insignificant. According to the data of K. Etay, Turks mined ores as early as in 1870 at the locality of Madenköy. The investigated area is shown on the geological map of Turkey sheet Kars 1:500,000. It is worth mentioning that the new investigations of Soviet geologists on the Minor Caucasus offer better insight into geological, stfuctural and facial characteristics Which pass to the Black Sea region of the NE Turkey. The investigated area belongs to the geotectonic unir of the Adjaro-Trialete zone (Mağa-

klyan, 1960; Dzocenidze & Tvalcrelidze, 1968; Pejatovic, 1971). In 1972- 1973, a large number of ore occurrences were insvestigated and some mining was started by the BAMAŞ company of Ankara.

LITHOSTRATIGRAPHIC CHARACTERISTICS

This ground is formed of volcanic-sedimentary, volcanic and sub-volcanic-intrusive rocks of the Senonian to Quaternary ages. The description includes the whole range of formations from the oldest to the youngest ones.

Andesitic breccias

This member is identified in lower section of Çukur D. Andesitic breccia is the oldest member in the investigated area. They are volcanic-sedimentary. Some parts look like pyroclastic breccias with angular fragments. [Inserted andesitic lumps varies from 2 to 10 cm^3 and rarely are in blocks over 0.5 m^3 in size. There exist rare flowing areas dipping 10° to 20°. Fresh parts are grey.

The texture of andesitic breccias is lithoclastic and crystallo-lithoclastic. The rock is formed of angular fragments of andesites and angular grains of plagioclases. Altered Fe-Mg minerals are rare. The cement consists of tuff—argillitized—chlorite mass with pronounced oolitic texture. The accessory minerals are magnetite converting into martite, while pyrite and chalcopyrite are rare.

Tuffaceous sandstone, andesitic microbreccia, limestone and diabase

This member is gradually transiting into andesitic breccia at both sides of the Çukur D. west from the mine of Hasan'ın Açması, tuffaceous sandstones and limestones underlie amygdaloidal andesites and breccia. In the eastern and southeastern part of the investigated area (Çağlayan D. and Meydancık Ç.) andesitic microbreccias, tuffaceous sandstones and limestones overlie amygdaloidal andesite. Such relationship may be explained by the fact that this member was formed before and during the extrusion of amygdaloidal andesites and that volcanic-sediments continued to be deposited over the amygdaloidal andesites.

The member described is volcanic-sedimentary in origin and is consisting of andesitic microbreccias, tuffaceous sandstones and limestones and in a lesser degree of diabases. The often pronounced stratification strikes south-east, rarely east and north-east. The dip angle varies between 12° and 35°, is rarely steeper and horizontal layers are noticed locally. Rythmical alternative of amygdaloidal andesites, tuffaceous andesitic breccias and tuffaceous sandstones are also noticed in the area.

Andesitic microbreccias are silicified, argillitized and calcitized. The texture is lithoclastic and crystalloclastic. The rock is formed of fragments of andesites and plagioclase. The cement mass is calcitic with pronounced silification.

Tuffaceous sandstones often alternate with carbonate, sandstones and sandy limestones. The structure is microbrecciated, lithoclastic and medium grained. The rock is formed of angular and subangular grains of plagioclase and fragments of andesites and tuffs. Cement mass is tuffaceous, argillitized, chloritized and calcitized.

In the andesitic microbreccias and tuffaceous sandstones a large number of faults were identified with pronounced pyritization and silification. These faults are often accompanied by sulphide mineralization (Cu, Zn, Pb).

Numerous micropaleontological analyses of limestone strata have shown the presence of microfauna at the localities of Kopek D. and north of Şarapul M. The following species and genera have been identified: *Globotruncana lapp. coronata, Globotruncana tricarinata, Globotrnncana* cf. *concavata, Globotruncana lapparenti, Globotruncana* cf. *area, Globotruncana* cf. *calcarata, Globotruncana area, Globotruncana linneiana, Globotruncana* cf. *linneiana, Globotruncana* sp., *Gümbelina* sp., Radiolaria, Textularidae. According to the microfauna classification and the superposition of geological members, this member corresponds by age to the Middle Senonian (Santonian-Campanian) and though the presence of *Globotruncana concavata* leads us to the Santonian.

Diabases occur in form of interstratified flows which are like tuff-carbonate sandstones. These diabases are characterized by the absence of shortage of augites contrary to the Tertiary effusions and penetrations. Accessory minerals are magnetite which is coverted into martite, with pyrite, chalcopyrites and bornite in traces. North of the mouth of the river Çukur D. (on the roadcut) there is an old tunnel in diabases which follows the fault striking 325°. In the tectonic diabase breccia there are pyrite, chalcopyrite and azurite, with intensive silification.

Amygdaloidal andesite and breccias

This member forms the central part of the investigated area. It strikes NW-SE and stretches along about 4 km with the average width beeing 1.5 km. Amygdaloidal andesites often alternate with andesitic breccias. Younger parts have porphyric and amygdaloidal texture. Megascopic investigation reveals feldspar crystals are visible and colourful constituents are chloritized, sericitized and limonitized. Their colour varies from grey-yellow to white (depending on the degree of dissintegration). Amygdaloidal andesites and breccias are intensively hydrothermally altered and pyritized (Photo 1). Andesite is very much argillitized (illite or montmorillonite), silicified, chloritized and calcitized, partly sericitized and albitized. Pyritization is most pronounced along faults.

The andesite texfure is porphyric, rarely combined holocrystalline porphyric, amygdaloidal and fluidal. Phenocrystals are made of plagioclases (andesine-oligoclase). Fe-Mg minerals are most frequently chloritized. The groundmass contains fine grains of plagioclases and fluidal oriented glassy compounds. As accessory minerals it contains pyrite, chalcopyrite, sphalerite, rarely rutil and magnetite. Two phases of pyritization may be identified: the first phase is synchronous with andesite formation (syngenetic) and the second phase is parallel to the sulphide mineralizations (Cu, Zn, Pb). The primary phase of pyrite is confirmed by numerous ore-microscopic analyses which identify pyrite as an accessory mineral in andesite. Amygdaloidal andesites and breccias are important members of the investigated ground as they contain the maximum number of sulphide ore veins some of them being those which were mined in 1972-1973 exclusively lie in them. An interesting piece of information is conspicuous, namely that the routes of effusive areas of these andesites strike south-west at the dip angle of about 35° (at the Binektaşı mine) which means a deviation from the strike of all other members of the area investigated.

Andesite

This andesite is distinguished in the region of Şarapul M. - Kurdiçvan M. By its specific appearance it differs from other rocks being very bleached and silicified with phenocrystals of bleached feldspars. It overlies tuffaceous sandstones and andesitic breccias. In some parts it is characterized by heavily pronounced prismatic effusion (Fig. 2).

The andesite texture is porphyric. It is intensely argilized, silicified, and limonitized, rarely calcitized, albitized and chloritized. Phenocrystals are plagioclase and rarely potassium feldspar.

The groundmass consists of fine plagioclase grains and it is partly with pronounced fluidal texture. Fe-Mg minerals are totally altered.

North of Şarapul M., and along the faults there are minerals of Pb, Zn, Cu in argilized, pyritized and silicified andesites.

Stratified andesitic breccias and tuffs

These rocks form the northwest portion of the area investigated (Tepebaşı-Akkavak-Biiyiik9ukur) and the area southeast of the Dereiçi M. They are formed of andesitic and tuffaceous breccias with andesite intercalations. They alternate with small layers of tuff sandstones and carbonate sandstones while sandy limestones are noticed rarely. The texture is breccoid and lithoclastic. Colours are grey and often bright yellow (limonitized parts). Andesitic tuff breccias combined with microbreccias are intensely silicified and argillized. Slightly pronounced is the stratification, striking east, rarely north-east and south-east. The dip angle varies between 10° and 40°.

The structure of stratified andesitic breccias is crystallo-lithoclastic and lithoclastic. The rock is composed of angular andesitic fragments, plagioclase grains and altered Fe-Mg minerals. The cement mass is tuffaceous. Minor parts of andesite with porphyric and amygdaloidal texture are encountered in these breccias.

Tuffaceous sandstones and clayey tuffs are chloritized calcitized, silicified and carbonatized. Their textures are crystallo—lithoclastic and fine—grained. Brecciation and silicification is pronounced along the faults which are also accompanied by pyritization and sulphide mineralization of Pb, rarely Zn and Cu (Fig. 1).

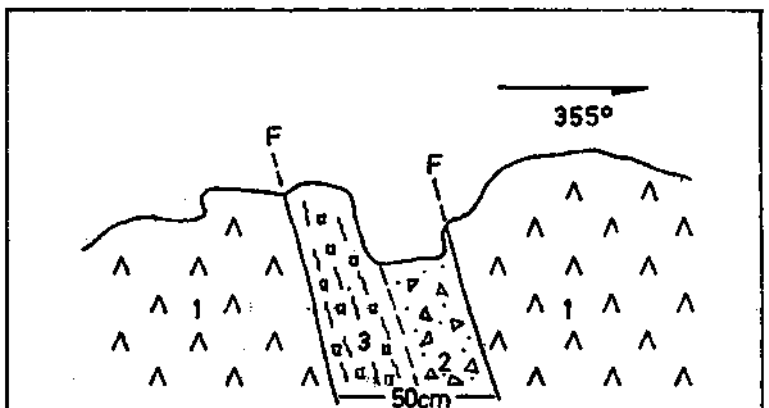


Fig. 1 - Profile southward of Tepebaşı. 1 - Andesitic breccias; 2 - Brecciated and argilized zone; 3 - Silicified and mineralized zone.

In the upper parts of tuffaceous sandstones there are limestone lenses like shoals which contain sections and fragments of rudist fauna. The following forms of microfauna are determined in limestones: *Lepidorbitoides* sp., *Siderolites* sp., *Textulariella* sp. and Rotalidae. According to the superposition of members and scanty fauna, this member probably corresponds to the Maestrichtian substage. Stratified andesitic breccias and tuffs very likely represent an extent of the amygdaloldal-andesite extrusions in forms of pyroclastic fades.

Rhyodacite and dacite

These rocks spread over a small area of the area investigated south from Akkavak M. They occur as breaches of minor bodies, sills and veins. They are penetrating into tuffeceous sandstones and stratified andesitic breccias and tuffs. The macroscopic observations show that both dacite and rhyodacite have porphyric and hyaline texture. Feldspar and quartz may be noticed in it. Colours are white and yellow, rarely light grey.

Rhyodacite and dacite are porphyric and holocrystalline in texture. Phenocrystals are plagioclase, grains of corroded quartz and rarely K-feldspar. Fe-Mg minerals are totally altered. The groundmass is consisting of quartz grains, plagioclase and K-feldspar. Rocks are as a rule intensely silicified, argilized, sericitized, less limonitized, chloritized and calcitized. The accessory mineral is metallic. The age of rhyodacite and dacire according to their composition, rock habitus and locations falls into the younger stage of rhyodacite and dacite near Hopa (Koprivica, 1971, 1977) and Artvin (Koprivica, 1973a).

Limestone

Limestone have been identified over a small area in the southwest part of the geological map but they spread much more outside the area investigated. They are formed of clastic materials and macrofauna fragments, are not pure and contain plenty of tuff materials. They are stratified in banks and strike WSW at the dip angle of 23°. Steep ridges of 10 to 30 m are strongly marked along a fault striking NNE-SSE. The limestones contain the following microfauna species: Rotalidae and Algae. By age they most likely belong to the Maestrichtian.

Hornblende biotite dacite

This dacite is identified in the profile of the Çağlayan D. Large masses of dacite are impressed in form of sills and bresches (Photo 3) into tuffaceous sandstone and andesitic microbreccias.

The megascopic observation shows that the rock has dense habitus and lath texture. Crystals of feldspar and horblende are evident while quartz is less noticeable. Prismatic effusion with large number of fissures is the characteristic feature. They often fall off steep slopes and form thick deposits of rock debris.

Hornblende biotite dacite is albitized, chloritized and slightly silicified. Its structure is holocrystalline porphyric and porphyric. Phenocrystals are plagioclase (oligoclase-andesine) and less quartz with corroded edges. Coloured constituents are hornblende and biotite. The groundmass is composed of fine grained alkaline feldspar, quartz, amphibole and biotite scales. Accessory minerals are spatite and metalic one. As regards mineralization this dacite is fully sterile. We have no precise data on its age. According to Azizbekov *et al.* (1970), Paleocene volcanism with thin dacites occurred at the periphery of the Adjaro-Trialete zone at the boundary to the Artvin-Bolnic median massive. Therefore this dacite could be of the same age.

Hornblende andesit

These andesites form the central part of the area investigated. Hornblende andesite is characterized by porphyric structure with phenocrystals of feldspar and hornblende. It is often fresh but'there are parts which are altered and broke into balls. It may be assumed that the formation of hornblende andesite was multi-staged. In fresher parts there are coloured ingredients which form predominating ridges on the ground (Photo 4).

They contain abundant hornblende crystals, the length of which reach 2, cm and the width 0.5 cm. There are parts which contain over 50 % coloured constituents (predominantly hornblende). Colours are dark grey. Field investigation confirms intensive hydrothermal alterations of hornblende andesites. These alterations are most noticeable at the right bank of the Hanezori D., i. e. along the contact of amygdaloidal andesite and breccia. Hydrothermal changes are manifested by intensive argilization, silicification and pyritisation with minor occurrences of Cu and Pb.

The hornblende andesite texture is holocrystalline porphyric and porphyric. Phenocrystals are plagioclase (andesine-oligoclase). Fe-Mg mineral is hornblende, rarely also biotite and augite. Accessory minerals are metallic ones and apatite. On the basis of numerous petrographic analysis (D. Pesic) the acid tendence was identified in these hornblende andesites, i. e. some petrographic analyses have pointed to minor occurrence of hornblende dacite. This dacite has the same petrological properties as hornblende andesite except for the presence of inconsiderable quantities of quartz for which they can be taken as andesites with some quartz.

Hornblende andesite is later than the sulphide occurrences in the investigated area. Sufficient proof of this is intersected ore body of Kaya'nın madeni containing hornblende andesite.

Diorite

Minor differentiates of hornblende-augite diorite were identified in hornblende andesite together with some biotite diorite and quartz diorite. These intrusions have petrological properties comparable with volcanic rocks with which they are associated in the Black Sea region.

There are proofs of such occurrences in the Caucasus Minor published by Dzocenidze and Tvacrelidze (1968): «Intrusive gabbro, diorite-sienite and plagiogranite have petrological properties which correspond to volcanic rocks that they mix with and these intrusions behave as product of basalt magma in all respects». It is difficult to distinguish these varieties of hornblende andesite in the field and for this reason we have drawn our boundary as gradually transiting over from diorites into hornblende andesite. Such intimacy of diorite and hornblende andesite points to sub - volcanic level ot hardening and crystallization in the hybride rocks of the same magma.

The texture of diorite is coarse — grained and idiomorphic — grained. The rock consists of plagioclase grains (mostly of andesine, rarely albite and oligoclase). Fe-Mg minerals are biotite, augite grains and hornblende prisma. Interior spaces are filled with chlorite, secondary quartz and caleite. Accessory minerals are magnetite, pyrite, martite, rarely ilmenite, rutil, epidote and apatite. Also identified are the differentiates of gabbro—diabase and gabbro—diorite with grain and ophitic structure.

Compared to similar intrusions on the Caucausus Minor these intrusions may be considered to have been formed in the period between Middle Eocene and end of the Oligocene.

Final volcanic rocks

Andesite-basalts, diabases and basalts occur in the investigated area in form of minor bodies, veins and sills. The way of their occurrence and their relationship with surrounding rocks is characteristic in the Black Sea region while further towards the Caucasus Minor and the Anatolian plateau there are spacious and thick effusions.

Andesite-basalt. — Is identified in the region of Dereiçi M. and in form of a sill east of Tepebaşı. They are not easily distinguished from basalt. They look fresh in dark grey-green colour and with hyaline (fluidal) texture. Andesite basalts contain augite and hornblende. Their texture is

porphyric, rarely holocrystalline porphyric. Phenocrystals are plagioclase (labradorite and andesine). The groundmass is ophitic and granular consisting of plagioclase and rarely augite. Accessory minerals are magnetite, pyrite and chalcopyrite. Microscopic the rock show the properties of chloritization, argilization, silicification and calcitization.

Augite-diabase. — Is manifested in form of minor and larger veins and sills over the whole mapped ground. The most characteristic ones are two veins like walls between the villages of Gigezeler M. and Dereiçi M. (Photo 5).

The veins of augite-diabase strike NW - SE. Their thickness varies from 2 to 10 m. They are altered but over the surface only. Their colour is dark-green to grey olive. The diabases as a rule contain augite. Their texture is ophitic and rarely combined with porphyric, fluidal and amygdaloidal ones. The rock consists of plagioclases, most frequently labradorite, rarely albite. Interstities are filled with chlorite, rarely with secondary quartz and calcite. Accessory minerals are magnetite, rarely chalcopyrite and very rarely pyrite and martite. Frequent and pronounced alterations are chlorization, calcitization, argilization and silicification. The albitization has rarely been seen.

Augite-basalt. — Occurs in form of minor veins, rarely sills in all formations at the mapped area. They generally strike SW - NE. When broken, they show fresh and dark green colours. As a rule, basalt contains augite and less olivine. Their texture is porphyric and holocrystalline porphyric. Phenocrystals are plagioclases (labradorite, less bitovnite). Augite is found in crystals and grains while olivine is serpentinized. The groundmass consists of plagioclases ophitic in texture. Interstities are filled with quartz, metallic mineral, rarely calcite, chlorite and olivine. The accessory minerals are magnetite, pyrite and chalcopyrite. In addition to their fresh appearance augite-basalts are partly silicified, calcitised and chloritised.

Alluvium

Alluvial formations lie only along the Meydancık O. profile in river windings and expanded parts of the river bed. There are deposits of naturally granulated sand and gravel fractions. They are formed of quartz and volcanic sedimentary rocks. Sand and gravel serve as input materials in the manufacture of building materials.

TECTONICS AND MAGMATISM

The investigated area belongs to the Pontid-Adjaro-Trialete geotectonic unit. According to numerous studies by Soviet geologists of recent dates: Magaklyan (1960), Dzocenidze & Tvalcrelidze (1968), Zaridze (1968) and others the geoteclonic units on the Caucasus Minor have been classified and they continue without interruption westwards. Therefore the Adjaro-Trialete system passes over into the Pontid geotectonic unit whose westward extension sinks under the Black Sea Adjaro-Trialete zone.

During its evolution in the Alpian cycle (Cretaceous-Tertiary) this unit had typical eugeosynclinal character. The chemical and mineralogical character of the formations in this geosynclinal zone is basic carbonate with periodical acidity while petrological properties are volcanic and sedimentary.

In the southern part of the Pontid-Adjaro-Trialete zone volcanic-sedimentary-carbonate formations were formed during the Seoonian (before folding). During folding throughout the Laramian phase (Upper Senonian-Eocene) the flysch-like sediments were formed such as carbonate and clays and marls (Hopa-Borçka-Artvin, by Koprivica *et al.,* 1971 and 1973a). The

Trialete folding stage in the Lutetian-Priabonian encompassed all parts of this geosyncline (Gamkrelidze, 1949; Zaridze, 1968), and is fixed by large scale sea regression and the end of volcanic activity. This geotectonic unit in the course of the Alpirle cycle was completed in full by Miocene.

Some lithological difference may be noticed between the Upper Cretaceous, formations in the Hopa-Murgul and Artvin areas on one side and Şavşat on the other. In the coastal Black Sea part and in the regions of Murgul and Artvin, the lower dacite series is almost, as a rule, underlying the basic volcanic-sedimentary series while in the region of Şavşat we have andesitic rock facies which correspond to the same interval. An important role in the facies separation was by all means played by the Artvin barriere (a dekyed anticline, made of Paleozoic granites and schists).

The volcanic-sedimentary complex starts with andesitic breccias in the, mapped area. These breccias alternate with tuffaceous sands and andesitic microbreccias with syngenetic diabase effusions. The amygdaloidal andesite and breccia extrusion occurred simultaneously with the formation of tuffaceous sandstones and microbreccias. All volcanic-sedimentary members are accompained by some limestone with microfauna which points to short intervals of peaceful volcanic activity. Dacite and rhyodacite are manifested in a minor area and probably correspond to young rhyodacite at Hopa and Artvin. The hornblende facies of andesite developes over the larger part of the area in form of breaches and effusions. Minor occurrences of diorite differentiates represent the intrusions formed in sub-volcanic levels and originated from the same magma.

All members of the volcanic-sedimentary formation of the mapped area generally strike east; namely at the south they strike E-SE and at the north E-NE. In the area of Çukur dere-Tepebaşı gentle folding is evident as shown on the E-W geological cross section. Amygdaloidal andesite and hornblende andesite are discovered in the apex of an irregular brachy-anticlinal formation striking along the NW-SE axis.

Faults are very prominent and mostly two fault systems predominate. The first system strikes NW-SE and the other NE-SW, The faults striking NE are less prominent. The NW - SE fault system is longitudinal i.e. its strike coincides with the strike of geological members. The majority of sulphide ore NW-SE striked: Binektaşı, Fikri'nin madeni, Kaya'nın madeni, Hasan'ın açması, Yeni açması. The faults striking NE-SW and N-S are accompained by intense pyritization with rare polymetallic mineralization. The majority of fault structures serve as favourable routes for hydrothermal solutions of sulphide polymetallic mineralization. The whole process is accompanied by intense silicification and argilization. The predominant hydrothermal processes were developed in form the amygdaloidal andesites and breccias.

Most fault structures were reactivated in the post ore period (Eocene - Quaternary) with members of final volcanism (andesites, diabases and basalts).

Between Miocene and Quaternary the phenomenon of general rising of the Caucasus Minor which was mostly reflected in the regions of geoanticline is known. According to Aslanyan (1958) this rising reached 2 to 3.5 km. This refers to the surrounding region of the mapped area with the paleogenetic sediments lying at the altitudes of over 2,000 and 2,500 m.

SULPHIDE MINERAL DEPOSITS

Ore and mineral occurrences lie in the very altered zone of amygdaloidal andesite, breccias and tuffs. The altered zone strikes NW-SE (Akkavak Y. - Dereiçi M.), in the length of 6 km over the investigated area and the average width is about 2 km. Outside the investigated area, towards northwest this zone passes into ore occurrences of the Üzümlü Y. and Madenköy.

In this zone a large number of sulphide veins of copper, lead and zinc were identified. The investigations of the BAMAŞ company of Ankara coincided with our investigations (1972-1973) and they also mined rich ore veins in the localities of Binektaşı, Talat'ın madeni, Fikri'nin madeni, Hasan'ın açması, Yeni açması and Kaya'nın madeni. In addition to the above mentioned ore deposits we discovered a large number of ore occurrences of which the more important ones are described in this chapter. According to Sopko (1971) these deposits fall into the group of vein polymetallic deposits of the Adjaro-Trialete zone.

On the basis of geological way of occurrences and mineralogical composition in this zone there are three distinct types of sulphide mineralizations and ore deposits.

I. Complex sulphide ore and mineral deposits

II. Chalcopyrite-pyrite ore and mineral occurrences in the tectonic andesite breccias.

III. Quartz veins with chalcopyrite and pyrite.

Type I

The first type occurs in form of veins in intensively argilized andesite and breccias. Ore veins differ in thickness (from several cm to 3.5 m). These veins often thicken and thin out i.e. occur in lenticles. The main ore vein often branches into several thin veins which again converge into one vein along the fault. The veins of this type are characterized by relatively high metal content. This type of ore deposits is found at the localities of Talat'ın madeni - Binektaşı - Fikri'nin madeni.

1. *Binektaşı ore occurrence.* — Is the typical representative of complex sulphide type mineralization (Cu, Zn, Pb). This vein was discovered on the erosive surface and could be traced along about 130 m. Its thickness varies from several cm to 3 m. It strikes NW - SE dipping towards SW at an angle of 45° - 50° and at some places even 80°. Three runnels were made for investigation and use of this vein.

In the uppermost horizon (922.53 m) the ore is rather broken and occurs in rich veins which fill cracks and fissures in andesite inside the fault zone. The average metal content at this horizon assays: Cu 1.43 %, Zn 5.21 %, Pb 0.73 % while the mean thickness of the vein is 0.64 m. In the middle horizon (905.00 m) the vein is compact and the metal content is relatively high (no sample was taken due to flood). In the lowest horizon (880.27 m) the vein is distinct but due to the large quartz content the metal percentage is low and the chemical content is: Cu 0.81 %, Zn 3.24 %, Pb 0.55 %. In this horizon the length of economically worth vein is smaller than in the preceding one. This clearly shows that the largeness of ore vein and the metal content diminish at the depth. This was confirmed by a borehole drilled deeper than this horizon, which gave negative results.

2. Fikri'nin madeni ore occurrence. — Strikes NW-SE along the fault. The length of the ore vein at the surface is about 200 m. The thickness varies reaching 2.5 m max. and the average thickness is about 0.70 m. It dips towards SW at angle of 50-70°. To explore this ore vein the investor prepared seven tunnels. The uppermost one lies at the level of 1106.30 m and the bottommost at the level of 1024.85 m (Photo 6).

The mining shows that the vein thins out. By its mineral composition this vein is similar to the Binektaşı ore vein. It contains high metal percentage. Minerals occurring are sphalerite, chalcopyrite, galena and pyrite. The associates are quartz and carbonates.

3. Muzo ocağı ore occurrence. — Lies about 200 m west of the Fikri'nin madeni. The ore vein strikes NW-SE dipping towards SW at an angle of 65°. The vein is lenticular interrupted

and can be traced more than 50 m. It was explored with two tunnels, differing in altitude by 25 m. The vein contains rich and complex ore with dominating sphalerite followed by chalcopyrite and galena. For its high metal content this occurrence deserves attention.

4. Gigezeler ore occurrence. — The Fe, Zn, Cu, Pb sulphide vein is intersected by an intrusion of young diabase. Both sediments strike NNW-SSE dipping towards SW at an angle of 40°.

North of diabase breach the ore vein of similar character was identified, too. It strikes NW - SE and is mostly composed of sphalerite and chalcopyrite.

5. *Talat'ın madeni ore occurrence.* — Lies north of the road at Dereiçi. Andesitic rock containing ore is intensely argilized and partly silicified and pyritized. The ore was identified in a channel distinctly showing the character of occurrence. The width is 6 m and strikes N-S. The boundary between the ore body and andesite is sharp at the east and gradual at the west. Ore occurs in form of crack filling along the fault zone and in form of stockwork and impregnations. Metallic minerals are pyrite, chalcopyrite, sphalerite and galena and non-metallic one is quartz. It is evident that sphalerite is the predominant mineral. Chalcopyrite is noticed in form of exsolutions and galena in form of veinlets in sphalerite. The chemical analysis taken by means of a channel sample assayed Cu 0.15 %, Zn 2.62 %, Pb 0.37 %. 10 m below the ore deposit was intersected by a shaft in which the tendency of thinning out was present.

6. Dereiçi ore occurrence. — In the village of Dereiçi right from Meydancık Ç., there is an outcrop of an ore vein in altered andesite. It is 0.50 m thick and strikes WNW-ESE dipping towards NE at an angle of 50°. Due to cover the vein could not be traced up. Sphalerite prevails with galena abundant and much less chalcopyrite. Non-metallic minerals are quartz and still less carbonates. Metalcontent in the ore vein at the outcrop is: Zn 8.34 %, Pb 2.38 %, Cu 0.99 %.

In the Dereiçi village also but on the left of the Meydancık Ç., chalcopyrite, sphalerite and galena occur. Mineralization is in hydrothermally altered and argilized andesite. It is shown in forms of large and small veins. The thickness of the mineralized zone is about 3 m. Ore occurrence strikes E-W dipping southward at an angle of 75°. Due to the debris coverage the vein could not be traced all along its length. The samples taken by means of a channel sample assayed less metal than the preceding one.

Similar mineral occurrences are identified at the localities of *Tariyadere* (7), *south - east o Binektaşı* at the distance of 500 m and from Biril M. (8) where four mineral veins occur, notably in a very inaccessible locality. Both localities lie in andesite, highly hydrothermally altered. The chemical analyses assayed relatively low metal content.

Type II

Chalcopyrite-pyrite ore occurrences are also identified in tectonic breccias along the faults. These occurrences are discovered at the localities of Hasan'ın açması, Yeni açması and Köpek Dere. In the tectonic andesitic breccia there is chalcopyritic mineralization with pyrite and very scarce sphalerite. The ore deposit is not uniform and occurs in form of filling in cracks and fissures and impregnations.

At the surface these mineral occurrences are manifested in form of yellow-red and green colours resulting from the transformation of pyrite and chalcopyrites into limonite and malachite. At this locality there are extensive ore veins of this type some of which used to be mined even (1972-1973).

9. *Hasan'ın açması ore occurrence.* — Occurs in tectonic breccia of amygdaloidal andesite along the fault which strikes WNW-ESE and dips towards south at an angle of 85°. The ore vein can be traced on the surface by about 90 m in length.

The ore is about 1.20 m thick and the copper content exceeds 2 %. In the course of investigation and mining two tunnels were made. In the upper horizon (1420 m) the ore vein was traced through a tunnel, 82 m long and at the lower horizon along the 42 m long tunnel. The mining works showed that ore vein thinned out and metal content dropped with the depth.

10. *Yeni açması ore occurrence.* — Also lies in the faulted breccia of amygdaloidal andesite. The mineralization is manifested in form of veins and veinlets and chalcopyrite and pyrite impregnations with some sphalerite. The ore vein strikes WNW-ESE dipping northward at an angle of 85°. The thickness changes very much from several cm to 2 m. The vein is uniformity rich both along the strike and dip.

11. *Tarlasırtı ore occurrence.* — Is associated with the faulted andesite breccia. Intense mineralization frequently alternates with poorer one. So changing the thickness reaches 4 m. The vein can be traced 50 m on the surface while further it is covered with debris. The identified minerals are chalcopyrite, pyrite and very scarce sphalerite. Along the channel sample assayed Cu 0.99 % and Zn 0.33 %.

12. *Köpek Dere ore occurrence.* — In the stream profile erosion had outcroped a vein 1 m thick with chalcopyrite. The vein is striking WSW-ENE and dipping southward at an angle of 64°. The ore vein could be traced along 10 m and is covered by debris. The chemical analysis assayed Cu 3.47 % and Zn 1.20 %.

13*th* *and* 14*th* *ore occurrences.* — Similar mineral occurrences are registered at the locality of Kopek Dere. They lie in tuffaceous sandstones and andesitic microbreccias along the faults.

15. Sakondriyat ore occurrences. — Lies in andesitic breccias and tuffs and is also associated with the fault breccia striking N-S and dipping eastward at an angle of 80°. The ore vein contains pyrite, chalcopyrite, galena and some sphalerite. Quartz is frequently present. The metal content as proven in the channel sample assays: Cu 1.16 %, Pb 3.30 %, Zn 0.73 %. This ore vein was followed along 10 m and reached 1 m in thickness.

16*th* *ore occurrence.* — North of the phenomena described a similar mineral occurrence was registered (16) with minor copper content (Cu 0.9 % and Zn 0.30 %). Then at the locality of Akkavak Y. - Tepebaşı in the same rocks, there are several veins of galena and sphalerite. According the field investigations and the results of chemical analyses these occurrences have no economic importance.

Type III

This type of mineralization is characteristic for its quartz veins with chalcopyrite and pyrite and less sphalerite. They lie in amygdaloidal andesite. They very in length and thickness and in the intensity of mineralisation. The contact of quartz veins and andesite is generally sharp but there are parts in the quartz mass in which andesitic origin can be noticed.

The veins mostly consist of white crystalline quartz, then porous quartz with voids filled with limonite. The pyrite and chalcopyritic mineralization occurs in the quartz mass in form of minor impregnations and crack and fissure fillings. The medium copper content is relatively low.

17. *Kaya'nın madeni ore occurrence.* — At this locality, two parallel quartz veins were discovered. They lie about 3 m apart. One vein is 1.84 *m* thick and the other 1 m. The thicker vein can be traced along 160 m on the surface and it strikes NW-SE. The ore contains pyrite, chalcopyrite and sphalerite. Galena is scarce. Of non-metallic minerals the main ingredient is quartz. Chemical analysis in a cutting at the level of 1320 m and from both veins assayed as

follows: Cu 0.62 %, Zn 0.59 %, Pb 0.098 %. At the level of 1305 m one tunnel was made to intersect both ore veins 4 m apart. One is 1.67 m thick and the other 3 m. The average metal content is Cu 0.37 %, Zn 0.46 % Pb 0.04 %. The second tunnel at 1274 m cut an ore vein 1.5 m thick. The ore at this level is the richest in copper (Cu 3.28 %) with some zinc (Zn 0.34 %). This shows that the thickness declines with the depth and the copper content rises.

18th ore occurrences. — May be considered as a part of the ore occurrence no. 17 which is intersected by late intrusions of hornblende andesite. This ore vein has the same strike (NW-SE) and vertical dip. It is 3.90 m thick. Its average metal content is: Cu 0.92%, Zn 0.46 %,Pb 0.04%. The character of this ore vein can be seen on the vertical section (Fig. 2).

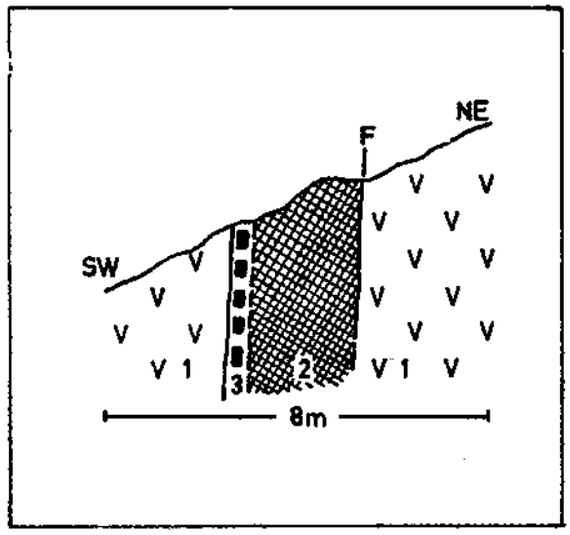


Fig. 2 - The ore vein; cross section in Kaya'nın madeni 18. 1 - Amygdaloidal andesite; 2 - Quartz vein with chalcopyrite and sphalerite; 3 - Intense pyritization; F - Fault.

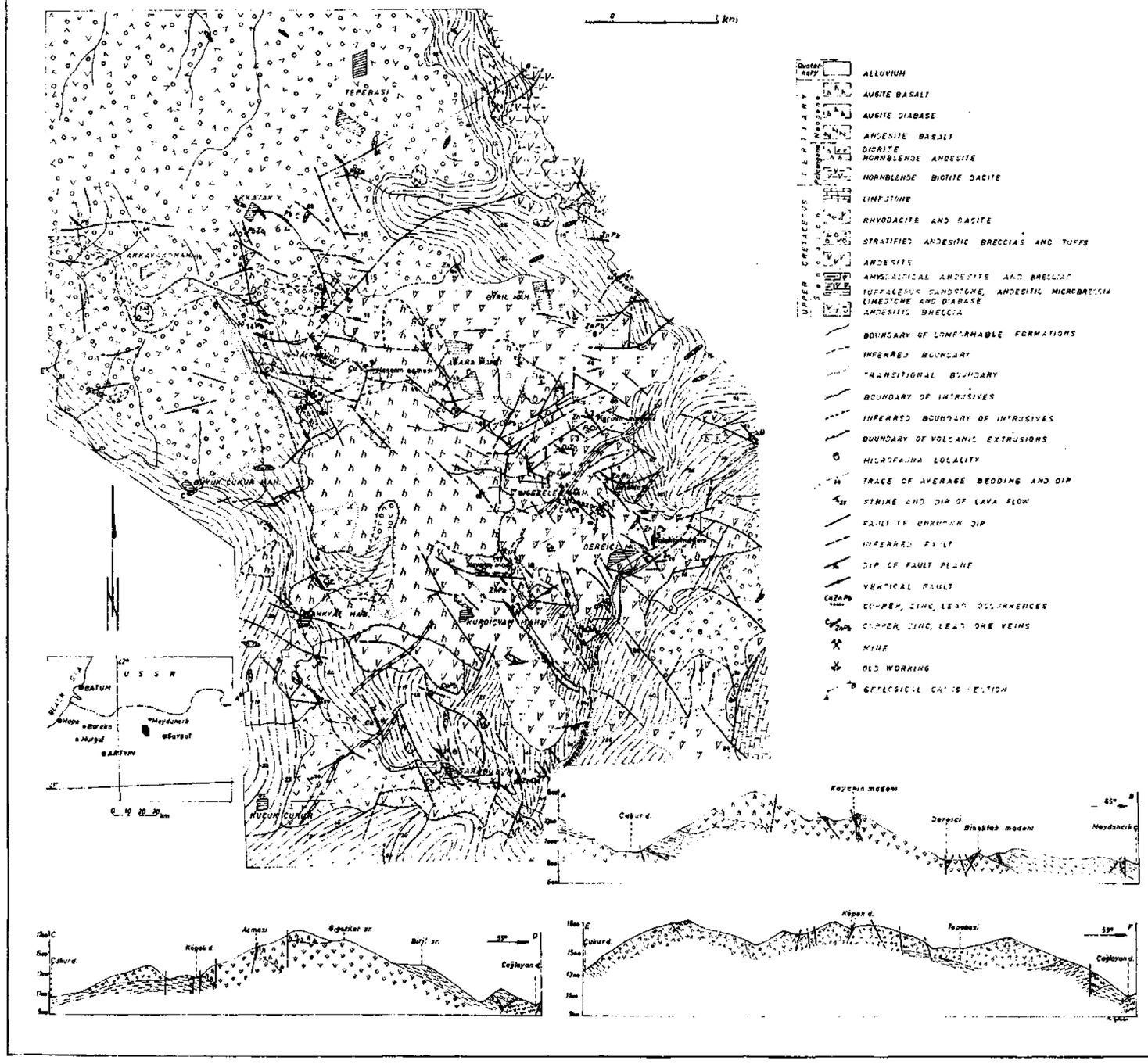
The above shows that a number of ore veins was known at the investigated area. Some were only investigated and some even mined in 1972-1973 by the BAMAŞ company. In the course of our investigations all ore veins identified were geologically treated in detail. Besides, a number of new ore veins and mineral occurrences were identified.

The following new ore veins and occurrences were identified: Dereiçi (6), Yeni açması (10), Tarlasırtı (11), Köpek Dere (12, 13, 14), Sakondriyat (15, 16), of numerous mineral occurrences assessed as economically insignificant we mention: Akkavak Y., Tepebaşı and Biril M., where a number of Pb - Zn sulphide occurrences were identified. At the locality of Şarapul M. and right from Meydancık Ç. a large number of sulphide Cu - Zn mineralizations were also discovered.

METALLOGENESIS

Sulphide polymetallic (Cu, Zn, Pb) mineralizations are associated with faulted structures in the rock of amygdaloidal andesite and stratified andesitic breccias and tuffs, their age to our thinking being the Santonian-Maestrichtian. They are very much altered hydrothermally (intense argilization and silicification) and some ore veins are intersected by hornblende andesite (Kaya'nın madeni). This points lead to a conclusion that sulphide polymetallic mineralizations happened in the

GEOLOGICAL-STRUCTURAL MAP OF DEREİÇİ-TEPEBAŞI AREA, WNW OF ŞAVŞAT (NE TURKEY)



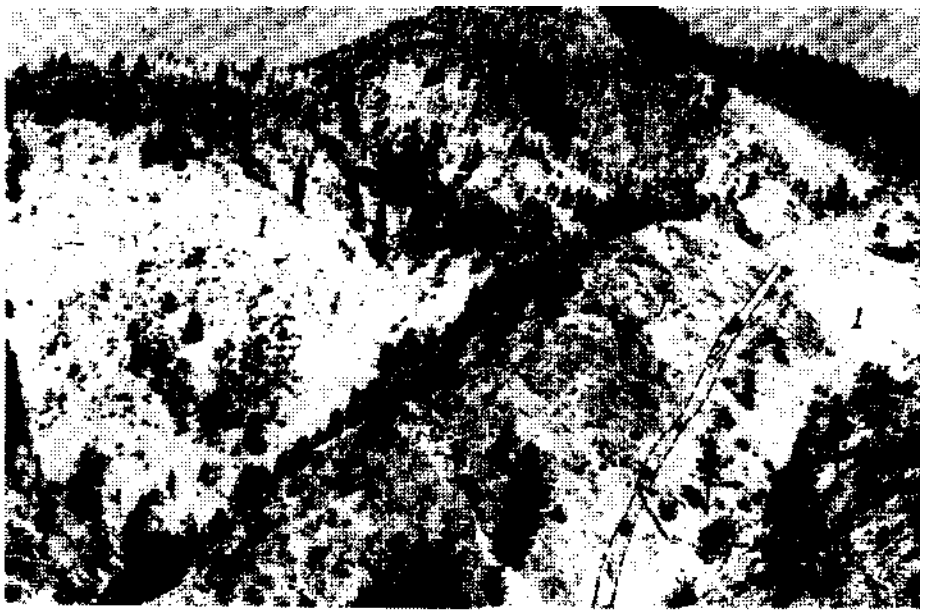


Photo 1 - Fikri'nin madeni.
1 - Bleached amygdaloidal andesite and breccias, strongly argilized;
2 - Ore vein with mining works.

Photo 2 - Left side of Çukur D. Fine expressed prismatic jointing in andesite with flow surface.

Photo 3 - The profile along the road, left of the Çağlayan D.
1 - Andesitic microbreccia and tuffaceous sandstone; 2 - Hornblende biotite dacite.

Photo 4 - North of Yeni açması. Prominent outcrops of hornblende andesite with expressed columner jointing, strongly cataclized.

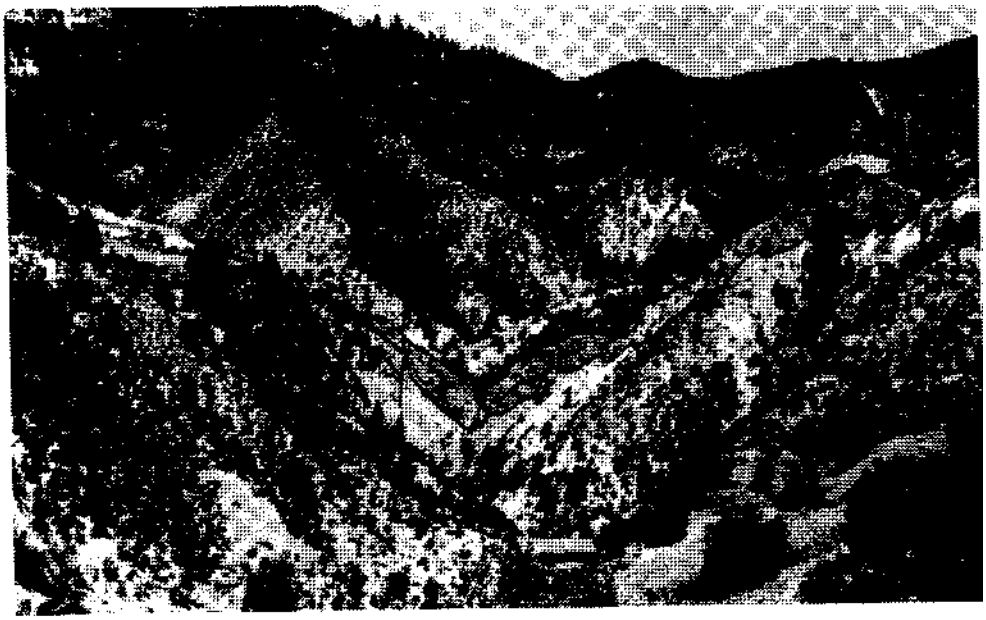


Photo 5 - North of Dereiçi M. 1 - Hydrothermally changed amygdaloidal andesite and breccias; 2 - Great wall like diabases cutting river profile.

Photo 6 - Fikri'nin madeni, the view at the sulphide Zn, Pb, Cu ore vein and mining works.

Photo 7 - Hasan'ın açması; left side of spring.
1 - Amygdaloidal andesite; 2 - Ore vein and mining works.

interval between the Uppermost Maestrichtian and the beginning of Eocene, i.e. probably in Paleocene.

The mineralizations are hydrothermal and of vein-type and were created in mezzothermal stage. No scarn occurrences or high-temperature minerals were formed. These veins of copper, zinc and lead sulphides are accompanied by aboundant pyrites and quartz.

On the basis of the geological way of occurrence and mineral composition all ore occurrences are subdivided into three types: 1- Complex sulphide mineralizations (Cu, Zn, Pb); 2- Chalcopyrite-pyrite mineralizations and 3 - Quartz veins with chalcopyrite and pyrite.

According to Sopko (1971) these ore deposits lie in volcanic rocks near to the contact of intrusive mass of gabbro-diorite composition. The presence of diorite was identified in the investigated area, too.

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REFERENCES

ASLANYAN, A.T. (1958): Regionaljnaja geologija Armenii. «Ajpetrat».

AZIZBEKOV, A. Sh. & DZOCZENIDZE, G.S. (1970): Magmatizma of the Caucasus, Iran and Turkey. *Geological series,* no. 12, Moskva.

DZOCENIDZE, G.S. & TVALCRELIDZE, G.A. (1968): Sravniteliwya harakteristika magmatizma i metalogenii Kavkaza, Kryma i Karpat. *Serija geolegiceskaja.* no. 8, Moskva.

GAMKRELIDZE, P.D. (1949): Geologiceskoje strojenije Adjaro-Trialetskoy skladcatoy sistemi. Izd-vo AN Gruz. SSR.

ERAY KIRAÇ (1945): Artvin vilayetinin Şavşat kazasında, bir maden araştırmasında alınan neticeler. *M.T.A. Rep.,* no. 1662 (unpuplished), Ankara, Turkey.

ERENTÖZ, C. (1961): Geological map of Turkey «Kars» 1:500,000 *M.T.A. Publ.,* Ankara, Turkey.

KOPRIVICA, D.; MARKOV, C. & PEJATOVIC, S. (1971): Report of geological mapping in 1:10,000 scale at the Hopa-Kavak-Gürgençlik area. *M.T.A. Rep.* (unpublished), Ankara, Turkey.

—-—NOVOVIC, T. & POKRAJAC, S. (1973): Report of geological-structural mapping in 1:10,000 scale with special review on the sulphide (Cu, Zn, Pb) occurrences in the area NW of the Şavşat place. *M.T.A. Rep.* (unpublished), Ankara, Turkey.

———, & POKRAJAC, S. (1973a): Report of geological-structural mapping in 1:10,000 scale and prospection in the Artvin-Ahlat area. *M.T.A. Rep.* (unpublished), Ankara, Turkey.

———(1977): Geology, structural features and sulphide and manganese occurrences of the Hopa-Arhavi (NE Turkey). *M.T.A. Bull.,* no. 87, Ankara, Turkey.

MAGAKLYAN, I.G. (1960): Structural-mctallogenic zones of Minor Caucasus. In the bock «Regularites in distribution of the mineral raw materials», vol. 3, *Ac. Sci. U.S.S.R.,* Moskow.

PEJATOVIC, S. (1971): Metallogenic zones in the eastern Black Sea-Minor Caucasus regions and distinguishing features of their metallogeny. *M.T.A. Bull.,* no. 77, Ankara, Turkey.

SOPKO, P.F (1971): Kolcedanie mestorozdenija Malogo Kavkaza. Moskva.

ZARIDZE, M.G. (1968): O geosinklinalnom tektono-magmaticeskom sikle razvitiya Malogo Kavkaza v Alpiskuiu Epohu. *Geologia irazvedka,* no. 8, Moskva.