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ORE-FORMING SYSTEMS IN VOLCANOGENIC-SEDIMENTARY SEQUENCES BY THE EXAMPLE OF BASE METAL DEPOSITS OF THE CAUCASUS AND EAST PONTIC METALLOTECT

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ABSTRACT.- By the example of Alpine volcanogenic base metal deposits of the central part of the Alpine-Himalayan fold belt (East Pontic Metallotect and Caucasus), it has been demonstrated that their hydrothermal systems naturally emerge at various stages of active interaction of microplates-continental fragments of Eurasia and Gondwanaland. During the divergence stage, at the microplates-boundary zones within the marginal sea, hydrothermal-sedimentary Cu and polymetallic deposits have been formed; at the early convergence stage, within the paleo-island-arc systems, epigenetic Cu and in lesser extent, barite-polymetallic (Lesser Caucasus), and later both combined (hydrothermal-sedimentary and stockwork) and epigenetic (mainly Cu- and Zn-containing) deposits have been originated (East Pontic Metallotect). In the beginning of collisional stage, in connection with antidrome volcanism within the back-arc volcanic structures, polyformational deposits (barite, barite-polymetallic, Cu, Au) have been formed. This tendency persists during the whole collisional stage - in the withinplate and transplate Eocene volcanic depressions - mainly polymetallic deposits have been originated in which the increasing contents of Ag take place in comparison to Au. The authors share the opinion that the primarily- anomalous environments for Cu-Zn deposits can have been "specialized" basic and medium-acidic volcanics whereas for baritic and barite polymetallic deposits gray colored and evaporitic sequences in the volcano-structure pedestals with buried highly mineralized brines seem to be most favorable.

Key words: Lesser Caucasus, Eastern Pontides, volcanogenic/sedimentary deposits, Murgul, Madneuli

INTRODUCTION

Volcanogenic deposits are typical of the active paleomargin of the Eurasian continent, more precisely, of its "fragments" - microplates (Scythian, Transcaucasian - Pontian) interacting with the passive Gondwanian paleomargin (represented by the Kırşehir, Taurus and Daralagez blocks). The continental blocks are separated from one another by suture zones most of which are marked by ultrabasic "melange" (Fig. 1). According to some authors (i.e. Vrielinck, 1994), the passive continental blocks drifted together with the oceanic plates. The mountain - fold belts contain the lithofacial information about changing geodynamic regimes under existing kinematics of lithospheric plates. Numerous publications (i.e. Monin and Zonenshain, 1987; Yılmaz et al., 1997; Okay and Şahintürk, 1977) indicate that among the main tectonic events conditioning the geologic framework of the Alpides are: 1- detachment of the Iranian microplate in Permian-Triassic time from Gondwanaland and its amalgamation to the active Eurasian margin; 2- opening Neotethys in Late Triassic-Early Jurassic (possibly its both branches) (Biju-Duval et al., 1977) in connection with the formation of rift systems; 3- obduction of oceanic complexes in Senonian marking the "death" of the ocean (Monin and Zonenshain, 1987).

The above events designate the principal stages of the historical - geological development in the Alpine cycle: first, divergence of microplates (Triassic-Early Bajocian) which caused the formation of the branches of Neotethys and activity of mantle diapirism; then, their convergence (Late Bajocian-Early Cretaceous) with especially island-arc andesitic volcanism at the margins and riftogenic volcanism in the central part of the Transcaucasian-Pontian microplate.

Maximum island-arc volcanic activity in the Transcaucasus took place in Bajocian - Late Jurassic while in the East Pontic metallotect - in Turonian - Santonian. Lately, on the basis of

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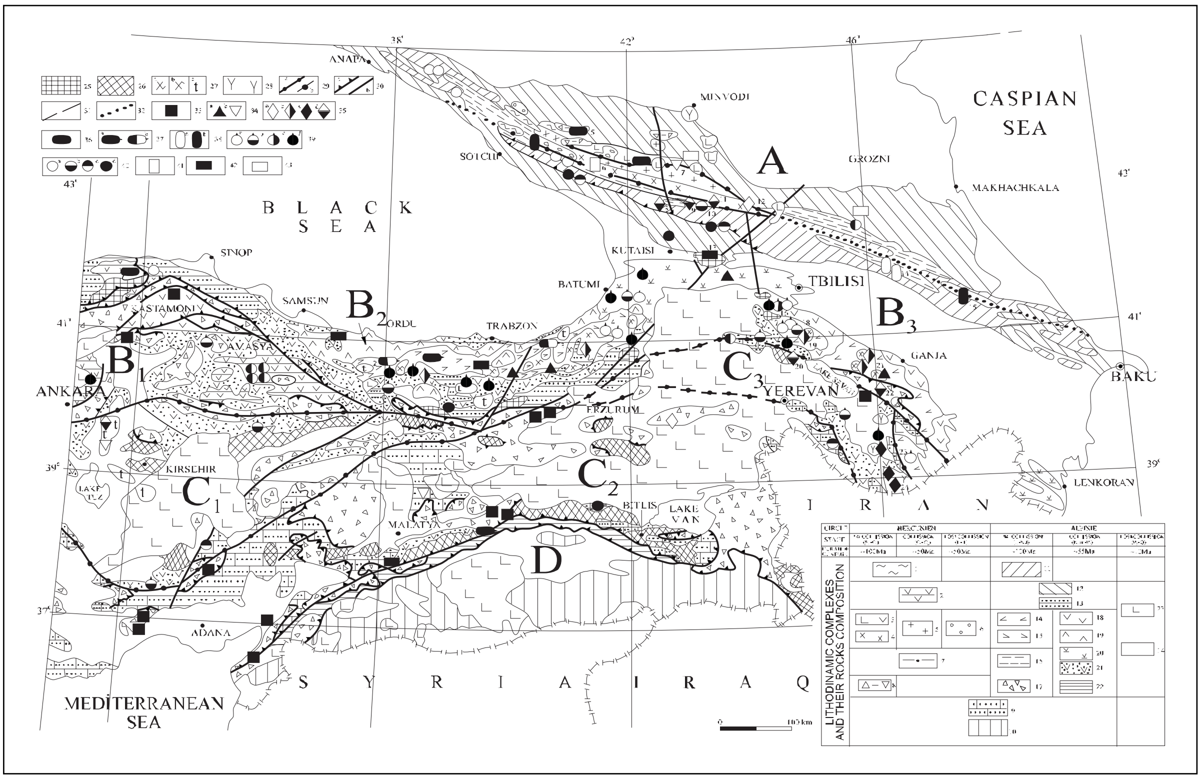

Fig. 1- Scheme of distribution of litho - geodynamic complexes and main types of metallic deposits of the central part of the Alpine-Himalayan belt (Eastern Turkey and the Caucasus), litho-geodynamic complexes; Hercynian: active margin of the East European paleocontinent: 1- Shelf and continental slope (Devonian-Carboniferous andesite-basalts, coaly-clay shales, limestones, greenstone alteration; Greater Caucasus); 2- Shelf zones of the continent (Carboniferous-Triassic sandstones, conglomerates, coaly shales, andesite-basalts; greenstone alteration; Pontides); 3- Ensimatic island arc (Devonian-Lower Carboniferous basalts, rhyolites, cherts, calcareous sandstones; Greater Caucasus); 4- Ensialic island arc (gabbro, granodiorites, parametamorphites of greenschist and amphibolite facies, blocks of pre-Cambrian schists; Greater Caucasus); 5- Uplifted activized blocks of ensialic arc (collisional granites, stavrolite and biotite-muscovite schists; Greater Caucasus); 6- Continental depressions (Permian- Triassic clays, sandstones, andesite-basalts, rhyolites; Greater Caucasus); 7- Paleo-marginal sea (Devonian-Triassic coaly-clayey shales, sandstones, andesite-basalts, olistostrome horizons, limestones; greenstone alteration; southern slope of Greater Caucasus); 8- Oceanic bed (calcareous and flint shales, basalts, peridotites, rhyolites in allochthonous occurrence; Greater Caucasus). Passive margin of Gondwanaland and later, since Mesozoic, of Afro-Arabian paleocontinent: 9- Shelf zones (Paleozoic- Cretaceous clays, sandstones, limestones, andesite-basalts, tuffites; Kırşehir, Taurus, Daralagez blocks); 10- Shelf zone of Arabian Block (Paleozoic-Eocene sandstones, clays, limestones, conglomerates). Alpine: active margins of the Eurasian paleocontinent: 11- Continental slope and rise of the Transcaucasian microcontinent (Jurassic-Lower Cretaceous andesite-basalts, trachyandesites, terrigenous - calcareous flysch, coaly-clay shales, granodiorites; southern slope of Greater Caucasus); 12- Shelf zones and slopes of the Scythian and Transcaucasian microcontinents (Jurassic-Paleogene andesites, andesite-basalts, shales, sandstones, multicoloured clays with sulphates, limestones and dolomites, marls, tuffites; Greater Caucasus); 13- Shelf zones and slope of the Pontian microcontinent (Lower Jurassic andesite-basalts, sandstones, limestones, shales; Late Jurassic- Cretaceous conglomerates, limestones, basalts, coral limestones, marls; Upper Cretaceous terrigenous-carbonaceous flysch; Pontides); 14- Lesser

Caucasian ensimatic island arc (Bajocian-Lower Cretaceous andesite-basalts, rhyodacites, tuffites, sand stones, shales, tonalites, diorites; southern margin of the Transcaucasian microcontinent); 15 - Pontian ensimatic island arc (Upper Cretaceous andesite-basalts, rhyodacites, marls, sandstones, shales); 16- Troughs within the marginal paleo-sea (Lower and Middle Jurassic shales, basalts, rhyolites, gabbro-diabases; Greater Caucasus); 17- Oceanic zones in allochthonous occurrence (in the form of sutural and obducted deformed slabs - ultrabasic "melange", harzburgites, serpentinites, gabbro, tholeiites, alkaline basalts, flysch with ophioclastic olistostromes, radiolarites; Pontides, Taurides, Lesser Caucasus); 18- Residual Lesser Caucasian back-arc paleodepressions (Senonian-Danian andesites, rhyodacitic ignimbrites, rhyolites, trachyrhyolites, limestones, basalts, granodiorites); 19- Residual Pontian back-arc paleodepressions (Campanian-Danian basalts, rhyodacites, trachyrhyolites, coral limestones); 20- Intraplate superimposed riftogenic depressions (trachyandesites, trachybasalts, volcano-terrigenous flysch with olistostromes, gabbro-diorites, monzonites, syenites, alkaline gabbroids and syenites); 21-Superimposed marine volcanodepressions (Eocene andesites, trachyandesites, terrigenous-carbonaceous flysch, sandstones, shales); 22- Flysch troughs (south margin of the Taurus carbonate platform) emerging as a result of collision of the Taurus with Eurasia (Senon-Eocene-Oligocene sandstones, marls, shales, ultrabasic fragments); 23-Volcanic plateau-activated blocks of fold systems (Neogene-Quaternary andesites, andesite-basalts, basalts and their pyroclastics); 24- Intramontane depressions and foredeeps of fold sysems (Oligocene-Quaternary marine and continental molasse); 25- Crystalline basement of the Eurasian continent (pre-Cambrian-Early Paleozoic); 26 - Crystalline basement of Afro-Arabian continent (pre-Cambrian?); 27- Granitoids (pre-collisional: a - Lower Cretaceous, b - Upper Cretaceous, c - Eocene-Oligocene collisional); 28- Post-collisional monzonites, syenites, granodiorites; 29- Suture zones (a - reliable, b - presumable beneath the younger sediments); 30 - Faults (a - thrusts and reverse faults, b -subvertical faults); 31- Caucasian lineaments interpreted from space photographs; 32- Presumable boundary between Scythian and Transcaucasian microplates. Genetic types of deposits: 33- Magmatogenic (chrome minerals); 34- Skarn (a- iron-ore, b- tungsten-molybdenum); 35- Hydrothermal-plutogenic (a- polymetallic, b- copper-porphyry, c-copper-molybdenum-porphyry, d- gold-bearing); 36- Hydrothermal-sedimentary in volcanic rocks (copper with zinc); 37- Combined hydrothermal-sedimentary and stock work in volcanic rocks (a - copper, b - copper-zinc); 38- Hydrothermal-sedimentary in shales (a - polymetallic, b - copper metamorphogenic); 39- Hydrothermal-volcanogenic epigenic (a - copper, b - polymetallic with barite, c - polyformational: copper, barite, barite-polymetallic, gold-bearing in secondary quartzites, d - gold-bearing); 40- Hydrothermal "amagmatogenic"-telethermal (a - mercury, b - arsenic-realgar-orpiment with gold, c- lead-zinc , d- barite); 41- Hydrothermal-metamorphogenic (tungsten); 42- Sedimentary and volcanogenic-sedimentary (?) (manganese); 43- Sedimentary (celestine). Main deposits of the Eurasian active paleomargin:1- Aşıköy (Cu); 2- Lahanos (Cu, Zn, Pb); 3- Çayeli-Madenköy (Cu, Zn); 4- Murgul (Cu, Zn); 5- Urup (Cu); 6- Kty-Teberda (W); 7- Thir-Nyauz (W); 8- Lukhra (Au); 9- Tcana (As, Au); 10- Lukhumi (As); 11- Zophito (Au, Sb); 12- Sadon (Pb, Zn); 13- Chiatura (Mn); 14- Filizchai (Zn,Pb, Cu); 15- Kızıldere (Cu); 16- Madneuli (Cu, Pb, Zn, Ba, Au); 17-Alaverdi (Cu); 18- Chamlug (Cu); 19- Tekhut (Cu); 20- Megradzor (Au); 21- Dashkesan (Fe, Co); 22- Zoti (Au); 23- Kafan (Cu); 24- Kadjaran (Mo, Cu). The paleomargin of the Eurasian continent active during the Alpine cycle: microplates: A- Scythian, B- Pontian-Transcaucasian (B1- Western Pontides, B2- Eastern Pontides, B3- Transcaucasia). Passive paleomargins of the Afro-Arabian continent: microplates: C1- Kırşehir, C2- Taurus, C3- Daralagez (North Iranian). Microplates are divided by suture zones. D - Arabian projection (boundary with the Taurus is marked by system of thrusts). The western part of the scheme is compilied on the base of maps published by MTA (Turkey): geological, on a scale 1:500 000 (1961) and 1:2 000 000 (1989); metallogenic, on a scale 1:2 500 000 (1977) and 1:1 000 000 (2000). Besides, it has been used an unpublished map of the Eastern Pontides on a scale 1:250 000.

comparative structural-facial analysis, Yılmaz et al. (2000) have convincingly shown the differences in the geodynamic evolution of individual segments of the Transcaucasius - Pontian microplate. The beginning of the collision was different in time in western and eastern parts - joining the Transcaucasia and Daralagez block took place in Coniacian (Monin and Zonenshain, 1987) whereas the East Pontic metallotect was amalgamated with the carbonate platforms somewhat later - in Campanian (Dixon and Pereira, 1974).

During the collisional stage in Late Cretaceous-Eocene, volcanic activity first appeared in the residual back-arc basins and, later, in depressions superimposed on older tectonic structures in Eocene volcanics. The process of collision was accompanied by intensive reorganization of earlier geomorphological structures. The overthrusting of oceanic flyschoid series on adjacent continental blocks and obduction of oceanic crust were marked by diverse forms of volcanic activity-parallel with andesitic volcanism there appeared subalkaline and alkaline volcanics; besides, some crustal magmatic sources were activated as well.

The process of disruption of macrostructures - destruction in the north connected with the formation of Paratethys followed by intensive emergene of mountain-fold systems-continued during the whole postcollisional stage which remains beyond our study as bearing no relation to the genesis of base metal deposits.

The scheme shows that volcanogenic deposits are associated with geodynamic complexes formed in the following situations:

1- Depressions of marginal seas (hydrothermal-sedimentary Cu and pyrite-polymetallic mineralization of the divergent stage, Cu in Dagestan and Turkey, polymetallic in Azerbaidjan);

2- Intra-arc marine basins of different age (hydrothermal-sedimentary and epigenetic Cu and Cu-Zn deposits of the East Pontic metallotect and the Lesser Caucasus. Within the uplifted blocks there are Au-polymetallic deposits as well - Shaumian in Armenia and Cerattepe in Turkey);

3- Residual back-arc Cretaceous volcanostructures (epigenetic near-surface Cu, barite, barite-polymetallic and Au-bearing deposits of the Bolnisi district in Georgia);

4- Withinplate and transplate collisional Eocene volcanic depressions (epigenetic polymetallic, with silver and Au, and barite deposits of Georgia, Armenia and Turkey).

The most significant deposits are concentrated within the first three types of volca-nostructures.

VOLCANOGENIC DEPOSITS

Hydrotheral-sedimentary deposits of the divergent stage have been discovered in the east in shales of the Greater Caucasus, and in the western part of the Pontides, in the volcano-sedimentary Küre complex. Ore bodies are within allochthonous slabs, some of which are intensively deformed; primary mineralization has sometimes been subjected to metamorphism as in case of the Kızıldere deposit in Dagestan.

The Cu-pyrrhotite Kızıldere deposit is located at the junction of the Scythian and Transcaucasian microplates in the paleo-depression of the marginal sea strongly deformed by subsequent tectonic stresses. Lower Jurassic shales together with syngenetic pyrite deposits were deformed into a series of complicated folds. Shales, at some distance from the deposit, contain greenstone-altered tholeiitic basalts and medium-asidic intrusions (Borodaevskaya, 1979; Bogdanov et al., 1983). The pyritic bodies forming two large lenses are related to a synclinal fold; they are composed of syngenetic pyritic and epigenetic Zn-pyritic and younger Cu-pyrrhotite ores.

The Filizçay pyrite-polymetallic deposit forms a single large ore body (Bogdanova et al., 1983) situated at the boundary between the shales and overlying flyschoids. A sheet ore deposit of syngenetic ores is made up of individual pyrite-carbonate, sphalerite-galena, chalcopyrite-pyrite and clayey "rhythms". In the flanks of the deposit, ore "flysch" is developed and underlain by shales bearing veinlet-impregnated mineralization. Characteristic features of the enclosing shales near the deposit are pyritic concretions and, at some distance, sideritic. In the eastern part of the deposit coarse-grained spotted pyrite-sphalerite-galena ores derived from the recrystallization of the primary ores are developed. The impregnation ores in the hanging wall are dissected by vein-shaped Cu-pyrrhotite mineralization. At some distance from the submarine depressions with stagnant water where hydrothermal fluids discharged, local volcanic centers of basalt-andesite-dacite eruption were situated. It may be assumed that in case of the Filizçay deposit, the substratum of ore-bearing formation could have been rigid sialic blocks whereas the Cu-pyrrhotite ores Kızıldere-type were originated in the axial zones of riftogenic structures characterized by tholeiitic basalt volcanism.

One of the examples of divergent deposits is Aşıköy located within the allochthonous Küre complex of the Pontides (Fig. 2). Some researchers (i.e. Ustaömer and Robertson, 1993) attribute the Küre complex composed of Triassic-Lower Jurassic volcano-sedimentary sequences to south-vergent accretionary structure squeezed from the marginal basin of Paleotethys. According to the above mentioned authors, the Küre complex demonstrates the standard succession of rock units characteristic of the axial parts of rifts: serpentinous peridotites, cumulate and isotrope gabbro, diabase dyke complex, greenstone-altered tholeiitic pillow basalts. The latter are overlain by shales the contact zone of which contains Cu-bearing pyrite deposits similar to those in Cyprus (Güner, 1980). In the Aşıköy quarry (Fig. 3), the following complicated pattern of rock relationship can be observed: serpentinized peridotites are overthrust the basalt-clay-shale complex; the complex itself is overturned to the south with pillow lava overthrusting the shales; the latter contain a body of fine-grained pyritic ores. The basaltic flows are marked by the presence of tectonites within which fragments of rocks, and the pyritic ores are cemented by coarse-grained chalcopyrite-pyrrhotite matrix.

Volcanic rocks developed within island arc systems are characterized by the presence of both hydrothermal-sedimentary and epigenetic ores. In the East Pontic metallotect, the ore deposits are related mainly to Santonian dacites and their pyroclasts.

In the Madenköy deposit, massive-bedded brecciated pyrite-sphalerite-chalcopyrite ores form a large body overlain by silicified and ferruginated tuffites. The underlying dacites show veinlet-impregnated mineralization. The overlying sequence is composed of interbedding tuffs, tuffites and basalt flows.

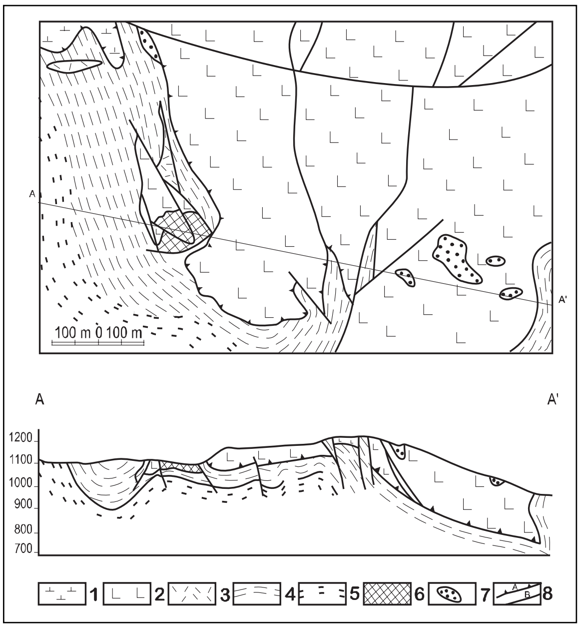

Fig. 2- Geological map of the Aşıköy deposit. 1- ultra basics (allochthonous); 2- greenschis basaltes; 3- dacites; 4- sholes with rare sandstones; 5- alternation of sandstones and shales; 6- massive pyrite chalkopyrite ores; 7- iron hat; 8- faults: a- thrusts, b- subvertical.

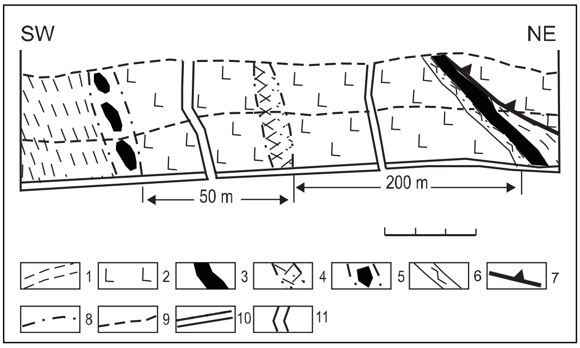

Fig. 3- Sketch-map of western part of the Aşıköy quarry.

The deposit is quite significant by its dimentions: about 900 m along the strike, 600 m along the dip, and up to 100 m thick. The upper horizons of the deposit, which reveals a certain similarity to Kuroko, contain polymetallic brecciated ores composing of pyrite, chalcopyrite, sphalerite, and small amounts of galena, bornite and sulphosalts. The vein varieties are represented by barite, dolomite, quartz, sericite and kaolinite. The clastic ores are underlain by massive black sphalerite, with admixture of chalcopyrite and yellow pyrite-chalcopyrite ores; besides, some types of brecciated ores are also present.

The best examples of stockwork deposits in the East Pontic metallotect are Lahanos and Murgul. In Lahanos, the stockwork of sphaleritepyrite-chalcopyrite composition is within the dacitic stock. Veinlet-impregnated mineralization is concentrated within the quartz-sericite-chlorite metasomatite areal. According to Özgür (1993), the deposits of Lahanos and Madenköy are of Kuroko-type deposits.

The resembling geological position is occupied by the Murgul deposit (Fig. 4). The stockwork of pyrite-chalcopyrite ores is limited at the top by quartz-ferruginous (jasper-like) sediments with gypsum lenses. Ore-bearing dacitic lavas are eroded and unconformably overlapped by Campanian-Maastrichtian volcanites. The Murgul deposit might be interpreted as a transitional type tending to porphyry Cu deposits (Özgür, 1993).

The deposits of pre-collisional stage in the Lesser Caucasus are represented by epigenetic ore bodies (Fig. 5) formed in Late Bajocian-Bathonian (Alaverdi, Kafan) and in Late Jurassic (Shamlug).

In the Alaverdi ore knot, the ores are concentrated in the andesite-dacite Bajocian unit overlain by volcano-sedimentary rocks of Callovian age. In Alaverdi, the Cu ores (lenses, stockworks and veins) are concentrated beneath the cover of Late Bajocian sedimentary rocks; in Shamlug, Callovian rhyodacites serve as screen for ore bodies; in Akhtala, barite-polymetallic mineralization does not overstep the limits of the rhyodacitic stockwork. In Kafan, the distribution of the

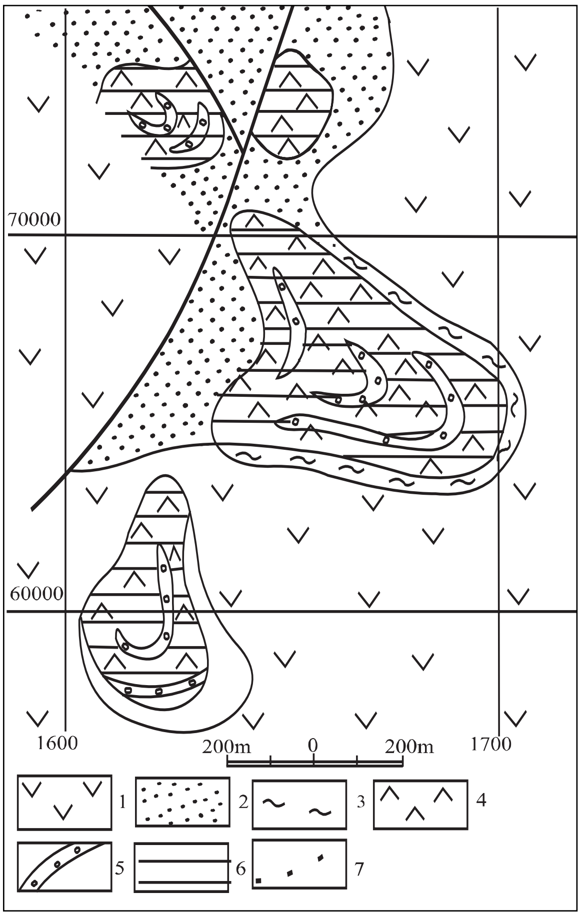

Fig. 4- Geological sketch-map of the Murgul deposit. Late Senonian (Campanian-Maastrichtian) rocks: 1- Andesites and dacites; 2- argillites, sandstones, tuffites (overlie mineralization); Early Senonian (Santonian) ore-bearing rocks: 3- siliceous-iron sediments; 4- dacite lavas and their pyroclastolites (within the mineralized, blocks) - breccias and quartz-sericit-chlorite metasomatites; 5- gypsum lenses; 6- shtock work pyrite-chalcopyrite sphalerite ores; 7- faults.

stockwork and Cu ore veins is controlled by a subvolcanic dacitic volcanism. Here, ore-bearing rocks are overlain by tuff-sandstones with lenses of gypsum and pyritic impregnation. The flows of unaltered andesitic lavas rest on the top of ore-bearing rocks. In all the deposits, the mineralization is accompanied by quartz-sericite metasomatites locally revealed against the background of areal propilites.

In the Bolnisi district of Georgia, the volcano-tectonic depression is filled with andesite-dacite lava-pyroclastic material and shallow-marine terrigenous sediments of Turonian-Early Santonian age and Late Santonian rhyodacitic lavas and ignimbrites. The lower volcano-sedimentary sequence is composed of K-Na granodiorite porphyry and quartz diorite.

Within the exploited Madneuli deposit (Fig. 6) localized on the slope of a large volcanic edifice under the screen of rhyodacitic extrusions and ignimbrites, there have been identified spatially disconnected Cu, barite-polymetallic, barite and Au (in secondary quartzites) ores. Ore-bearing clastic tuffites have been subjected to very intensive explosive brecciation and transformation. The upper levels of the secondary quartzites contain barite and barite-polymetallic gently sloping ore bodies and veins; the lower horizons composed mainly of quartz-sericite-chlorite metasomatites enclose pyrite-chalcopyrite stockworks and veins.

The boundary between the quartzite-breccias and quartz-sericite metasomatites coincides with a tectonic zone, locally with traces of ferrugination and gypsum mineralization. The same level reveals lens-shaped pyrite concentrations with small amount of chalcopyrite and sphalerite. At the depth, the Cu stockwork is replaced, along narrow zones, by poor chalcopyrite-pyrite-Mo impregnation accompanying by anhydrites. The latter are observed in quartz diorites, at a depth of 900 m from the surface. The secondary quartzites are dissected by blueish chalcedony-like quartz with Au.

The authors of this paper dispose data on isotopic composition of strontium and concentrations of rubidium and strontium in rocks located near volcanogenic and possibly having paragenetic bonding with latter (see table I, sample MR is produced by R. Migineishvili).

It is considered, that isotopic correlations of elements with high mass number remain invariable in magmatic processes of evolution and correspond to isotopic composition of primary source of rocks (Balashov, 1985; Abramovitch et al., 1989). From the table 1, it is seen, that basalts, monzonites, gabbro-monzonites and dacites represent "differentiation" products of depleted mantle. In basic rocks melted from depleted mantle, rations between strontium isotopes is equal to 0.7045, while the magma source of lamprophyres and rhyolites could arise in the earth's crust.

Recently published paper (Gugushvili et al., 2002) contain data on rare-earth elements and other rare-elements concentrations in volcanic rocks of Bolnisi district of Georgia. On upper-crustal source of rhyolite and ignimbrite magmas of Madneuli deposit testify determined rations of Eu (for rhyolites - Eu/Eu*= 0.65-0.68, for ignimbrites - Eu/Eu*=0.52-0.58) and indicates characteristic enrichment by light rare-earth elements and large-ion lithophilic elements (K, Rb, Ba, Sr). In dacites and andesite-basalts enrichment by light rare-earth elements were manifested as well. Eu/Eu* ratios turned out to be 0.72-0.77 and 0.72-0.81. Characteristic feature of basalts is enrichment by Eu (Eu/Eu* = 1.01-1.07). Gugushvili et al. (2002) infer on various levels of formation of magma for rocks of volcanic structure in Bolnisi district for uppercrustal rhyolites and ignimbrites, lowercrust for dacites and andesite-basalts and mantle for subalkaline basalts.

According to geological observations-"antidromous" character of volcanisms at the collision stage, at the beginning crustal sources of magma are activated and later on the mantle ones as well. Despite the different ways of ore-formation (hydrothermal-sedimentary and epigenetic), volcanogenic deposits are characterized by a number of common features. Their hydrosystems are functioning in volcano-depressions whose basements are complicated by intrusions. The roots of the latter in the present-day active zones of oceans (Greenberg et al., 1990) are located at a depth of 1-2 km beneath the sea floor; in epigenetic deposits (e.g. in the Bolnisi district) they are at a depth of 1-1,5 km beneath the paleo-surface (according to borehole data). The componental composition of deposits is essen-

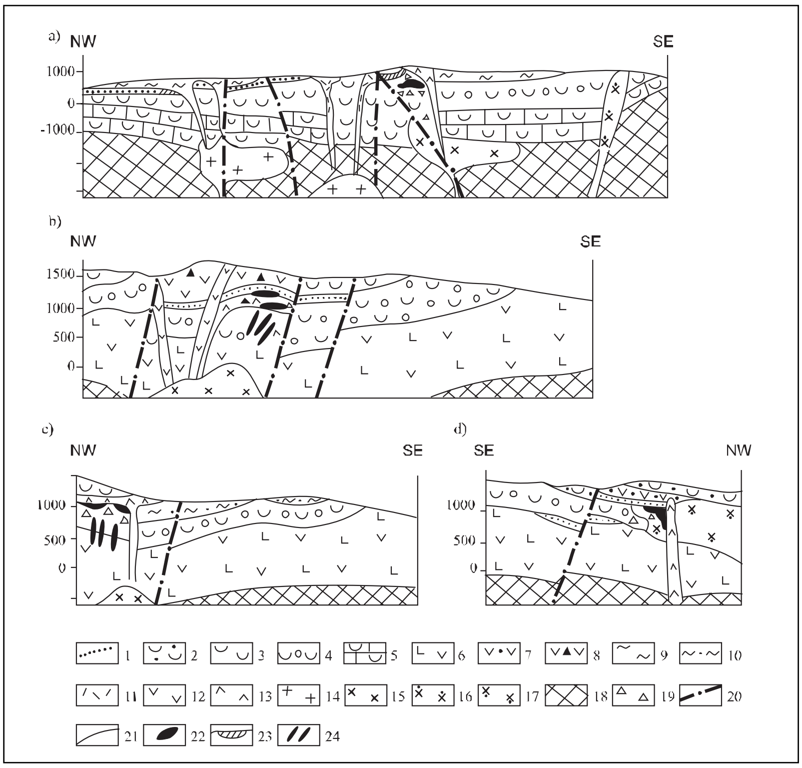

Fig. 5- Fragments of ore-bearing volcanic structures of the Lesser Caucasian island paleoarc. Fragments of: a- Late Cretaceous backarc residual depression (deposits: complex barite, barite and polymetallic and Cu- Madneuli and David Garedji); b, c, d- the Baiosian-Late Jurassic intraarc depression (b- Bathonian Cu Alaverdi deposit, c- Late Jurassic Cu Shaming deposit, d- the Middle Jurassic Cu Kaphan deposit). 1- carbonate-terrigenous sediments (thin horizons); 2- terrigenous-volcanogene rocks (Late Jurassic volcanogene flysh); 3- psammo-psefitic tyffites, andesite-dacite horizons [Late Cretaceous (a) and Middle Jurassic (b, c, d)]; 5- tuffites, limestones, sandstones, andesite, andesite-dacite, andesite-basalt lavas (Lower Cretaceous complex of the Bolnisi depression); 6- lavas and lava breccias of andesite-basalts and basalts, tuffites (the Early Bajocian); 7- andesite lavas (Middle Jurassic); 8- lavas and lava breccias of andesites, andesite-basalts (Middle Jurassic-Bathonian); 9- ignimbrites (Late Cretaceous); 10-hyaloclastics (Middle Jurassic); 11- K-Na rhyolites (Late Cretaceous); 12- andesite-dacites (Middle Jurassic); 13- dacites and rhyodacites (a- Late Cretaceous, c- Late Jurassic, b,d- Middle Jurassic); 14- K-Na grano-diorites and granites (Late Cretaceous); 15- Na granodiorites (Late Cretaceous, Late Jurassic and Middle Jurassic); 16- quartz diorites (Late Cretaceous); 17- quartz diorite porphyries (Middle Jurassic); 18- Pre-Mezozoic basement; 19- explosive breccias; 20- faults; 21- conditional margins of geological bodies; 22- stock-like Cu orebodies; 23- barite lodes; 24- Cu vein bodies.

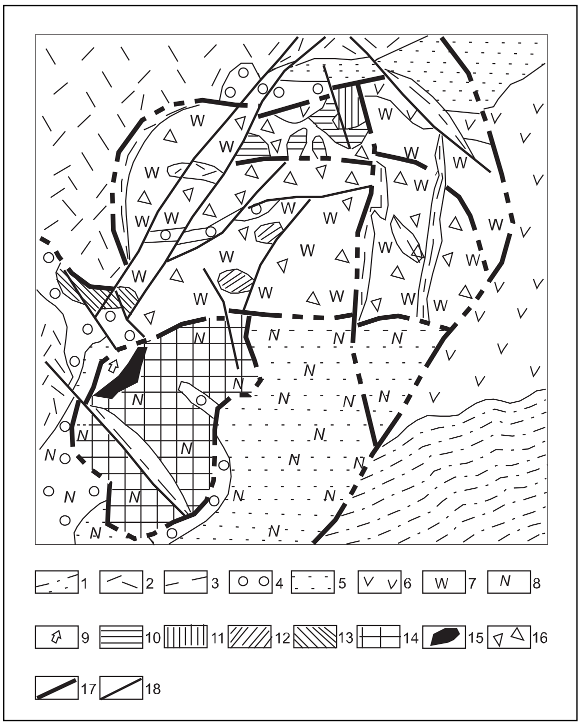

Fig. 6- Geological and structural map of the Madneuli open pit mine. 1- extrusive rhyodacites; 2- rhyolite lavas; 3- subvolcanic rhyolite bodies; 4- vortoclastic tuffs; 5- psammo-psephite and alevrolitic tuffs; 6- aglomerate and psammo-psephitic xenotuffs; 7- secondary quartites; 8- quartz-sericite-chlorite metasomatics; 9- gypsum and anhydrite accumulations; ores: 10- barite; 11- massive barite-Pb-Zn; 12- veinlet polymetallic; 13- veinlet Cu-Zn; 14- veinlet and impregnation Cu; 15- base metal massive sulphide; 16- explosive breccia; 17-gentle faults; 18- subvertical faults.

tially influenced by geological environment. In the present-day rift zones and in older structures, Cu-pyrite-Zn deposits overlie directly the Cyprus-type basalts. At the same time, in the presence of thick sedimentary layer with evaporites, as in the Gorda ridge (Koski et al., 1985), the ores turn into polymetallic. The generally-accepted genetic model (Franklin et al., 1984; Krivtsov, 1989) implying extraction of metals by overheated sea waters encounters some difficulties in explaining the mechanism of accumulation of huge masses of polymetallic ores (Filizçay) or barite (Madneuli). The authors are rather inclined to share the idea that the source of barite-polymetallic deposits may be the high-mineralized chloride brines buried in evaporitic fillings of volcanic depressions. In the Caucasus, as in the other parts of the Mediterranean belt, geodynamic (shallowing Paleothetys at the end of the Hercynian cycle) and climatic conditions of the Triassic time do not exclude the possibility of formation, within vast shelf areas, of residual terrigenous salt-bearing gray-coloured rock units with buried brines, such as now observed throughout the globe (Lebedev, 1975; Weisberg et al., 1982; Goleva, 1993; Kislijakov and Shchetochkin, 2000).

Cu-bearing hydrothermal-sedimentary deposits are dominated by massive pyritic concentrations enriched in Cu and Zn. The deposits, in most cases, are overlain by microquartzites or siliceous-hematite jaspers. At this level and sometimes on the flanks between stockworks and bedded ore bodies of Kuroko type (Matsukama and Khorikosi, 1973) gypsum concentrations are also observed. The epigenetic deposits (Madneuli, Kafan, Murgul) are not the exceptions to the rule. Here also, above the stockwork ores there are zones of jasper-like quartzites and not very large lenses of gypsum and pyrite.

Microrhythms in the Filizçay polymetallic deposit reveal a certain similarity to the mineral zonality observed in the epigenetic deposits (Madneuli). Barite-polymetallic coarse-grained massive aggregates in Madneuli are downward replaced by veinlet mineralization; in the lower horizons, the replacement of the galena-sphalerite association by the sphalerite-pyrite (with Cu) one takes place. Very impressive is also the resemblance of the barite-polymetallic part of the Madneuli deposit with the Kuroko-type deposits (Matsukama and Khorikosi, 1973).

The PT conditions of ore accumulation were similar within the epigenetic and hydrothermal-sedimentary deposits. In epigenetic, as well as in some hydrothermal-sedimentary deposits, the process of boiling - the solution with precipitation of ore material in the form of gel - was followed by a period of slow emission of the solution and

Table 1- Isotopic analysis of stroncium and definition of rubidium and strontium concentration by the method of isotopic dilution was carried out by the Institute of Pre-Cambrian Geology and Geochemistry of Russian Academy of Sciences.

Number of samples	Location	Rocks	Rb ppm	Sr ppm	$^{87}Rb / ^{86}Sr$	$^{87}Sr / ^{86}Sr$	+/- 26
8	Bolnisi District Georgia	Basalt	9,82	538	0,0506	0,704910	23
19	Merisi Ore region Ajara, Georgia	Monzonite	96,9	507	0,5523	0,704606	18
20	Same location	Gabbro-monzonite	63,1	700	0,2608	0,704766	17
21	Same location	Lamprophyre	76,9	542	0,4106	0,705361	15
22	Bolnisi District Georgia	Dasite	19,8	399	0,1436	0,704563	18
32	Same location	Rhyolite	19,3	28,7	1,943	0,710269	16
MR	Murgul Deposit, Turkey	Rhyodasite	64,5	94,7	1,971	0,707739	19

crystallization of mineral masses. As a rule, the level of boiling at the temperature of more than 270°C in regions of recent volcanic activity is located at the depth of 300-400 m from the present-day surface (Sinyakov, 1986). As for the "quiet" period of ore-accumulation in the epigenetic deposits, its PT conditions (Kekelia et al., 1993) were corresponding to the pressure of about 20 MPa and the following temperatures: 370°-260°C for Cu ores, and 280°-180°C for barite-polymetallic ones. The baritic deposits were formed under low temperature (~ 100°C) and pressure (~ 5MPa). In Filizçay, the pyrite ores were ennobled by mineralization of the second polymetallic phase, within temperature range between 250-100°C; the following superimposed Cu-pyrrhotite association was formed under 370-400°C (Bogdanova et.al., 1983). It is also noteworthy that the most favourable PT-conditions for the stable accumulation of hydrothermal-sedimentary deposits were created at the bottom of sea basins with a depth of about 2 km (Stackelberg, 1985).

"Ore" hills can rise at the even greater depths, up to 3000 m (Gablina et al., 2000). The shallower portions of the sea-floor also are not restricted for ore-accumulation, especially for barite and barite-polymetallic ores, but they are not favourable for the stable course of the process owing to the upwelling and rough conditions of shelf zones. Within the pre-collisional depressions (irrespective of the way of ore-accumulation) the hydrothermal activity had mainly single-phase character while in the collisional volcanostructures this process was multiphase due to the discontinuous and antidrome manifestation of volcanism.

It has been already mentioned the resemblance between the Madneuli and some Miocene Japanese deposits (the presence of isolated barite bodies and barite-polymetallic mineralization, including gypsum in the lower horizons). The main difference, however, is that in Madneuli the process of ore-accumulation was realized within the closed volcanostructure whose final formation took place in submarine situation. The earlier model (Kekelia et al., 1991) assumed the participation of buried bedded sea waters in ore-accumulation some of them might have primarily been ore-bearing (brines); the others, occuping higher horizons at a considerable distance from the volcanostructure, were involved in the process of ore-formation in the later stage and metamorphosed, and acquired the ability for extraction of ore components.

During the first stage, squeezing rhyolitic extrusions along the ring structures on the slope of the volcano resulted in the formation of a closed dome-shaped ore-bearing structure; then, heated and saturated with volatile magmatic components, bedded waters were "sucked in" and subjected to collapse at a depth of 400-500 m from the surface. As a result, explosive breccias were formed, mainly at the expense of tuffites and effusive rocks, beneath the impermeable screen. Under the action of hydrothermal activity, they underwent pre-ore transformations with segregation of two paleohydrochemical zones: the upper one - sulphate-ammonium (the level of secondary quartzites), and the lower one-chlorite-sodium (quartz-sericite-chlorite metasomatites); the boundary between the zones is traced by jasper-like quartzites and gypsum concentrations. The creation of pre-ore situation was facilitated by:

1- Boiling of the solution and its alkalization due to separation of acidic components and precipitation of sulphides, native metals (Au), quartz, carbonate, adular;

2- Oxidation of H_2S, HCl, CO_2, NH_4 in the higher levels;

3- Exchanging reactions with the surroundings possessing buffered properties.

Barite and barite-polymetallic ore-formation (ores superimposed on disintegrated secondary quartzites) proceeded against the background of the earlier paleohydrochemical situation with synchronous accumulation of sulphates and sulphides in the boundary zone. Beneath the latter, in traps saturated with hydrogene sulphide, pyrite ore bodies of limited dimentions have been concentrated.

The later Cu veinlet-impregnated ores are considered to be the products of an independent ore-formation stage. They were formed under new tectonic dislocations imposed on the volcanostructure and injection of a quartzdiorite intrusion.

For both epigenetic Cu and hydrothermal-sedimentary Cu-Zn pyrite deposits, the most logical is the convective model. The model assumes that metals were transported in the form of hydrosulphide complexes and precipitated, according to the generally accepted opinion, as a result of falling in temperature and oxidation of the solution.

The formation of volcanogenic-sedimentary polymetallic (with barite) ores proceeded in a different way. The solutions involving in the hydrothermal system are practically devoid of H_2S-containing components (Lebedev, 1975; Weissberg et al., 1982; Kraynov et al., 1988). Lebedev (1975) carried out an experiment mixing metal-containing brines with H_2S-containing waters obtained from various levels of above-hole drilled in the Cheleken peninsula (Turkmenistan). As a result of the mixing, the precipitation of sulphides of Pb and Zn took place. It is noteworthy that the Cheleken brines are very similar in temperature and salinity to the brines of the Red Sea (Degens and Ross, 1974).

The above material allows to speak of the specific conditions of the discharge zones, namely brine outflow was preceded by accumulation of H_2S- containing oozes in the sea depressions. The enrichment of the oozes with hydrogen sulphide can be realized:

1- As a result of biogenic reduction of sulphate in sea water;

2- At the expense of hydrogen sulphide derived from deeper katagenic zones where it is generated by abiogenic ways;

3- As a result of degassing shallow-occurring magmatic source. Taking into consideration data on isotopic ratio of sulphur in sulphides (Bogdanova et al., 1983) we give preference to the third way. Precipetation of ore material in mass volumes is, most likely, a result of mixing H_2S-containing waters with outflowing brines.

DISCUSSION

Most researchers hold the opinion that the hydrosystems of volcanogenic deposits developed according to the convective model implying involvement of exogenic waters in the hydrothermal process (Franklin et al., 1984; Ovchinnikov, 1988; Krivtsov, 1989). However, the problem of "specialization" of geological space still remains controversial. Recent investigations show the presence of oxidized ores with high metal contents in oceanic basalts (Procoptsev and Procoptsev, 1990) and ore liquates in feldspar and clinopyroxene in alkaline basalts (Akimtsev et al., 1993). It has been noted (Rekharski et al., 1983; Barnam, 1983) that Cu possessing comparable energy of breaking chemical bondings with protoxide iron, magnesium and calcium, can be a part of Mg-Fe silicates and, in case of sufficient amount of sulphur, can also be separated in the form of sulphides. Sharapov et al. (1999) indicate that the salinization of porous space in intrusive rocks takes place within the temperature range of 950-650°. Drop-shaped aggregates in intrusive rocks are represented by solid solutions of FeS-NiS-CuS, troilite, pyrrhotite, pentlandite, cubanite, chalcopyrite, sphalerite. Judged by these data and backing the convective model of development of hydrosystems of Cu-Zn-pyrite deposits we can assume that the concentration of ore-forming elements was facilitated by the following successive natural processes: crystallization and liquative differentiation of basic magmas followed by the interaction between the overheated surface waters and "specialized" magmatites.

In case of barite and barite-polymetallic deposits, taking into account their connections with the geological space, it can not be excluded the participation of high-mineralized (> 350 g/l) evaporitic waters in the ore genesis. These brines are distinguished by high content of Ba, Ca, Zn, Pb, Cu and Mn (Weissberg et al., 1982; Kholodov and Kiknadze, 1989; Goleva, 1993).

Hydrothermal solutions forming hydrothermal-sedimentary deposits (Butuzova, 1989), are considered to be metamorphosed marine waters. By their salinity they are close to common marine water but differ from the latter by lower content of Mg and SO_4^{-2}, high content of K, Ca, Si, and enrichment by several orders in Fe, Ag, Pb, Cu and Zn. The scope of hydrosystems convectioning around intrusions (energy source) may be defined by the so-called prophylite areal - the area of their influence on the country rocks. Data on the isotopic composition of hydrogen in fluid inclusions and oxygen in quartz, barite and calcite in epigenetic barite-polymetallic ores (Bolnisi district of Georgia) have been interpreted in favour of a considerable role of meteoric waters in ore formation process, whereas the data on Cu stock-works indicate that meteoric water in hydrosystems was of less importance than magmatogenic one (Kekelia et al., 1991).

Some authors (i.e. Hannigton et al., 1986; Elijanova, 1999) explain the zonality in unmetamorphosed hydrothermal-sedimentary ores by redistribution of ore-forming components, from lower levels to upper ones, by solutions diffusing through ore concentrations. As an example it may be adduced the Explorer Ridge in the Pacific where high-temperature sulphides of Cu and iron underlie a layer of more low-temperature iron-Zn sulphides, barite and silica. Grychuk (1999) has proposed a thermodynamic model of convective hydrosystem very close to natural system comparable with the Cyprus type in which the evolution of the hydrothermal solutions and mineral replacements within an ore-body is assumed. "Embryonic" anhydrite-pyrite concentrations in due course are replaced by a silica-sulphide matrix; sphalerite precipitates in the peripheral zones whereas, in the central parts, pyrite is replaced by magnetite and appearance of Cu sulphides takes place.

Anhydrite precipitation in the subsurface zones of "ore hills" can also be explained by supplanting near-bottom waters into discharge zones by high-temperature fluids (>300°C). Near-bottom sea waters are heated to 160°C resulting in the anhydrite precipitation (Cherkashev et al., 1999). The processes occurring in the "ore hills" may have their paleoanalgues, most likely, in the deposits of Kuroko type.

In depressions filled with oozes containing hydrogen sulphide, the mechanism of ore formation seems to be somewhat different. Judged by the regular rhythms identified within ore deposits, the precipitation of ore material was realized intermittently over vast oxidative-reductive and geochemical barriers. The example of such a situation is the Filizçay deposit, while its recent analogue may be the Red Sea whose axial zone is filled with evaporites and pyroclastolites (Degens and Ross, 1974).

In the Kuroko type epigenetic and hydrothermal-sedimentary deposits, the initial stage was characterized by entering Ba^- and Ca^- containing brines into the solfataric zones as a result of which there were formed spatially separated barite and anhydrite deposits. The latter, in due course, turned into gypsum deposits. The disconnection of calcium and barium sulphides (the latter occupy higher levels of low-temperature zones) can be explained by the different temperature regimes of their precipitation from solutions and also by the retrograde solubility of anhydrite (Holland et al., 1982); Ovchinnikov, 1988). Simultaneous precipitation of sulphides and sulphates noted in latter barite-polymetallic ore bodies, becomes possible (Franklin et al., 1984) under minimum values of PO_2 coinciding with the lower boundary of barite stability field and equal activities of H_2S-SO^{-2}_4. The zonality in distribution of sulphides of Cu, Pb and Zn in polymetallic ore bodies was conditioned, most probably, by the activity of S^{-2} in the discharge zones. It is supposed (Kraynov et al., 1988) that the efficiency of the hydrogen sulphide barrier is conditioned by small concentrations of S^{-2}. It is also possible that $\sum S$ in discharge zones was sufficient for Cu to precipitate, whereas Pb and Zn showed tendency to pass the barrier with changing the chlorite ligande by sulphide. In this case, anion-precipitant plays a role of solvent-complex generator.

As for Au-bearing quartzites, they are characteristic of polyformational deposits (Madneuli). The generation of Au-bearing quartz veinlets coincides, in our opinion, with the time of formation of explosive breccias and appearance of the above-mentioned hydrochemical zonality within the volcanostructure. Precipitation of Au, quartz and small amounts of sulphides can be regarded as an one-act process related to the destabilization of the fluid of magmatogenic nature under the conditions of high oxydative potential accessible at the level of secondary quartzite generation.

CONCLUSIONS

The above-stated material allows to make an inference that volcanism and ore formation are interrelated processes accompanying the convergence and divergence of lithospheric plates. During the divergent stage, there occurred a rise of mantle material (tholeiitic basalts and, in lesser degree, plagiogranites) to the surface along the rift zones. At some distances from the rifts where the influence of continental blocks was essential enough, volcanites have different - crustal and mantle - sources (basalt- andesite-dacite- rhyolite accumulations). Within the rift zones there were originated Cu-bearing (with small amount of Zn) ore forming systems, whereas, in the regions with well-developed continental crust, polymetallic ores concentrated in the ooze sediments of deep marine depressions.

The subduction stage is characterized by wide-spread andesitic island arc volcanism: first, within the ensimatic fore- and intra-arc volcanostructures mainly Cu-bearing systems functioning; later, they are supplemented by Cu-Zn-bearing systems (sometimes with Pb as well). The examples of the first are the Lesser Caucasian epigenetic deposits; the second - volcanogenic-sedimentary and epigenetic deposits of the East Pontic metallotect.

During the transitional (from divergent to collisional) stage, the rapid change of submarine volcanism by subaerial took place; there were formed the antidrome and intermittent series of volcanites accompanied by also intermittently functioning diversified systems. At this time, both mono and polyformational deposits appeared; the example of the latter is Madneuli.

Metal solvents in fluid systems of Cu-Zn volcanogenic deposits were mainly sea waters metamorphosed under the influence of intrusions thermal field and enriched in magmatic exhalations, whereas the metal solvents of baritic and polymetallic deposits were potash-chloride solutions of evaporitic sequences.

The following conditions are obligatory for the origin of ore formation systems: 1- the presence of "specialized" geological ore-bearing environments (basic and medium-acidic volcanites, saliferous sedimentary sequences); 2- source of sulphur (biogenic and endogenic); 3- stable energy supply (intrusions); 4- prolonged and stable functioning of physical and geochemical barriers; 5- sufficent amount of solvents. All these conditions, as has been shown, are realized at the early stages in rift troughs, and later - in marine basins within deep structures which originally might have had a transform character.

Finally, it should be noted that the collision of microcontinents accompanied by their distinction and heterogenization, as well as the shallowing of sea basins, are not favourable to a large-scale volcanogenic ore formation. At that time, one can observe the increasing role of plutonogenic (Cu-Mo-porphyry and Au-bearing), skarn rare-metal, and magmatogenic Pb-Zn, Hg and As deposits.

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AURIFEROUS MINERALIZATIONS IN THE MURGUL - ARTVİN - MARADIT AREA (NORTHEASTERN TURKEY)

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ABSTRACT.- The auriferous mineralizations, as the subject of this paper, are placed in the Murgul, Artvin and Maradit surroundings, in the extreme northeastern part of the Turkey. The area is between Black Sea coast to the northwest and Çoruh river to the east, northerly bordered by the Georgian - Turkish border and by the Artvin - Fındıklı line to the south, including spring of the Murguldere. The field is made up of volcanic, volcanic-sedimentary, sedimentary and granitoid formations, from Jurassic to Quaternary time. In that period numerous composite petrogenetic complexes had been formed. The oldest is volcanic and volcanic-sedimentary complex including volcanic rocks of andesitic or intermediate-acidic character, Jurassic in age. They are accompanied by the Iskalka köprüsü and Budiyet köprüsü copper mineralizations. Gold in this complex has not been studied yet. This rock assemblage is overlain by the acidic rhyolitic and rhyodacitic volcanic and volcanic-sedimentary complex, associated with large copper deposits and a large number of still not explored or partly investigated copper occurrences, formed during the Upper Jurassic - Lower Cretaceous. The gold-bearing, related to this complex, is not distinctly developed. According to the present knowledge, precious metals as trace elements are registered in copper deposits in the Murgul surroundings (Anayatak, Çakmakkaya, Aduca dere, Kilise tepe etc), then in the Artvin vicinity (Kuvarshan, Irsa Maden, Sinkot, Seyitler and Umasen). The similar gold and silver appearances are to be expected in the other copper mineralizations, particularly in the Hopa circles (Peronot, Sivrikaya, Kutunit and others). These copper occurrences and deposits are characterized by relatively low gold grades (mostly less than 0.5 ppm) and variable silver contents, with locally high grades (from traces to 180 ppm). However, if large copper reserves are taken into consideration, amounting more than 100 million tons, low grades became significant; at least 50 tons of gold and several hundred tons of silver is expected to be found. The next petrogenic complex was formed during the Upper Cretaceous - Paleogene time. This is a composite petrogenic unit, enclosing volcanic, volcanic-sedimentary and sedimentary formations. They represent a complete development, beginning from basalts and spilites, throughout andesites, to dacites and rhyolites. The most important rocks in this complex, bearing precious metals, associated with copper, zinc and lead mineralizations, are andesites, partly sediments, composed of re-deposited products of andesitic volcanism. In this petrogenic rock assemblage in the related metallogenic stage, two types of gold-bearing mineralizations are distinguished. These are the Akarşen, Hohur sırtı and Madenköy base metal deposit near Çayeli, with gold grading up to 11,43 ppm (in Madenköy) and silver contents ranging from several tens grams per ton of ore up to 241 ppm, including even 350 ppm in Akarşen galena. In the same complex, including the potentially ore-bearing sediments, such as tuffaceous sandstones, contents of 0,11 ppm gold and 2,25 ppm silver have been found. To the next precious metals type belong mineralizations nearby Pehlivan köy near Maradit. They occur in the highly hydrothermally altered andesites, with pyrite and copper minerals. As a special alteration type, adularization is remarkable, indicating the epithermal copper origin and accompanying the gold mineralizations. In only one sample 0,72 ppm gold and 50 ppm silver were detected. These features indicate it as a special mineralization type. The third of auriferous mineralizations is found in the Melo dere ravine (Gorge) near Artvin. This is the quartzdiorite, Eocene in age, locally bearing high chalcopyrite concentrations, with low gold grades (up to 0,03 ppm), but with higher silver (7,2 ppm). As it is visible from the presented facts, the Murgul - Artvin - Maradit area is considered as very interesting for the gold-bearing copper, zinc and lead mineralizations.

Key words: Gold, silver, volcanism, Murgul, Kuvarshan, Artvin, Maradit, Turkey

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INTRODUCTION

The terrain with auriferous mineralizations that is the subject of this paper encompasses the metallogenic region between Hopa, Murgul, Artvin and Maradit (Artvin region, Fig. 1). Regardless of the fact that this region has been the object of interest and previous exploration, in the last 100 years or more, very little attention was given to gold and sliver. However, during exploration for copper sulphides, zinc, lead and iron the gold content was occasionally determined. But, except data published by Kraeff (1963) on the gold and silver content in the polymetallic deposit Akarşen; data in the MTA inventory from 1966 for the deposit Kuvarshan, data on the gold content in Sinkot near Artvin (Kovenko, in Novović, 1979); Erseçen (1989) and Özgür (1992) for the deposits Anayatak and Çakmakkaya, there were no serious attempts to investigate the concentrations, distribution and other characteristics of the noble metals in the mentioned region.

During exploration in the region of Murgul-Artvin-Maradit a large number of samples from numerous Cu, Zn and Pb mineralizations were collected from this region as well as samples from the sulphide deposit Madenköy near Çayeli. At the same time samples from the flotation concentrate were also taken. The collected material was analyzed and interesting results were obtained that served as a basis for this paper. Besides this, on the basis of field notes and limited literature data, knowledge was gained concerning the potential of some auriferous copper occurrences. Based on all the available data it was considered that it would be very useful to publish this data especially because, besides the published data by Özgür (1992) and sporadic information on the content of gold in some ore deposits, no published data exists.

BASIC GEOLOGICAL CHARACTERISTICS OF THE AURIFEROUS REGION MURGUL - ARTVİN - MARADIT

The most important geological characteristic of this region is volcanism. It represents those

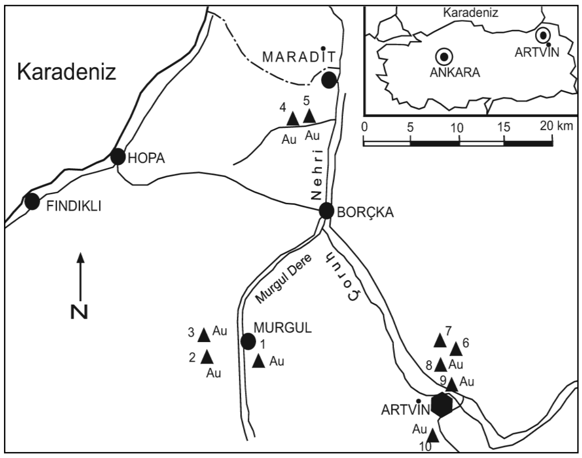

Fig. 1- Location map of gold- and silver-bearing sulphide occurrences in NE Turkey. 1. Anayatak and Çakmakkaya, 2. Akarşen, 3. Hohur sırtı, 4. Pehlivan köy, 5. Çavuşlu, 6. Kuvarshan, 7. Irsa Maden, 8. Sinkot, 9. Seyitler and Umasen mahallesi, 10. Melo

activities which in a volcanogenic and volcanogenic-sedimentary environment played a leading role in the formation of sulphide deposits, mainly copper, followed by zinc, lead and molybdenum and with them associations of gold and sliver.

Basically, in this region several periods of volcanic activity can be distinguished. The first occurred during Jurassic time, but it still is not more precisely defined.

In this period intermediate acid volcanogenic and volcanogenic-sedimentary formations were formed mainly composed of andesite volcanic rocks.

This is followed by Upper Jurassic - Lower Cretaceous volcanism that gave volcanogenic and volcanogenic-sedimentary formations mainly of rhyolite composition with which the largest copper deposits in this region are associated. After this period there is a break in volcanic activity, which is reactivated in Upper Cretaceous resulting in the creation of volcanogenic and volcanogenic-sedimentary formations. This volcanism is characterized with complete development, starting with basic rocks followed by intermediately acid to acid rocks. According to data of Pejatović (1979) it is mainly of tholeiitic composition. The intermediately acid part of this volcanism is characterized by the presence of copper, zinc and lead deposits with elevated contents of gold. However, they are of smaller economic interest then the deposits associated with the Upper Jurassic - Lower Cretaceous acid volcanism.

SIGNIFICANT METALLOGENIC CHARACTERISTICS OF VOLCANOGENIC ACTIVITIES WITH SPECIAL EMPHASIS ON NOBLE METALS (GOLD AND SILVER)

As already mentioned, the most significant characteristics of the Murgul region are large copper deposits of Upper Jurassic - Lower Cretaceous age with ore reserves totalling to over 100 million tons and a copper content of approximately 1%, and Upper Cretaceous - Eocene deposits (generally polymetallic) of copper, zinc and lead. Exploration of these deposits are not concluded and according to the existing knowledge the estimated ore reserves are bellow 5 million tons, but potentially much larger and with contents of copper, zinc and lead over 3%. In both cases these are mainly volcanogenic and volcanogenic-sedimentary deposits, of different mode of occurrence, starting with massive via stockwork-impregnation up to vein types and insignificant skarn mineralizations.

On the basis of existing data the most significant occurrences of gold and silver are in the deposits Anayatak, Çakmakkaya, Aduca dere, Hohur sırtı and Akarşen (in the vicinity of Murgul); Kuvarshan, Sinkot, Irsa Maden and others (vicinity of Artvin); and in the vicinity of Maradit (Güresen dere valley). All these localities are known as copper bearing where zinc is the most important accompanying metal and partially lead. However, gold and silver are also associated with these metals. Auriferous occurrences can be classified on the basis of the type of deposit and period of volcanic activity.

The oldest, auriferous mineralizations are associated with copper deposits formed during the activity of acid volcanism of rhyolite and rhyodacite composition during Upper Jurassic - Lower Cretaceous. This is the period when large copper deposits were formed. However, regardless of the fact that tennantite (silver bearing tetrahedrite) is often present in the paragenesis, in this period gold was not deposited in significant quantities, contrary to silver which often shows high concentrations.

After the Upper Jurassic - Lower Cretaceous metallogenic period a new Upper Cretaceous - Tertiary magmatism of tholeiitic composition followed. This volcanic activity is characterized by the presence of polymetallic deposits (copper, zinc and lead) and significant quantities of gold of which the most significant ones are Hohur sırtı and Akarşen (near Murgul), Pehlivan köy and Çavuşlu (near Mardit) and Madenköy (near Çayeli).

As an especially interesting copper occurrence, which has not yet been more precisely classified (it is believed that it is of Tertiary age) is represented with mineralized andesite volcanic rocks in the vicinity of Pehlivan Köy. Besides a high content of copper this occurrence also has elevated concentrations of gold. However, its significance is based on a very characteristic type of alteration that determines it as an epithermal type of deposit. The type of alteration in question is adularization, which was precisely determined. This is an important fact why this type of deposit is separated as a specific type of deposit and thus shall be presented as such.

AURIFEROUS MINERALIZATIONS IN THE VICINITY OF MURGUL

All auriferous mineralizations, in the vicinity of Murgul are grouped into two time periods. The first group is Upper Jurassic - Lower Cretaceous age when large copper deposits were formed. The second group is Upper Cretaceous - Tertiary (Palaeogene) in age when polymetallic deposit with significant concentrations of gold and silver were formed. In general these deposits are of smaller economic interest then the first.

Upper Jurassic - Lower Cretaceous auriferous occurrences

As already mentioned, in this period large masses of rhyolitic volcanic rocks were formed in sub-volcanic and volcanic (mainly submarine) regions. At the same time, in association with these volcanic rocks large copper deposits were formed in the eastern Pontides. In the vicinity of Murgul a large number of copper deposits and occurrences with noble metals (Au and Ag) were formed. However a low content of gold is characteristic for these deposits. At the same time the content of silver varies with occasional high concentrations. Among these deposits the biggest and most important are Anayatak and Çakmakkaya followed by Aduca dere, Kilise tepe, etc.

Anayatak and Çakmakkaya.- Concerning the gold content for these two deposits very heterogeneous data exists. Pejatović (1979) quotes a report prepared by Daniels Grifith's Co - London from 1966 according to which 100 kg of flotation concentrate from Anayatak contains 1.2 g of gold (12 g/t) and 78.5 g (785 g/t) of sliver. Subsequently in a joint paper (Engin, 1986) experts from M T A - Ankara quote the existence of gold occurrences in the vicinity of Artvin and Murgul. However, more detailed data and the gold contents are not cited. Furthermore, Özgür (1992) quotes that the average content of gold is 0.2 g/t and 25 g/t of silver.

Investigations carried out by the author of this paper were more detailed. Samples from Anayatak were analyzed and the obtained results are very interesting. Not taking into consideration the mineral composition and contents of the main elements (Cu, Zn, Pb, Fe, etc.) samples of different types of material were used: chalcopyrite with minor amounts of pyrite (or in other word rich chalcopyrite ore), amethyst, crystalline pyrite (pentagonal dodecahedron and octahedron) rhyolite tuff (hanging wall of the ore) mineralized rhyolite tuffaceous breccia, mineralized rhyolite tuff, flotation concentrate of pyrite and chalcopyrite - pyrite (the last two were sampled 6.10.1970) from the Murgul flotation plant. The results of analyses of these samples are presented in table 1.

Data from table 1 clearly indicates that the gold contents are low and that the situation with silver is somewhat more favorable. In this sense the results of our investigations differ from the data quoted by Daniels Griffit's Co - London (1966, in Pejatović, 1979). In comparison to our results, significant differences are evident, which are difficult to explain. One of the possible explanations is that the flotation technology in 1970 was already out of date and that in the last years of the flotation plant in Murgul the percentage of recovery was considerably lower then in the beginning, not only for gold and silver but also for copper. However, it is a fact that the content of gold in the ore, which is mainly represented with chalcopyrite, and which can be almost set equal to the flotation concentrates low contents (table 1) of gold.

Table 1- Contents of microelements in ore and flotation concentrates from the Anayatak Deposit (ppm)

	Au	Ag	As	Bi	Mo
Chalcopyrite with minor quantities of pyrite	0.45	76-180	340	70	500
Crystalline pyrite	0.03	2	170	-	-
Amethyst mineralized with pyrite and chalcopyrite	0.05	1	250	-	5
Chalcopyrite-pyrite flotation concentrate	0.98	63	1740	320	60
Pyrite flotation concentrate	0.53	61	1140	-	-

According to this data it can be concluded that the copper deposit Anayatak basically has a low content of gold while the situation with silver is much more favorable. In the remaining samples the gold content are not of specific interest.

Kilise tepe.- Kilise tepe is located in the same zone as Anayatak and Çakmakkaya. All three belong to the same volcanogenic phase of formation; they have the same mineral composition and occur in the same lithologic environment. However, investigations of noble metals, with the exemption of two samples, were not carried out. One sample represented pyrite-chalcopyrite impregnations in rhyolite tuffs. The gold content was 0.1 g/t and silver 7 g/t. The second sample represented mineralized quartz diorite (with 506 g/t of lead, copper 810 g/t and zinc 1.27%) where only 0.02 g/t of gold and 3 g/t of silver were found. For the other deposits, that are synchronous with Anayatak and Çakmakkaya, no data for the content of noble metals is available.

Regardless of the fact that no systematic investigations were carried out this situation leads to the conclusion that Jurassic - Neocomian metallogeny of copper is not characterized with elevated contents of gold. As a whole it can be concluded that the gold content in these copper deposits is generally low. Silver is of interest only locally when it is associated with chalcopyrite.

In the case of pyrite, which is illustrated by the crystalline pyrite sample, it is evident that gold is not associated with this mineral. The situation with silver is very similar. It is interesting to mention that higher concentrations of zinc are associated with elevated concentrations of noble metals. However, this correlation is not completely proven.

Considering the minerals that are carriers of gold and silver it can be assumed that chalcopyrite, arsenopyrite, probably sphalerite, and certainly tennantite are the main carriers of noble metals.

Upper Cretaceous - Tertiary (Palaeogene) auriferous sulphide mineralizations

Auriferous mineralizations, associated with this geological time period, located in the northeast part of Turkey cover a large area. In the northeast - southwest direction it spreads for approximately 150 km, in the northwest - southeast some 40 km. In the northeast this zone begins at Maradit and in the southwest ends at Çamur yayla. However, this is not its end towards the southwest; many authors consider that it continues towards Madenköy at Çayeli. All auriferous mineralizations were formed in this time period and are associated with volcanogenic and volcanogenic-sedimentary formations with which polymetallic occurrences and ore deposits are also associated. In relation to the Upper Jurassic - Lower Cretaceous volcanogenic and volcanogenic-sedimentary complexes, sulphide deposits in this Upper Cretaceous - Tertiary complex are characterized with considerably higher concentrations of gold.

Auriferous occurrences in this period are localized in a region that is bordered with the international border of Turkey with Georgia, river Çoruh, Balıklı yayla and Çamur yayla. These are occurrences near Maradit (Çavuşlu and Pehlivan köy), near Murgul (Hohur sırtı and Akarşen) near Artvin (Melo dere Gorge). The polymetallic deposit Madenköy near Çayeli should be included in this group.

Hohur sırtı.- Occurrences of auriferous sulphide mineralizations at Hohur sırtı are located on a ridge that connects Hohur and Akarşen. This occurrence is located some 2.5 km west of the small town Murgul. The auriferous sulphide mineralization is located on the northwest slopes of Hohur sırtı with the highest point of 1075 m.

The geology is represented with marl, marly limestones, basalts, spilites, andesites, partially dacites and dacite-andesite pyroclastic rocks (tuffs, agglomerates, breccias, and tuffaceous sandstones), sandstones and limestones.

The auriferous mineralizations are associated with sulphides of copper, zinc and lead.

Due to the thick overburden of diluvium sediments and presence of active landslides, only one occurrence can be characterized as an "in situ" outcrop. However, the mechanical aureole of dispersion allows the assumption that there are several outcrops on this terrain. On the location of one outcrop an old shaft and slag dump exist. Unfortunately it was not possible do determine by whom and when mining was carried out. It can be assumed that copper was mined. This ore occurrence was opened with extensive trenching with a team of geologist where the author of this paper was a member. Trenching showed that it belongs to an ore zone that could be followed for approximately 200 m and with an approximately north - south strike (Popović, 2002). This zone is intensely hydrothermally altered where kaolinization, silicification, pyritization and carbonization are the most dominant alterations. In the paragenesis the main ore minerals are: pyrite, chalcopyrite, sphalerite and occasionally galenite and tetrahedrite. The last mineral occurs as inclusions in chalcopyrite and sphalerite. Besides this traces amounts of marcasite, bismuth sulfosalts and secondary minerals of copper were determined.

Systematic sampling of the trench showed that the gold content varies from 0.5 to over 5 g/t and silver from 16 to 182 g/t (Table 2; Popović, 2002). Based on the mode of occurrence in the outcrop it can be concluded that this mineralization is of the stockwork-impregnation type with significant concentrations of gold and silver. Outside the mentioned outcrop only partial exploration was carried out rocks from the mechanical dispersion halo. Similar or identical results, concerning the contents of noble and base metals, were obtained. Other exploration works were not carried out.

Besides this occurrence, on the ridge between Hohur and Akarşen, in the horizon with tuffaceous sandstones, sulphide mineralization occurrences with elevated contents of gold and silver were also discovered (Table 3).

Due to the fact that this is a sedimentary rock it is certain that this mineralization (in spite of the low contents of gold) was formed by volcanogenic-sedimentary processes. The content of lead and zinc are higher then those of copper. However, this does not change anything. On the contrary, the contents of noble and base metals clearly indicate that this environment represents a significant setting for the discovery of new deposits in the Murgul metallogenic region.

Akarşen.- Akarşen mountain with its 1769.8 m peak is located some 4 km southwest of the Hohur sırtı. A polymetallic deposit of copper, lead, zinc and noble metals is located in the vicinity of this peak. This deposit is known for over 100 years and it was mined in one period.

The geological formations in this region and in the vicinity of the deposit are almost the same as those at Hohur sırtı. The difference is that at Akarşen several smaller masses of quartz diorite occur that are accompanied by contact-metamorphic alterations.

The ore deposit Akarşen is composed of numerous ore bodies, of which some are associated with volcanic rocks. Their mode of occurrence is in the form of veins or impregnations. It is assumed that they are of volcanogenic origin but some of the ore bodies are of volcano-sedimentary origin. This is evident from the oval ore structures (Vujanović, 1976; Popović and Vakanjac, 2002) and sediment rocks with sulphide mineralization (this was described with the auriferous occurrences at Hohur sırtı).

In the ore paragenesis of this deposit the following minerals were identified: pyrite, chalcopyrite, sphalerite, galenite, tetrahedrite and argentite. It seems that tennantite is the main tetrahedrite mineral and is thus, together with argentite, the main carrier of noble metals.

According to the data of Kraeff (1963) the content of gold in the ore varies from 0.25 g/t to 7.2 g/t (the highest content of gold in the region of Murgul), according to the same author the content of silver is 338 g/t. With our investigations the following results were obtained (Table 4).

On the basis of all available data for this deposit, ore reserves of over 1 million tons should be expected, with a high content of copper, zinc, gold, silver and bismuth. At the same time it is estimated that 2 to 3 tons of gold and over 50 tons of silver can be expected. These

Table 2- Chemical composition of auriferous sulfide mineralizations at the Hohur sırtı (Popović, 2002).

contents ppm			contents %				
Au	Ag	Cd	Cu	Zn	Pb	As	Bi
5.32	84	-	4.84	7.75	0.10	0.10	0.022
0.44	20	42	2.72	13.50	0.02	0.04	-
0.85	22	-	1.26	0.60	0.26	0.13	-
0.48	16	-	2.11	0.41	1.03	0.03	-
x	182	1280	1.00	1.50	0.26	-	-

x- not analyzed

Table 3- Contents of some metals in tuffaceous sandstone.

contents in ppm					
Au	Ag	Pb	Zn	Cu	As
0.11	2.25	2200	2950	556	217

Table 4- Contents of noble metals and some microelements

contents in ppm				
Au	Ag	As	Bi	Cd
1.9	53	590	1700	40
3.84	75	x	x	x

x- not analyzed

estimates are a great challenge and encouragement not only for geologists but also for investors.

In the scope of this it should be mentioned that in the river Murgani Hevi, that drains the tributaries from Akarşen, a fragment of galenite was found where 0.03 g/t of gold and 350 g/t of silver were registered. This also has to be taken into account when evaluating the significance of Akarşen for noble metals.

OCCURRENCES OF NOBLE METALS IN THE VICINITY OF ARTVİN

Occurrences of noble metals in the vicinity of Artvin are mainly connected with sulphide mineralizations of copper. These are: Kuvarshan, Irsa Maden, Sinkot, Seyitler, Umasen and the Melo dere Gorge. Similar to the vicinity of Murgul the auriferous mineralizations can be classified according to the petrogenetic environment in which they occur. On the basis of this the following type of occurrences can be distinguished: associated with rhyo-dacite volcanogenic and volcanogenic-sedimentary complex (Jurassic - Neocomian) and occurrences associated with rock of Palaeogene age. Sulphide occurrences and deposit of copper, a lesser amount of zinc and lead are located on the right bank of the river Çoruh. The others are associated with granitoid rocks in the Gorge Melo dere.

Upper Jurassic - Lower Cretaceous auriferous occurrences

The auriferous sulphide occurrences, on the right bank of the river Çoruh, are associated with the rhyo-dacite volcanogenic and volcanogenic-sedimentary complex, regardless of the fact that numerous authors disagree about their age of formation. But due to similarities with the same types of formations in the vicinity of Murgul it is considered that these occurrences, considering the time of formation, should be treated the same way.

The region of Kuvarshan.- encompasses several occurrences and deposits of which only the locality Kuvarshan on the right bank of the river Çoruh is wellknown. According to this it is logical that this zone, some 10 km long, is named after this deposit and therefore the ore zone

Kuvarshan includes deposits and occurrences Kuvarshan, Irsa Maden, Sinkot, Seyitler and Umasen. All of these deposits and occurrences are located in the same petrogenetic environment (rhyo-dacites) and are characterized with intense hydrothermal alterations, especially pyritization, kaolinization, bleaching and silicification (Fig. 2).

The copper bearing ore deposit Kuvarshan is located some 4 km east of Çoruh. It is characterized with several ore bodies in the form of veins of lenses. According to data of previous authors (especially Kovenko, 1942; Kraeff, 1963; Novović, 1979; Simonović, 1972) copper ore in this deposit is associated with a tectonic (fault) zone and rhyo-dacite as the host rock. The ore, besides copper minerals such as chalcopyrite, bornite, chalcocite, contains pyrite as the most abundant mineral and this is why this copper deposit is defined as a pyrite type. Besides, the quoted minerals the ore also contains sphalerite that is relatively abundant and galenite and tetrahedrite that are present in minor quantities. A very important characteristic, for this paper, represents tetrahedrite, more precisely tennantite, which strongly indicates that in this deposit, elevated contents of, primarily, silver and lower contents of gold can be expected. It should be pointed out that no systematic investigations for gold and silver were carried out. In some documents (Engin 1986) it is quoted that gold deposits exist in the vicinity of Artvin, but without precise data on the locations. However, in another MTA inventory (MTA, 1996) a sample that contains 1 g/t of gold and 25-30 g/t of silver is mentioned. On the basis of this fact as well as information for other copper deposits of the mineral, stratigraphic and genetic characteristics it is possible to expect elevated concentrations of these two noble metals. As a confirmation of this opinion one more relevant fact are the determined elevated contents of gold at the Sinkot occurrence. Unfortunately, sampling that was carried out by Simonović (1972) and where the determined copper content varied from 0.06% and 6.01%, zinc from 0.31% up to 0.74%, the contents of gold and silver were not analyzed.

Irsa Maden.- is located 3 km north of Kuvarshan. As in the previous case this deposit was explored several times during the 20th century. Based on the data of Simonović (1972) this is the richest deposit in the vicinity of Kuvarshan. The content of copper is in the range of 0.01% - 7.33% and zinc from 0.32% up to 34.69%. Lead is partially absent, but in the rare galenite accumulations the lead content varies from traces to 24.82%. The mineral composition is represented with: pyrite, as the most abundant, followed by sphalerite, chalcopyrite, enargite, and rare tennantite. The most abundant secondary copper minerals are bornite, chalcocite and covellite. Galenite is present in significant quantities only sporadically.

Similar to Kuvarshan, in the deposit Irsa Maden tennantite was also determined in quantities that could be defined as insignificant. On the basis of this it can be assumed that, primarily, relatively significant quantities of silver can be expected. However, gold should not be excluded. The presence of tennantite in almost all deposits of north-east Turkey, in the forms of exsolutions in chalcopyrite indicates that it is possible to expect significant concentrations of silver in these deposits.

Sinkot.- is the next locality in this ore zone. The occurrence is located some 2.5 km south-west of Kuvarshan. It is characterized with intense hydrothermal alterations and very often a developed iron hat (gossan) above parts of the deposit with high concentrations of pyrite. As in the case of the two previously described deposits this deposit was the object exploration on several occasions; it was concluded that pyrite, as the most abundant mineral and source of the gossan material, and chalcopyrite are the main constituents of the ore paragenesis. This is a typical pyrite copper deposit where the contents vary from 100 g/t up to 7.64% of copper. The content of zinc varies from 0.28% to 2.26%; the content of lead only sporadically reaches 0.25%. However, what is significant and indicates a certain potentiality for noble metals, not only at this locality, but also for the whole ore zone Kuvarshan, are the contents of Au and Ag. Accor-

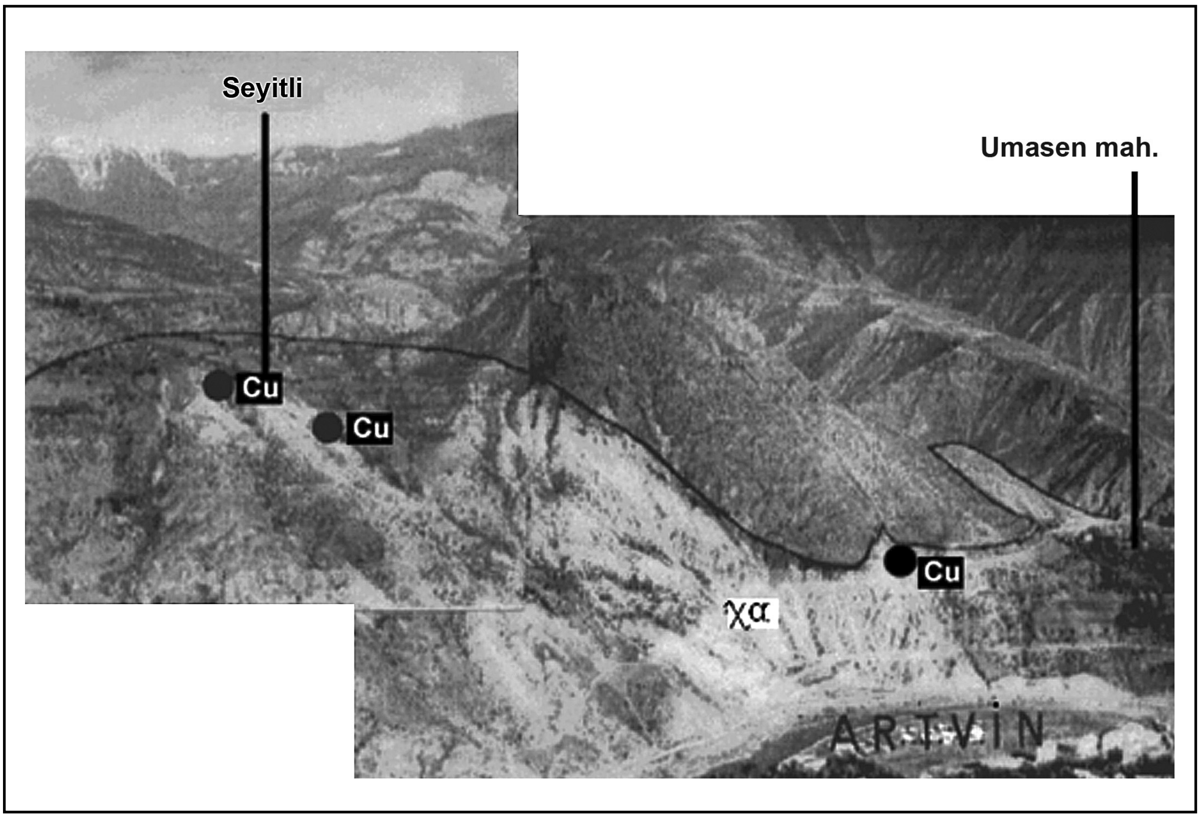

Fig. 2- View of the Seyitler and Umasen area with Cu, less Zn and rare Pb mineralizations in rhyolite volcanites (X^{α}) intensely hydrothermally altered.

ding to Novović (1979) who quotes Kovenkov' s data, the content of gold varies from 0.25 g/t up to 0.5 g/t. This is obvious proof that possibilities of discovering higher concentrations of gold and silver exist (Table 5). Previously, insufficient attention was given to these possibilities.

They are located in the most southern part of the ore zone in the immediate vicinity of the Çoruh river (Fig. 2). Here, at a distance of 1 to 2 km several copper mineralization outcrops occur. The occurrences were also investigated in the past on several occasions. As in the previous occurrences, pyrite, chalcopyrite, sphalerite, rare galenite, tennantite were determined in the primary paragenesis. Chalcocite, covellite, malachite and limonite were identified among the secondary minerals. As shown it is obvious that tennantite is always present and taking into consideration that elevated contents of gold and silver were determined in them then it is logical to predict that the whole zone, starting from Kuvarshan, via Irsa Maden and Sinkota all the way to Seyitler and Umasen mahallesi is gold and silver bearing.

Upper Cretaceous-Tertiary (Palaeogene) auriferous mineralizations

Occurrences registered west of Maradit occur exclusively in Senonian - Palaeogene volcanic rocks. In this region numerous sulphide mineralizations of copper, zinc and lead were discovered. Noble metals that are associated with

Table 5- Contents of gold and copper in Sinkota (Novović, 1979).

Au ppm	0.50	0.25	0.28
Cu %	0.80	0.07	0.24

the base metals were only partially investigated on samples from outcrops that were discovered in the valley of Güresen dere. One outcrop is located near the village Çavuşlu and named after this village. The second is located in intensely altered andesite volcanic rocks and named as the Pehlivan köy occurrence (Fig. 1). They are located approximately 1 km from each other. The occurrence Çavuşlu is located 1 km from the confluence of Güresen dere into the Çoruh river.

Some of these occurrences were know earlier. It is not clear for which occurrence is the data quoted in MTA (1966). Metal contents for this imprecisely located occurrence are as follows: Copper up to 9.23%, lead 5.86% and zinc 0.81%. The content of gold varies from trace amounts up to 3.5 g/t and silver 41 g/t. On the basis of the zinc and lead content it can be assumed that this is the vein occurrence Çavuşlu.

Sulphide occurrence Çavuşlu.- Concerning this occurrence it should be mentioned that this is an outcrop of a galenite-sphalerite vein that was investigated in the first half of the 20th century. This is confirmed by the existence of an old adit that was used to explore the approximately 1 m thick vein. The strike of this vein is NE - SW with a 500 dip towards southeast. The paragenesis is represented with: galenite, sphalerite, pyrite, chalcopyrite, arsenopyrite, pyrrhotite, tetrahedrite (probably tennantite). Two 1 m samples were taken (Popović, 2002) and the following contents on table 6 were obtained. According to the element contents it is obvious that zinc is the leading component in this occurrence, but the contents of lead and copper are also significant.

Table 6- Chemical composition of the ore vein Çavuşlu

Sample No.	%				ppm	
	Zn	Pb	Cu	As	Au	Ag
Sample 1	10.00	1.50	0.60	0.10	0.04	47
Sample 2	9.50	1.90	3.50	0.15	0.07	65

Of the noble metals, because of its contents, silver is of prime importance. It is assumed that silver is associated with tennantite. The content of gold is low and is therefore of lesser importance.

Pehlivan köy.- It is located 1 km west of the occurrence Çavuşlu towards Pehlivan köy an intensely hydrothermally altered andesite rock impregnated with pyrite and chalcopyrite. Besides, alterations, this andesite has a high content of malachite regardless of the fact that it has a low content of chalcopyrite, and this is the source of the high copper content. This occurrence differs from the previous in many ways. The previously described occurrence is a sphalerite-galenite vein. This occurrence is exclusively characterized by a copper mineralization. Its mode of occurrence is of the impregnation or stockwork - impregnation type. The previous one is associated with a fault and this one is a mineralized andesite. And finally, a special characteristic is the occurrence of adularization, which is characteristic for epithermal alterations. On the basis of this it is considered that this is a typical epithermal mineralization.

Regardless of the fact that no systematic sampling was carried out, the results show that the contents of zinc and lead are very low (maximum 900 g/t of Pb). However the content of copper varies up to 11.35% (it should be noted that this concentration was obtained from samples that were taken from the surface of the outcrop where supergene enrichment occurred). It is not possible to bring precise conclusions about the content of noble metals because only one sample was analyzed. This sample gave 0.72 g/t of gold, silver varied from 14 to 50 g/t (Popović, 2002).

Taking into account the proven adularization allows an optimistic prognosis that this occurrence deserves much more attention, not only as an occurrence of copper but also for noble metals.

Having in mind the fact that this occurrence belongs to the Upper Cretaceous - Tertiary volcanogenic and volcanogenic-sedimentary complex which were synchronous with this complex, it can be concluded that all occurrences in the region Murgul - Artvin - Maradit are epithermal types. With this the total potentiality of the sulphide mineralizations with which noble metals are associated considerably increases.

MADENKÖY

During our investigations we also visited the large polymetallic deposit Madenköy near Çayeli. On this occasion several samples were taken which were analyzed for noble and base metals. Because, this deposit is located in the same tectonic and metallogenic zone as Hohur sırtı and Akarşen we consider that it is interesting to quote the contents of metals that were obtained in the taken samples. Connecting this into a unique Upper Cretaceous - Tertiary zone, it can be considered that the region between Akarşen and Madenköy has a significant auriferous potential. This is also the opinion of other authors (Pejatović, 1973/1979). Therefore we considered that it is necessary to present our informative data here. This is important because of the high concentrations of gold and silver in Madenköy. The gold content is up to 11.43 g/t and silver up to 241 ppm.

CONCLUSION

Starting with the presented data it is obvious that the north-east part of Turkey, i.e. the region of Murgul - Artvin - Maradit, has a very significant ore potential. Primarily this is valid for copper as the leading metal. This is supported by the fact that the estimated ore reserves (including the already mined) are over 100 million tons with an average content of 1% Cu. Zinc follows copper but with smaller potential, and it is associated with copper or polymetallic deposit where it is associated with Pb and Cu.

All the deposits and ore occurrences to a smaller or larger degree contain gold and silver. However, it should be pointed out that these sulphide deposits can be classified into two major groups. They are defined by their time of formation, association of metals, petrogenetic environment in which they occur, dimension of the deposits, content of metals and degree of gold and silver contents. On the basis of noble metals the deposits and ore occurrences can be classified associated with Upper Jurassic - Lower Cretaceous volcanogenic and volcanogenic - sedimentary complex of rhyolite and rhyo-dacite composition. The second group is represented with deposits and ore occurrences that are genetically associated with volcanogenic, volcanogenic - sedimentary and partially to sedimentary complex that was formed during Upper Cretaceous and Tertiary (Palaeogene) times.

The most dominant in the first group are deposits of copper that is followed by zinc and minor quantities of other metals (Pb, Mo). Usually, these are large deposits with ore reserves (individually) of over 10 million tons and content of copper around or over 1%. The second group is represented with polymetallic deposits with Pb, Zn and Cu as the leading metals. In general, these are small deposits and in the studied region the reserves of these deposits (individually) are less then 10 million tons with an average content of Pb + Zn + Cu over 5%. The polymetallic deposit Madenköy is an exemption because a part of the ore bodies contain over 1% of copper and ore reserves over 10 million tons. In the second group of ore bodies Pb - Zn are dominant with ore reserves of over 20 million tons and an average content of over 10% for the two metals.

Considering noble metals an important characteristic is the presence of tennantite in all deposits in the Murgul - Artvin - Maradit region. Besides, these argentite was registered in the polymetallic deposits which is a convincing fact concerning serious concentration of silver in both type of deposits. However, for the older Jurassic - Neocomian deposits the gold contents are generally low (below 0.5 g/t). In the second case, the content of gold and silver in the polymetallic deposits are considerably higher (up to 11.43 g/t of gold and almost 400 g/t of silver).

On the basis of the existing knowledge the average gold content in Anayatak is 0.24 g/t; silver varies from 20 g/t up to 180 g/t but with an average of 25 g/t. Similar or even lower contents of gold and silver were registered in the vicinity of Artvin.

On the other hand in the polymetallic deposits at Murgul (Hohur Sırtı and Akarşen) the gold content varies from 0.44 g/t up to 8 g/t and silver from 22 g/t up to 180 g/t. In one sample of galenite, from the vicinity of Akarşen, 350 g/t of silver were found.

For the vicinity of Artvin there is little data for the content of noble metals in the Upper Cretaceous - Palaeogene formations. In the case of Maradit the gold content in the polymetallic vein occurrence Çavuşlu varies from 0.04 g/t up to 0.07 g/t, silver is from 47 g/t up to 65 g/t. In the second occurrence in this region, at Pehlivan köy, the content of gold is 0.72 g/t and silver up to 50 g/t. However, what is more important is the adularia type of hydrothermal alteration, which indicates epithermal mineralization. This opens numerous possibilities for the discovery of copper and gold deposits of epithermal type.

Finally in this paper Madenköy near Çayeli is included where 11.43 g/t of gold and 241 g/t of silver were determined.

As it can be seen the region of Murgul - Artvin -Maradit has exceptionally large potential not only for copper, zinc and lead but also for noble metals, in this case gold and sliver.

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BIVALVIA AND SCAPHOPODA FAUNA OF KASABA MIOCENE BASIN (WESTERN TAURIDS, SW TURKEY)

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ABSTRACT.- In this study, 28 Bivalvia and 1 Scaphopoda species were determined in the Uçarsu and Kasaba formations of the Kasaba Miocene basin and the systematic characteristics and stratigraphic levels of them have been revealed. Chronostratigraphical and paleogeographic characteristics of the species have shown that the age of Uçarsu formation is Upper Burdigalian (Upper Eggenburgian - Karpatian) and of the Kasaba formation is Langhian (Lower Badenian). Species such as *Pecten zizinae* Blanckenhorn, *Cardium praeaculeatum* Hölzl , *Venus (Antigona) burdigalensis producta* Schaffer and *Pitar (Paradione) lilacinoides* (Schaffer) found in the Uçarsu formation are peculiar to Early Miocene and these species have not been known in Middle Miocene. *Divaricella ornata subornata* Hilber found in the Kasaba formation is a species which had been peculiar to Middle Miocene. Most of the mollusc fauna determined from the examined units is wide-spread both in Thethys and Central Paratethys during Early and Middle Miocene. *Chlamys (Macrochlamys) latissima praecedens* (Sacco), *Pecten benedictus* Lamarck, *Pecten fuchsi* Fontannés, *Pecten zizinae* Blanckenhorn, *Pseudochama gryphina taurolunata* (Sacco) and *Cardium praeaculeatum* Hölzl from the class of Bivalvia and *Dentalium (Antalis)* cf. *bouei* Deshayes from the class of Scaphopoda are species which had only distributed in Thethys realm. In the study area, only a limited number of species, known from the marine stages of Central Paratehys have been found. *Divaricella ornata subornata* Hilber found in the Kasaba formation is a species which has been peculiar to Lower Badenian and *Cardium praeaculeatum* Hölzl, *Venus (Antigona) burdigalensis producta* Schaffer found in the Uçarsu formation are species peculiar to Eggenburgian.

Key words: Antalya, Kasaba, Miocene, Bivalvia, Scaphopoda, Systematic, Paleontology

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FRASNIAN BRACHIOPODA FAUNA FROM THE LATE DEVONIAN GÜMÜŞALİ FORMATION IN THE SAİMBEYLİ REGION (ADANA-EASTERN TAURIDES)

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ABSTRACT.- In this study, Frasnian brachiopoda fauna of the Gümüşali formation in the Saimbeyli area (Eastern Taurides) has been identified and described for the first time in Turkey. The measured section, located near Naltaş village, Gümüşali formation is well exposed and very rich in macrofossils. This macrofossils occur in local accumulations within the limestones and sandstones. The section which represents lower part of the formation is formed by fossiliferous limestones at the basal part, by sandy limestone-shale alternation at the middle part and by sandstones interbedded with thin shales at the top. The sequence was deposited in a shallow marine environment. It contains brachiopods, corals and subordinate bryozoa and crinoidal elements. The detemined brachiopoda assemblage includes *Douvillina dutertrei* (Murchison), *Cyphoterorhynchus arpaensis* (Abramian), *Desquamatia* sp., *Cyrtospirifer bisinus* (Lehon), *Cyrtospirifer schelonicus* Nalivkin, *Cyrtospirifer* sp., *Apousiella bouchardi* (Murchison), *Spinatrypina chitralensis* (Reed), *Uchtospirifer multiplicatus* Brice. This assemblage can be correlated with those from the Frasnian of Iran, Afghanistan and Western Europe.

Key words : Late Devonian, Frasnian, brachiopoda, Saimbeyli, Eastern Taurides.

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TRACE FOSSILS OF THE EASTERN FAN IN CİNGÖZ FORMATION (NW ADANA)

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ABSTRACT.- This study considers the trace fossils within the Early-Middle Eocene turbiditic submarine aluvial fan deposits of the Cingöz formation around Karaisalı-Çatalan-Eğner to the N of Adana. Regarding the morphological characteristics twenty trace fossils are described. From these, fourteen are determined as ichnogenus (*Arthrophycus tenius, Halopoa annulata, Nereites irregularis, Cosmorhaphe sinuosa, Helminthorhaphe flexuosa, Helicolithus tortuosus, Desmograpton dertonensis, Desmograpton ichthyforme, Urohelminthoida dertonensis, Paleodictyon strozzii, Paleodictyon delicatulum, Paleodictyon majus, Paleodictyon croaticum, Paleodictyon submontanum*), and six of ichnospecies (*Phymatoderma* isp., *Lophoctenium* isp., *Helminthopsis* isp., *Desmograpton* isp., *Paleodictyon* isp., ?*Megagrapton* isp.,) level.

Key words: Adana, Cingöz formation, trace fossils, ichno genus, ichnospecies.

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THE USAGE OF PUMICE IN THE MANUFACTURING OF ISOLATED MONOLITHIC MATERIAL

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ABSTRACT.- In this paper the experimental results of developing refractory monolithics containing pumice, expanded perlite, kieselguhr and Portland cement are presented. Using Andreasen Equation, three different aggregate grads have been tried to obtain N class insulating monolithic refractory composition to comply with ASTM standards. The results of analysis of pumice, perlite and kieselguhr are given. Bulk densities, linear changes after drying and firing (925°C) and cold crushing strengths have also been determined on the samples prepared according to ASTM standards. As the best values, the bulk density after drying was 0.94 g/cm³ and the linear change after 925°C was calculated as -1.7 %, which are given as 0.88 g/cm³ and -1.5 % respectively in related ASTM standard.

Key words: Pumice, monolithic, isolated, refractory

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