A NEW TYPE OF SULPHIDE ORE DEPOSITS IN SUBDUCTION ZONES

Vladimir I. Gugushvili*, Michael A. Apkhazava**
Tandoğan Engin***, and Ali Yılmaz***

*Geological Institute of the Academy of Sciences, 380093, Tbilisi-Georgia,
**Georgian State Department of Geology, 380062, Tbilisi-Georgia,
***General Directorate of Mineral Research and Exploration, 06520, Ankara-Turkey

ABSTRACT

It is well known that porphyry-copper and Kuroko type deposits are mainly manifested above subduction zones. The porphyry-copper deposits are related to andesitic and dacitic stratovolcanos. Kuroko type deposits are related to postcollapse rhyolitic lava domes injected at the last stage of rhyolitic ignimbrite activities, which are usually terminated by the cauldron subsidence. In the Bolnisi ore district, we studied a group of sulphide deposits which belong to the subduction zone. These deposits differ from typical porphyry-copper, as well as from Kuroko types. They are related to the felsic magmatic chamber which subsequently fed the ignimbritic activity. Generation of these deposits is preignimbritic and precauldron, hence, we consider them to be a new type of ore formation and we propose to distinguish this formation and name it the Bolnisi type deposit.

INTRODUCTION

The Bolnisi ore district is situated 60-80 km South-West of the capital of Georgia, Tbilisi, in the vicinity of the administrative centre of the Bolnisi region (Fig., 1). The ore district contains several goldbearing copper-lead-zinc-barite deposits. The most important of these are Madneuli and Tsiteli Sopeli (Fig., 2). The deposits occur in the Late Cretaceous volcanic suite and are controlled by Late Cretaceous volcanos. The Late Cretaceous volcanic suite represents the alternation of rhyolitic ignimbrites and andesite-andesite-basalt lavas and tuff-breccias. The ignimbrites are prevalent and andesite-basalts are significantly subordinate. The volcanic suite is located in the Artvin-Bolnisi tectonic zone. The latter are continuing to the west in the Turkish Pontides and farther to the Bulgarian Srednegora (Fig., 3). They consist of the single widespread tectonic and geodynamic unit and are developed above the Post-Paleozoic subduction, due to closing of the northern branch of the Tethys ocean completed by the collision of Euro-Asian and Afro-Arabian plates in Late Cretaceous-Early Tertiary (Adamia, 1984, Tokel 1992). The evidence of the remnant of the ocean branch is the widespread ophiolitic belt extending from Sevano-Akera (Armenia) through the Anatolia to the Vardar zone in Greece (Fig., 3).
Above mentioned tectonic units (that are Artvin-Bolnisi and Pontides ) are represented by the fragments of Paleozoic granitoids and metamorphic salient covered by Mezo-Cenozoic volcano-sedimentary units consist mainly of Jurassic, Cretaceous and Tertiary calcalkaline volcanic suites with the copper-pyrite-molibden, copper-lead-zinc-porphry, Kuroko type and hydrothermal deposits, some of which are essentialy goldbearing. The Cretaceous volcanic suites are especially rich with ore deposits, such as well known porphyry-copper-molibden deposits : Chelopech and Medet (Bulgaria) , Maidanpeck and Bor (Yugoslavia), Moldova Nouva (Romania); Kuroko type deposits - Murgul , Madenköy, Lahanos (Turkey); Georgian deposits of the Bolnisi ore district.

The similarities and pecularities of these deposits is explained and some brief information given. The Pontid deposits composed of the Northern Turkey copper- lead-zinc belt (Engin, 1994). They are represented by Murgul, Kutlular , Madenköy, Lahanos. The deposits related to the Late Cretaceous rhodacitic volcanics of the Kuroko type. These volcanogenic massive polymetallic (Cu,Pb,Zn,Au) ore deposits are distributed around eroded calderas (Güven et al., 1992). The Murgul type is economicaly the most significant among them(Fig., 4). It consists of two main ore bodies Chakmakkaya and Damar, which are controlled by rhyo-dacitic dome. Up to date in both of them stock- work,veinlets and disseminated mineralization occur. Earlier there were the massive sulphide ore lenses, although now the presence of only very small-size massive ore lenses is reported. The massive ores bodies have been already mined out. The ore consists mainly of pyrite, chalcopyrite and lesser sphalerite and galena. Gang minerals are quartz, calcite, siderite ankerite, gypsum and barite. Secondary ore minerals are chalcocite, covellite, malachite and azurite. The ore bodies show zoning. In the upper parts lead-zinc, in the lower part copper and the lowermost part pyrite mineralization appear to have been developed. Silification, argillization, chloritization and carbonatization are the common wall rock alteration products. Silification is closely associated with the ore mineralizations (Er, 1994).

There are about 304 copper occurences and deposits in the Eastern Black Sea region 225 of those are massive sulfide and vein types related to calc-alkaline volcanics and are represented as typical Kuroko type deposits. There are also about 9 porphyry copper-molibdenium mineralizations in the region related to Late Cretaceous-Tertiary granitoid intrusions. The best of them Dereköy (Kirklareli) porphyry- copper deposit in the Thrace part of Turkey in the same belt. About 40 skarn and metasomatic occurences and deposits are known along the Northern Black Sea region (Engin, 1994).

Many goldbearing Copper-lead-zinc deposits and occurences are known in the Bulgarian Srednegora zone and in it’s prolongation in Serbia. In the latter the famous porphyry-copper deposite Bor and Maidanpeck occur. It is noteworthy, that in this tectonic zone, ignimbrite volcanic activity is not seen. The productive Late Cretaceous volcanics mainly andesitic and dacitic types are distinguished from prevalently rhyolitic and rhodacitic
volcanics of the Pontides and Artvin- Bohnisi zone. The Srenegora zone is not characteristic ignimbritic volcanic activity, caldera collapse and Kuroko type deposits. Here the prevailing type is porphyry-copper deposits with associate vein, stockwork and disseminated type.

Now we would like to give a brief review of the most significant and the most typical Bulgarian and Serbian Srednegora deposits (Fig., 5). The most illustrative example is Chelopech and Medet porphyry-copper-molibdenium-lead-zinc deposits, in the Bulgarian Srednegora.

Chelopech deposit is located at the Chelopech syncline structure (Fig., 6), here the Maastrichtian flischoid terrane is underlain by the Santonian-Campanian limestones and marls; the lower part of the Late Cretaceous volcanic suite, which consists of the andesitic and trachy-andesitic lavabreccias, tuffbreccias and tuffs occur. The volcanics are crosscut by the rhyolitic dikes and underlain by the Late-Turonian sandstones and conglomerates. The latter transgressivly overlay the Paleozoic slates and Precambrian gneises. The Late Cretaceous volcanics and dikes are ore bearing. Origin of the Chelopech deposit is typical metasomatic and bears all features of porphyry-copper deposits (Sillitoe, 1980, 1985). They are typical porphyries. Stock-work and disseminated parts of ore, magmatic-hydrothermal breccia pipes cemented by ore, massive ore stock bodies, veins etc are all present. The zoning begining with pyrite at the bottom grades upwards to goldbearing chalcopyrite with bismuth and tellure containing minerals, farther traversed into bornite and chalcosite zone and uppermost tenantite zone with tellur, bismuth, gold, silver and molibdenium are established (Bogdanov, 1986). Wall rock alteration is revealed in sericitization, chloritization, kaolinization and opalization.

Another significant and illustrative porphyry-copper- molibdenium deposit of the Bulgarian Srednegora is Medet (Fig., 7). The deposit is located in Upper Cretaceous quartz-montzodiorite and granodiorite intrusions, occurring in the Paleozoic slates and granites. The ore occurrence is superimposed on the Upper Cretaceous montzodiorites and granodiorites, and on the Paleozoic granitoids. The ore body has a column form with disseminated and stockwork ore in lower parts and brecciated pipes in upper part of the deposit. The ore mineralization is mainly copper- molibdenium in the deeper part and lateraly the proportion of copper to molibdenium slightly increases, so in this direction the proportion of the lead-zinc to copper also increases (Bogdanov, 1986). The wall rock alteration is represented by feldispahritization, actinolitization, chloritization, sericitization, silification and argillization. The Bulgarian explorers refers Medet to be a typical porphyry-copper- molibdenium deposit (Bogdanov, 1986).

The Srednegora zone continues in the Eastern Serbia and there is similar geological setting in the Late Cretaceous andesitic volcanic suite and dioritic and granodioritic intrusion. Here many porphyry-copper deposits occur, among them two famous - Bor and Maidenpeck (Fig., 5,8). As it is shown on the maps and cross sections (Fig., 8,9,10) these
deposits indicate all features characteristic to porphyry-copper deposits. They are related to banatite-dioritic and dioritic intrusive bodies, which were developed beneath andesitic stratovolcanos (Jankovic, 1982).

Bor ore district is characterized by various types of mineralizations: Massive sulphide, stock-work, disseminated and porphyry types (Fig., 9). Metallic minerals of the deposit are pyrite, chalcopyrite, bornite, molybdenite and magnetite. Gangue minerals are quartz, calcite and barite. The following types of hydrothermal alteration may be discriminated: kaolinization, chloritization, carbonatization, sericitization and pyritization (Milicic and Grujecic, 1979).

Another large scale porphyry-copper deposit of the Serbian Srednegora is Maidanpeck. It is situated at the 36 km NW of Bor. The vicinity of the deposit is built up of micaceous gneisses and the Proterozoic schists, the green schist facies of the Rifean-Cambrian age, Early Jurassic conglomerates and sandstones. The older magmatic rocks are Hercinian plagiogranites (Fig., 8,10).

The ore origin is related to the Upper Cretaceous andesites and diorites. In the ore deposit, remnants of volcanic breccias and tuffs are seen. Diorite, quartz-diorite-porphyry and diorite-porphyry intrusions took place in Late Cretaceous during the Laramian orogenesis. These intrusives are small size, but they have the principle role in formation of the Maidanpeck porphyry-copper deposit. The ore mineralization is typically characteristic for porphyry-copper deposits and are represented by the veins, stockwork and disseminated ore bodies. The ore mineralization is superimposed on the diorites, andesites, crystalline schists and gneisses, also on the Jurassic carbonates with of skarn deposit (Fig., 10, Spasov and Milovojevic, 1979). The ore mineralization simply consists of pyrite, chalchopyrite, bornite, tetrahedrite, molibdenate, native gold, sphalerite and gallena, arsenopyrite and marcasite. Hydrothermal alteration is represented by chloritization, carbonatization, sericitization and epidotization.

The Srednegora zone continues in Romania and there in the similar geological setting, very similar to Maidanpeck, Moldova Nouva Porphyry copper deposit occurs. So in the Lesser Caucasus in Armenia, along the Somkheti-Karabach zone, very close to the Bolnisi ore district beneath the Jurassic calc-alkaline andesite stratovolcanos, vein and disseminated copper deposits of Shamlug, Alaverdi and Kaffan are known (Magakian,1980).
GEOLOGICAL STRUCTURE OF THE BOLNISI MINING DISTRICT AND DEVELOPMENT OF THE BOLNISI VOLCANO-TECTONIC DEPRESSION.

The Bolnisi mining district is a part of the Artvin-Bolnisi tectonic zone and contains all the units from Paleozoic granitoids up to Quaternary sediments (Fig., 11). The country and contemporary rocks of most of the deposits of the district are mainly Cretaceous volcanic sediments (Gugushvili et al., 1984, 1988) and the deposits are controlled by Cretaceous volcanic structures, so here our attention has to be directed on Cretaceous rocks and on the situation related to the tectonic evolution and volcanic activity. As is shown on the sketch map, lithological column and cross sections (Fig., 11,12) the volcanic activity in Cretaceous began in Early Cenomanian, with the development of andesitic and dacitic tuffs alternating with limestone layers. These sediments transgressively overlaid the Paleozoic granitoids and metamorphosed rocks. Thin layered dacitic tuffs and silstones are deposited on the Cenomanian sediments, tephroir (flyshoid) types. They precipitated in the shallow sea and material was brought from distant volcanic centers. The suite is dated as Lower Turonian and is known as Didgverdi suite(*). This suite is the host rock of the most important deposits of Madneuli and Tsiteli-Sopeli districts. After precipitation Didgverdi suite, intensive ignimbritic volcanism began and as a result thick Mashavera suite developed in Late Turonian-Late Santonian. This suite mainly consists of the ignimbritic lava flows sometimes alternated with felsic flows, tuffs and pyroclastics(Fig., 12). Ignimbritic volcanic activity was terminated by cauldron subsidence (Fig., 11).

Collapsed calderas are related to annulate structures bordered with extrusions of felsic magma (Fig., 11). In the Mashavera suite, the copper-lead-zinc-barite ore deposits occur; they are vein type or disseminated and some of them are goldbearing. The ore reserve of these deposits (David-Garegi, Kvemo-Bolnisi, Sacdrisi etc.) are much less than Madneuli and Tsiteli-Sopely, but from the point of view of gold potential (Sacdrisi,David-Garegi), they are prospective. The Mashavera suite is overlain by the more basic andesite-basaltic Tandzia suite (Late Santonian). The thickness of this suite is variable from a few tens of meters to 500 m. Here are no known economic ore manifestations, present only native copper mineralization occurs. In the different levels of the suite rhyolitic fragments washed out from ignimbrite islands are present. In the basic tuffs ignimbrite material is included into andesitic matrix.

The Tandzia suite is succeeded by the thick ignimbrite Gasandami suite (Upper Santonian). The latter is analogous to the Mashavera suite and contain several economically insignificant copper-pyrite and lead zinc vein and disseminated ore

(*) Here we use the Georgian geological name of Bolnisi district for Cretaceous cross section.
manifestations. The latter is overlain again by basic basaltic suite named “Shorsholeti” (Late Santonian-Campanian). The suite is built up by Thrachibasaltic flows and tuff-breccias in which no ore manifestations are known. Above Shorsholeti suite Campanian-Danian limestones follow. In the South-Western part of the ore district, Tertiary (Eocene) volcanics are widespread. They are transgressively overlain by different stratigraphic units (Cretaceous, Jurassic). The suite consists of the andesite-basalts (the lower part), andesites and dacitic welded tuffs. The thickness of the Eocene sediments is significant-1200 m. In the basaltic and andesite basaltic rocks, one lead zinc skarn deposit occurs (Bejanishvili, 1965) and in the middle part of the suite porphyry-copper related dioritic intrusive occurs. The youngest in the region are Quartenary alluvion and basaltic lava flows.

The Bolnisi mining district is disposed between the two Paleozoic salients - Locki and Chrami massifs and represents a volcano-tectonic depression (Fig., 11). The origin of this depression is related to cauldron subsidence, connected to intensive Cretaceous ignimbrite volcanic activity.

Cretaceous sedimentation began with Senomanian transgression upon the rocks of the Paleozoic Locki crystalline massive and is represented by alternation of limestones and andesite-dacitic tuffs. Shallow sea sedimentation was continuing in the Lower Turonian, when tephroit sedimentation of dacitic psammitic tuffs and siltstones precipitated. A shallow sea situation in Lower Turonian time is confirmed by ripplemarks, crossbedding, fucoids, which characterize the Didgverdi suite. Afterwards, ignimbrite volcanic activity resulted in development of the Mashavera suite. It is well known that ignimbrite volcanism is subaerial. So, before and during the ignimbrite flow ejection the shallow sea area of the Bolnisi mining district, in Early Santonian had the tendency of the bottom elevation provoked by intrusion of the batholithic mass of felsic magma, which fartherly sourced the ignimbrite activity. It is evident that the sea bottom elevation was not simultaneous, some parts of bothom rested under the sea, but with strengthening of ignimbrite volcanic activity tendency of elevating was reinforcing. As a rule ignimbrite volcanic activity completed with caldera collapse and rhyolitic extrusion along annular structures as an evidence of cauldron subsidence. After completion of the ignimbrite ejection and cauldron subsidence the shallow sea situation returned and andesite-basaltic volcanism began.

The Tandzia suite contains marine fauna. Later in Upper Santonian new portion of felsic magma intruded with repeating elevation of sea bottom and another stage of the ignimbrite volcanism and as a result, the Gasandami suite occurred. The cauldron subsidence is evidenced by rhyolitic extrusions around new annular structures. It is noteworthy, that in the Bolnisi ore district area two groups of the annular rhyolitic extrusion are established. The first, according to potassium-argon age (79-81 million years) and it is evidenced by the caldera collapse connected with completion of Early Santonian ignimbrite ejection (Mashavera suite) and second (potassium argon age 70-75 ml years) is the extrusion completed caldera collapse related to the Late Santonian-
Campanian ignimbrite activity (Gasandami suite). After cauldron subsidence in the area repeating the shallow sea situation with sedimentation of the basaltic material (Shorsholeti suite) and furtherly deepening the sea with precipitation of Campanian-Danian limestones.

Because of the rigid state of Paleozoic substratum of the Mezo- Cenozoic cover, the modern relief forms and tendency of the block construction of the Bolnisi ore district area mainly depend on the Late Cretaceous sea bottom elevation and cauldron subsidence related to two stages of the intensive ignimbrite volcanic activity. It is the reason of modern depression of the Bolnisi mining district area and it’s block construction. Notwithstanding, we do not exclude also the weak tectonic movements, erosion and river valley formation in the origin of modern relief.

**PREIGNIMBRITIC ORE DEPOSITS**

As mentioned above in the Bolnisi mining district in the ignimbritic (Mashavera and Gasandami) suites, several copper-lead-zinc vein and disseminated deposits occur. They are not significant economically, except goldbearing aspects.

The most important two deposits located in preignimbritic Didgverdi suite are Madneuli and Tsiteli-Sopeli. The Madneuli deposit has been open mined for 20 years and experts have had opportunity to explore it in detail during this period. Another deposit Tsiteli- Sopeli is a blind ore body and it is not operating, because of the complicated hydrogeological condition. So information about the latter is much less, but on the basis of the drilling data, radiometric and geological information, it is analogous to Madneuli. The main body of the Madneuli deposit (Fig., 13,14) is brecciated pipe, belongs to the magmatic- hydrothermal breccias type classified by Sillitoe (1985). The dimensions of the main pipe are 0.5x0.4 km in horizontal and 300 m in vertical directions. The main pipe has several pipe off-shoots with much lesser dimensions (Fig., 13,14). Earlier in the deposit, there were other brecciated pipes with lead-zinc-barite, copper-pyrite and barite mineralizations. Now, they have been almost entirely mined out and only their remnants are left. On the deposit area, the layered tuffs and siltstones of the Didgverdi suite are entirely silicified and argillized with relics of the layered structure (Fig., 13). The fragments in the pipe are also represented by the same secondary quartzites, which are cemented by copper-pyrite or lead-zinc-barite mineralizations. Therefore, the widespread silicification in the deposit area preceded the ore-formation.

Noteworthy, that ore bodies, especially copper-pyrite are goldbearing and goldbearings are also secondary-quartzites. Goldbearing is pyrite disseminated in quartzites and chalcedony network veins in the quartzites. Goldbearing chalcedony precipitated in the fissure network. The latter was the result of explosion and pipe-formation in secondary quartzite. So, here two stages of gold formation occur. One was proceeding the ore-formation
and related with silicification and the other related with chalcedony veinlets connected with ore-formation.

In the deposit, several ore pipes occur with the different minerals such as pyrite, copper-pyrite, massive sulfid- mainly galena, lead-zinc- barite and barite. On the flanks gypsum mineralization is manifested. The temperature of origin of the various ores in the deposit is different. So pyrite and copper-pyrite ores temperature range between $370^0-260^0\text{C}$, lead-zinc-barite $-270^0-180^0\text{C}$, barite $< 120^0\text{C}$ (temperature of fluids trapped within gang minerals in veins, Gogishvili, 1980).

Origin of the ore-bearing pipes is due to several hydrothermal explosions. So in the deposit there are several pipe bodies. The main pipe body (Fig., 13) now being exploiting is pyrite and copper-pyrite with lead-zinc-barite offshoots. There were several lesser pipe bodies copper-pyrite, lead-zinc and barite and most of them are almost mined out. So it is evident, that the deposit represented different temperature stages of the hydrothermal solutions.

Each type of ore is characterized by the peculiar wall rock alteration developed along with the ore formation. So copper-pyrite ore origin was coinciding with the chlorite-carbonate alteration superimposed on the host quartzites, as lead-zinc-barite ore bodies formation coincided with jarosite-alunite mineralization.

On the presented sketch cross-section of the deposit (Fig., 14) the grandioritic intrusion (potassium-argon age 88 million years) evidenced by drilling on the depth of 500 m had to be the source of Cretaceous volcanic chamber. The intrusion itself underwent to quartz-muscovite alteration, graded upwardly into quartz-sericite alteration in Turonian layered tuffs, farther it is graded into goldbearing monoquartzites, the latter gradualy transferred into argillitized rocks (Potassium-argon age of silicified and argillized rocks is 93-84 million years). Uppermost level of the open mine is the thick ignimbrite-aglutinate flow with volcanic orifice containing the same ignimbritic material. Noteworthy that this orifice included the huge blocks of silicified rocks with thick lead-zinc veins in it (Fig., 13,14). Hence ignimbrite ejection was postore and post silicification. The ignimbrite flow itself includes a lot of silicified fragments. The rhyolitic extrusion in the deposit also inserted silicified fragments. According to potassium-argon age of the ignimbrite explosion is 85 million years. The rhyolitic extrusion’s age is 79 million years. This extrusion have to be the evidence of caldera colapse. If it is so, process of silicification and ore formation on the Madneuli deposit is precauldron too.

It is necessary to evaluate paleogeographic development of the Madneuli ore deposit. The area of deposite as the ore district entirely was covered by shallow sea in Early Turonian. Dacitic tuffs and siltstone material was deposited (Fig., 15 l), forming the Didgverdi suite. At the next stage at the bottom of the sea huge masses of felsic magma intruded, which due to elevated the sea bottom and emergens of the island simultaneously, the fluid of
the intrusion in subaerial condition started intensive silicification and argillization of the tuffs and siltstones (Fig., 15 II, III). Subaerial condition is favourable to oxidate hydrosulphure to sulphur dioxide in fluids and it is due to acidification, leaching base elements and silification of the country rocks. So, above the magmatic chamber, thick and dense (compact) screen was formed, which detained the arising volatiles from the felsic magma chamber. When accumulation of the volatiles attained to a critical point, it provoked hydrothermal explosions with pipe formation. The latter was successively mineralized by orebearing solutions (Fig., 15 IV). At last, in lower Santonian, the strongest explosion took place due to emergence of the volcanic orifice and ignimbrite ejection (Fig., 15 V). Afterwards, as it is characterized by ignimbritic volcanic activity and for Bolnisi district also the ejection of ignimbrites was followed by the caldera collapse. This is also the case in the Madneuli deposit area too (Fig., 15 VI). The evidence of caldera collapse is the tectonic contact of ignimbrites with the rocks of underlaying the Didgverdi suite (layered tuffs and siltstones) on the western and eastern flanks of the deposit.

Up to date situation of the deposit (Fig., 15 VII) may be explained by the erosion of arisen flanks of the collapsed caldera. The evidence of caldera subsidence on the area of deposit is also the annulate structure surrounded by rhyolitic extrusion and their occurrence on the western and eastern flanks of deposit nearby and the lateral contact of the ignimbrites with layered tuffs of the Didgverdi suite (Fig., 15 VII). The potassium-argon age of the extrusion (79 million years) is manifested the finishing of the first stage of ignimbrite ejection and caldera collapse. Noteworthy, that one rhyolite extrusion on the eastern flank of the deposit inserted fragment of secondary quartzites (potassium-argon age 86 million years).

Hence in the Madneuli deposit radiometric and geological data confirmed that the ore formation process was preignimbrite ejection and precaldera subsidence, but likely related to the same magma chamber, which subsequently fed ignimbritic activity.
DISCUSSION

In the extensive tectonic unit (including mainly Artvin-Bolnisi, Pontides and Srednegora units island arc system) which was originated on the North Tethyan Post-Paleozoic subduction zone in calc-alkaline Mezo-Cenozoic volcanic suites includes considerable number of copper-lead-zinc-barite deposits. Especially productive units are Late Cretaceous volcanics. The most significant ore deposits are genetically and temporarily related to them. That are: Bor and Maidanpeck (Yugoslavia), Chelopech and Medet (Bulgaria), Murgul, Kulalar, Madenköy, Lahanos (Turkey), Moldova Nouva (Romania), Madneuli (Georgia) etc.

The Upper Cretaceous volcanics occur in all the above mentioned tectonic units, but in the Bulgarian and Serbian Srednegora they are prevalently andesitic and partly dacitic, in the Pontides dacitic and rhyodacitic volcanics and in the Artvin-Bolnisi zone rhyolitic and rhyodacitic ignimbrites prevailed.

In the Srednegora area (Bulgarian, Serbian, Romanian) andesitic volcanics are characterized by the typical porphyry - copper deposits with all characteristic features of this type; such as relation to andesitic and dacitic stratovolcanos; zoning from porphyry type mineralization to brecciated ore pipes and stock-work and vein ores (Sillitoe, 1980, 1985). Porphyry-copper deposits are not characteristic to ignimbritic volcanic activity with cauldron subsidence (Sillitoe, 1980).

The most significant Kuroko type deposits widespread in Turkish Pontides in the Eastern region of the Black sea shore are Murgul, Lahanos, Kulalar and Madenköy copper-pyrite and lead-zinc deposit. All of them are located in the rhyo-dacitic volcanics and they are of Kuroko type (Engin, 1994). They are controlled by the rhyolitic and rhyodacitic domes and represent stratiform massive sulphide ores of submarine origin and Kuroko type mineralization.

Hence, it is evident that Bolnisi mining district deposits Madneuli and Tsiteli-Sopeli by mode of their origin are definitely distinguished from typical porphyry-copper deposits, as well as from typical Kuroko type. As it was shown by Sillitoe (1980) porphyry copper deposits are not characteristically related to the ignimbritic volcanic activity and are mainly related to dioritic (andesitic) magma chambers. Typical Kuroko type deposits are always related to postcauldron subsidence and to the formation to postignimbrite rhyolitic domes. Diagramatic cross-section of the Japanese Kuroko deposit after Russel (1993) is given in Fig., 16. Its difference from Madneuli deposit is evident. On the other hand the Madneuli deposit differs also from porphyry-copper deposits. Porphyry type ores and any relics of stratovolcano are absent here. It is related to felsic magma chamber which subsequently produced ignimbritic volcanic activity.
We believe our studies prove that the Madneuli deposit is a new preignimbrite and precauldron type connected to felsic magmatic chamber and originated in a subaerial condition developed on the subduction zone. We continue to search for further examples of this type which we have named as the Bolnisi type.

ACKNOWLEDGMENT

We acknowledge with gratitude for advices of our Turkish colleagues İsmail Hakkı Güven, Murat Er, İbrahim Aydın and Mustafa Karabıyıköğlu from MTA. We are very grateful to Dr. Güner Ünalan for help and support in our studies.

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Fig. 1 Location map of the Bolnisi ore area.
Fig. 3 Metallogenic scheme of the copper-pyrite, lead-zinc, gold and silver deposits of the Lesser Caucasus, Turkey Balkans and Carpats: I. Karpathian zone, II. Artvin-Bolnisi, Turkish Pontides, Bulgarian Srednegora zones, III. Anatolids, IV. Taurids, V. Ophiolitic outcrops. 1. Copper-pyrite, 2. Lead-zinc, 3. Silver, 4. Gold.
Fig. 4 Geological map of the Murgul group mine deposits of Turkey (After Er, 1994).
Fig. 5 Schematic map of the Late Cretaceous-Eocene and Neogene-Quaternary magmatic outcrops in the Carpatho-Balkans arc (After Boccaletti et al., 1973):

a) Late Cretaceous-Eocene (Banatitic) rocks;
b) Neogene-Quaternary rocks;
c) Carpathian folded arc and Balkan and Srednegora zones (Bulgaria).

1) Stiavnica Horst; 2) Northern Apuseni Mountains; 3) Drocea Mountains; 4) Poiana Rusca Mountains; 5) Banat; 6) Timok; 7) Sofia region (Western Srednogora); 8) Panagyurishte (Central Srednogora); 9) Yambol-Burgas (Eastern Srednogora); 10) Central Slovakia; 11) Borsony-Dunazug; 12) Cserhat-Matra-Bukk; 13) Tokay-Presov; 14) Transcarpathia-Vihorlat; 15) Oas-Gutii Mountains; 16) Metaliferi Mountains; 17) Calima-ni-Harghita; d) Copper-lead-zinc deposits (Chelopech, Medet-Bulgaria, Bor, Maidan Peck-Yugoslavia, Moldova Nouva-Romania).

Fig., 7 Geological map of Medet deposit (After Bogdanov, 1986): 1. gneiss, 2. Srednegora granites, 3. quartz-gabbro-diorites, 4. granodiorites, 5. quartz monzonites, 6. grano-diorite porphyry, 7. Srednegora granites contact zone alteration.
Fig. 8 Geological map of the Bor-Maidanpeck ore area (After Milicic and Grujucic, 1979).
Fig. 9 Cross section of the Bor area (After Milicic and Grujicic, 1979).
Fig., 11 Paleovolcanological Sketch map of the Bolnisi Volcano- Tectonical depression (Bolnisi ore district):
Fig. 13 Geological map of Madneuli deposit and its I-I’ cross section: 1. ignimbrites (aglutinates); 2. felsites; 3. rhyodacites; 4. andesites; 5. granodiorites; 6. fine grained, layered dacitic tuffs; ores: 7. barite; 8. barite-base-metal; 9. copper-pyrite; 10. pyrite; 11. gypsum; 12. quartz-muscovite metasomatic rocks; 13. secondary quartzite; 14. argillite; 15. orewall adularization; 16. orewall alunite-jarosite-hydromica metasomatics; 17. orewall chlorite-carbonate metasomatics; 18, 19. faults; 20. steps of the open mine; 21. wells numbers.
Fig. 15 Sketch of paleogeographic development of Madneuli deposit: 1. Ignimbrites (K\textsubscript{2} st\textsubscript{1}), 2. Tephroites (K\textsubscript{2} t\textsubscript{1}), 3. Andesite-dacitic tuffs (K\textsubscript{2} st\textsubscript{1}), 4. Pumice tuffs (K\textsubscript{2} t\textsubscript{2} - st\textsubscript{1}), 5. Andesitic tuffs alternates with limestones (K\textsubscript{2} cm), 6. Rhyolitic extrusions, 7. Granodiorite, 8. Micaceous and silification, 9. Secondary quartzites, 10. Argilizites, 11. Tuff-conglomerates, 12. Pyrite and copper-pyrite ores, 13. Lead-zinc-barite ores, 14. Barite, 15. Pyritization, 16. Chloritization and carbonatization, 17. Faults.
Fig. 16 Diagrammatic cross-section of a Kuroko deposit (After Russel, 1993).