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Hybrid nature of the Madneuli Cu-Au deposit, Georgia

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Abstract. The Madneuli Cu-Au deposit possesses a number of characteristics that are, in part, typical of Kuroko type VMS deposits and in part resemble volcanogenic epithermal gold deposits. It is recognized to be hybrid in character and is therefore assigned to the VMS-epithermal transition.

Key words: VMS-epithermal transition, hybrid, Madneuli deposit

Introduction

The Madneuli deposit is currently the only Cu-Au producer in Georgia, and has been mined for more than 30 years. The deposit is hosted by subduction-related Upper Cretaceous volcanic rocks. Its origin is controversial and previous opinions have included both epigenetic and syngenetic ideas. This contribution presents an analysis of hybrid nature of the Madneuli deposit.

General description

The Madneuli deposit is located in Southern Georgia in the Artvin-Bolnisi (AB) Unit of the Transcaucasus, which was formed in the framework of an active margin of the Eurasian continent (Yilmaz et al., 2000) (Fig. 1). The AB is characterized by Hercynian basement, unconformably capped by the Upper Carboniferous molasse and an Upper Jurassic-Cretaceous arc association. This unit is bordered to the north by the Southern Black Sea Coast-Achara-Trialeti Unit (Santonian-Campanian back-arc association) and to the south by the imbricated Bayburt-Karabakh Unit (Upper Jurassic-Cretaceous forearc association).

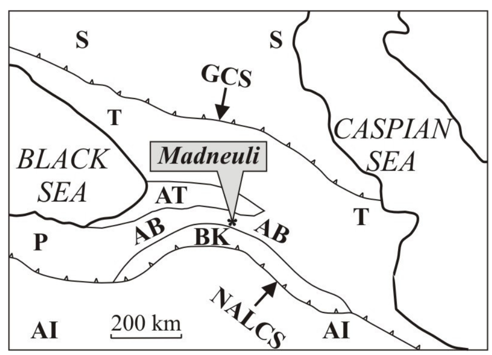

Fig. 1 Location map of the Madneuli deposit (adapted from Yilmaz et al., 2000). Abbreviations: S – Scythian Platform; GCS – Greater Caucasus Suture; T – Transcaucasus; AT – Southern Black Sea Coast-Achara-Trialeti Unit; AB – Artvin-Bolnisi Unit; P – Pontides; BK – Bayburt-Karabakh Imbricated Unit; NALCS – North Anatolian-Lesser Caucasian Suture; AI – Anatolian-Iran Platform

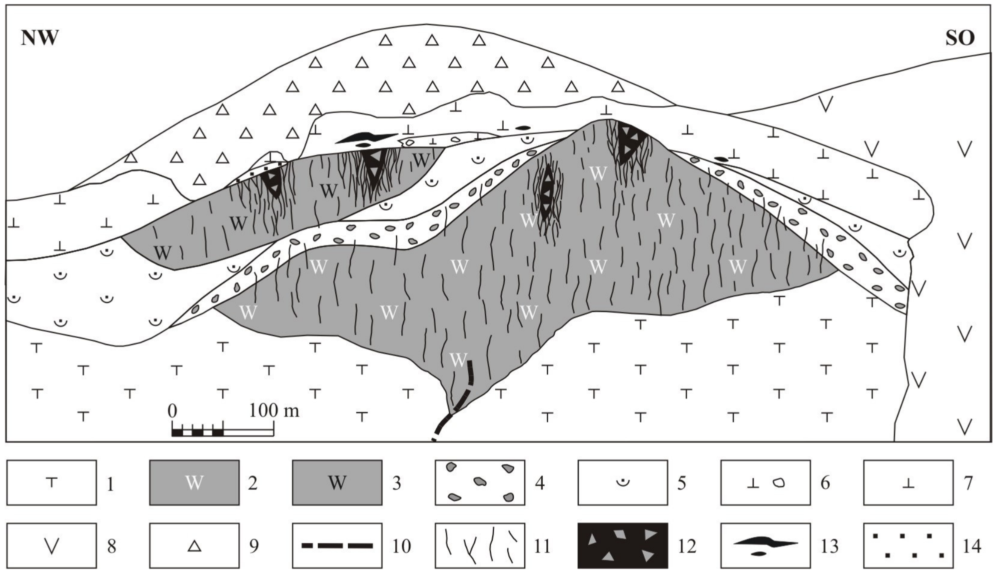

Fig. 2. An idealized section through the Madneuli deposit. Sizes of ore bodies are enlarged. 1 – Tuff hosting lower lens; 2 - Silica-rich lower body; 3 - Silica-rich upper body; 4 - Breccia-conglomerate; 5 – Tephroid; 6 – Tuffconglomerate-tuffbreccia; 7 – Tuff with pisolitic interlayers; 8 – Rhyodacitic extrusion; 9 – Ignimbrite; 10 – Inferred fault; 11 - Vein-disseminated ore; 12 - Breccia ore; 13-14 – Stratiform ores: 13 - Massive sulphide ore; 14 – Barite ore

The section of the Madneuli deposit is mainly built of pyroclastic rock strata capped by rhyodacitic ignimbrite cover, as well as an extrusive body of rhyodacitic composition (Fig. 2). There are two silica-rich bodies within the deposit, occupying distinct stratigraphic levels (Migineishvili, 2000). In the lower of these, the following alternation zones are identified from top to bottom: quartz-opal, quartz-sericite, and quartz-sericite-chlorite (Gogishvili, 1980). This body is overlain by a breccia-conglomerate apron which contains tuff debris, as well as debris of the lower silica-rich body. The upper silica-rich body is characterized by stratiform morphology and is conformable with host pyroclastic rocks. It mainly consists of quartz-opal aggregate. Silica-rich bodies also contain minor chalcedony, alunite, kaolinite, pyrophylite and jarosite.

Formation of both silica-rich bodies predates the ore-forming process. Presumably, the lower one arose as a sub-seafloor replacement, whereas the stratiform one may be formed through recrystallization of amorphous cherts accumulated on the seafloor (Migineishvili, 2000; 2004). Some minerals (alunite, jarosite, etc.) appear to have been introduced later, during ore-forming process to form near-ore metasomatites.

Beneath the Madneuli deposit, at a distance of 800-900 m below the present day surface, there is an intrusive body of granodiorite-porphyry and quartz-diorite-porphyry compositions. K-Ar dating yields synvolcanic ages of 88 Ma (Gugushvili and Omiadze, 1988).

Lithofacies architecture of the Madneuli deposit shows some intermittent phases of local uplifts and subsidence occurred in relatively shallow water setting (<200 m) to form its dome structure (Migineishvili, 2001; 2002).

The deposit contains both epigenetic and syngenetic portions of ore mineralization (Magalashvili, 1991; Migineishvili, 2000, 2004). The former holds the most part of the Cu-Au reserve and is formed by vein-disseminated and breccia ores. Breccia ores are thought to be formed by fragmentation of host silica-rich bodies due to boiling of hydrothermal solutions. Epigenetic ore is mainly confined to silica-rich bodies, what is caused by high fragility and fissuring of these bodies. In the lower silica-rich body quartz-pyrite-chalcocite-covellite-chalcopyrite ore prevails, whereas the upper one contains a quartz-pyrite-barite-sphalerite-chalcopyrite-galena assemblage. Syngenetic ore mineralization is comparatively small in scale and is situated on the top of epigenetic ore zone. At the deposit there are syngenetic stratiform orebodies with the following compositions: barite send, porous-spongy quartz-barite, banded quartz-barite, massive barite-sphalerite-pyrite.

Besides the main ore-forming minerals the following less-common minerals are identified at the deposit: brongniardite, tetradymite, aikinite, pavonite, emplectite, bismuthine, enargite, tennantite, freibergite, tetrahedrite, calaverite, krennerite, petzite, dyscrasite, bournonite (Kakhadze, 1963; Janjgava, 1966; Nazarov, 1966). These minerals occur in close association with chalcopyrite, but paragenetically were introduced later.

Two generations of gold are established (Geleishvili, 1990): (1) early fine gold is coeval with main sulphides, and (2) later gold formed after the main sulphides and presented by native gold in close association with rare-metal group minerals (sulphobismuthides and tellurides) and thread-like (1-2 mm thick) veinlets of bluish-greyish quartz, widespread in silica-rich bodies. The latter represents the major part of the gold mineralization.

In ores of Madneuli deposit a significant selenium concentration (1-20 ppm) has been revealed. It isomorphically enters into the lattices of sulphides (Janjgava, 1966).

Grades of the 80.5 Mt of copper ore reserve in the deposit are as follows element: Cu – 0.39-1.28% (522,258 t); Au – 0.73 g/t (5.77 t); Ag – 4.31 g/t (34 t); Se – 7.1 g/t (104 t); Te – 7.59g/t (115 t). The thread-like quartz veinlets in silica-rich bodies host 10.9 Mt of gold ore containing Au – 1.8 g/t (48.3t); Ag – 9.15 g/t (100 t) (Tvalchrelidze, 1998).

Fluid inclusions in quartz, pyrite, chalcopyrite, galena and barite from various mineralogical zones of the Madneuli deposit are characterized by δD values ranging from -68 to -83‰. Values of $\delta^{18}O$ vary from the basal Cu-rich zone (+3.9‰ in a crystal lattice of quartz) into the barite-polymetallic zone (-1.53‰ in a crystal lattice of barite) (Arevadze et al., 1983). Arevadze et al. (1983) suggested that a likely origin for these isotopic compositions is magmatic water that mixed with meteoric water at the level of barite-polymetallic zone.

δS^{34} values in sulphides vary from -9 up to +6‰, whereas sulphates have δS^{34} values very close to that of coeval sea water sulphate – from +10 up to +20‰ (Tvalchrelidze et al., 1972; Ivanitski et al., 1975; Buadze and Kaviladze, 1976; Arevadze et al., 1983). Tvalchrelidze et al. (1972) considered that a major part of sulphur has a juvenile origin, and a source for sulphate sulphur is seawater. Arevadze et al. (1983) supposed that sulphur was derived from a magmatic source and at the upper level of the deposit it underwent a partial oxidation due to mixing with meteoric water.

Isotopic data, as well as paleoenvironment of this deposit (synvolcanic intrusion and a transitional submarine-subaerial setting) suggest that the components of ore-bearing fluids could be derived from a complex combination of the following heterogeneous sources: (1) a crystallizing magma of synvolcanic intrusive; (2) host volcanic rocks; (3) meteoric water; (4) coeval seawater (Migineishvili, 2004).

Discussion and conclusion

By its geotectonic position, as well as the composition of the host volcanic rocks, the Madneuli deposit is similar to Kuroko type VMS deposits (KTVMSD), as well as to volcanogenic epithermal gold deposits (VED), which are associated with calc-alkaline volcanism of subduction zones.

The fact that syngenetic ores are present makes the Madneuli deposit similar to KTVMSD. Unlike them, however, at Madneuli: (1) syngenetic bodies are represented only by barite and barite-polymetallic ores, and the economic copper ores are hosted only by epigenetic portion of mineralization; (2) major part of ore mineralization is not confined to syngenetic bodies, but rather to the larger epigenetic ore mineralization.

In terms of the mineral composition of main sulphide and sulphate ores (formed in the course of a thermal intensification of ore-forming hydrothermal system), the Madneuli deposit is similar to KTVMSD. The mineralogy of the rare-metal group minerals (sulphobismuthides and tellurides) containing the late gold (formed after the thermal maximum of this system, i.e. in an epithermal stage of ore-forming process), however, makes the Madneuli deposit more like a Au-bearing VED deposit. The presence of both enargite and tennantite in this ores, as well as alunite in the near-ore metasomatites, stresses the strong resemblance of the Madneuli deposit to high sulphidation Au-bearing VED.

Hashiguchi (1983) established that formation of dome-shaped structures of some KTVMSD occurs in connection with processes of rhyolite extrusion, which took place during, and also after the ore-forming process (penecontemporaneous deformation). The dome-shaped structure in the Madneuli deposit was formed as a result of intermittent phases of local uplifts and subsidence occurred during and after the formation of ore and non-ore mineralization (penecontemporaneous deformation). These movements might be governed by a dynamic influence from a synvolcanic high-level felsic intrusion, situated beneath the deposit (Migineishvili, 2001; 2002). Therefore, in this respect, certain analogies can be drawn between the Madneuli deposit and KTVMSD.

Like KTVMSD, the syngenetic ores of the Madneuli deposit occupy certain stratigraphic levels, but, on the other hand, morphological features of its large-scale epigenetic mineralization resemble VED.

'Ordinary' KTVMSD are formed in deep-water oceanic conditions. Unlike these, however, the Madneuli deposit has been formed in a coastal shallow sea environment, in a transitional submarine-subaerial setting.

Similar to both KTVMSD and VED, the hydrothermal system of the Madneuli deposit was driven by the heat engine represented by the subjacent synvolcanic intrusion.

Unlike in most KTVMSD, meteoric water was incorporated in the hydrothermal system of the Madneuli deposit, but unlike VED, which formed in subaerial settings, a contribution of seawater is also established.

In contrast to KTVMSD, but similar to VED, the boiling of hydrothermal solutions is one of the mechanisms involved in precipitation of Madneuli's ores.

Thus, the Madneuli deposit possesses a number of characteristics that are, in part, typical of KTVMSD, and in part resemble those of VED. Nevertheless it differs from KTVMSD/VED in a number of important attributes. Therefore, the Madneuli deposit cannot be assigned readily to either deposit type.

A number of ore deposits elsewhere in the world have been recognized as transitional in character between submarine base metal massive sulphides and volcanogenic gold deposits in the epithermal environment. These have been named VMS-epithermal transition deposits (Hannington et al., 1999; Hannington and Herzig, 2000).

Upon analysis of the above-stated material one can ascribe the Madneuli to VMS-epithermal transition deposits.

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