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# Geological setting and lithological controls of breccia-hosted Cu-Au ore at the Late Cretaceous Kvemo Bolnisi prospect, Bolnisi, Lesser Caucasus, Georgia

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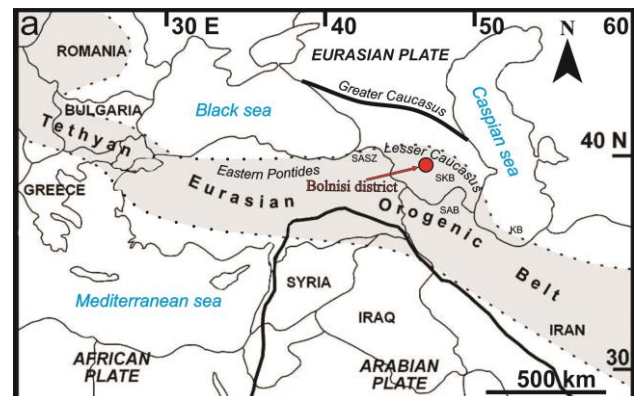
**Abstract.** Detailed field mapping and drill core description was undertaken at the Kvemo Bolnisi prospect located in the Bolnisi ore district, of the Lesser Caucasus, in Southern Georgia. This study facilitated the distinction between the main host rock facies units and understanding of the lithological control to copper-gold mineralization. The base of the oxidation zone controls the distribution of supergene gold and underlying copper mineralization in upper non-welded permeable ignimbrite, while the lower welded fiamme ignimbrite hosts copper ore mostly within the cross cutting the polymictic breccia pipe. The columnar jointed, post-ore dacite body represents the final volcanic event in this area.

## 1 Introduction

The Bolnisi ore district belongs to the renowned 10,000 km-long Tethyan Eurasian Metallogenic Belt (TEMB; Fig. 1; Jankovic 1997). The Kvemo Bolnisi Cu-Au mineral deposit is part of the Artvin-Bolnisi unit of the TEMB located in the northern part of the Lesser Caucasus. The Bolnisi district host numerous producing Late Cretaceous ore deposits, including the Madneuli, Sakdrisi, Beqtakari Cu-Au and polymetallic deposits. Kvemo Bolnisi breccia-hosted Cu-Au deposit is located at a distance of 6 km from the Madneuli deposit, which produced approximately 85 Mt of copper and gold bearing ore, at a reported grade of 1.0g/t Au and 1.0% Cu, over a period of 30 years. At Kvemo Bolnisi, the resources have been estimated as 947,000 tones at an average grade of 0.93 Cu and 0.15 g/t Au. ([https://polaris.brighterir.com/public/georgian\\_mining\\_corporation/news/news\\_rns/story/w0eq36r](https://polaris.brighterir.com/public/georgian_mining_corporation/news/news_rns/story/w0eq36r)).

New exploration programs are going on in Georgia and new prospective ore zones are investigated by

RMG (Rich Metals Group) company, including Bnelikhevi, David Gareji, and Mushevani. The Kvemo Bolnisi prospect represents the highest priority target for exploration by the Georgian Mining Corporation, which

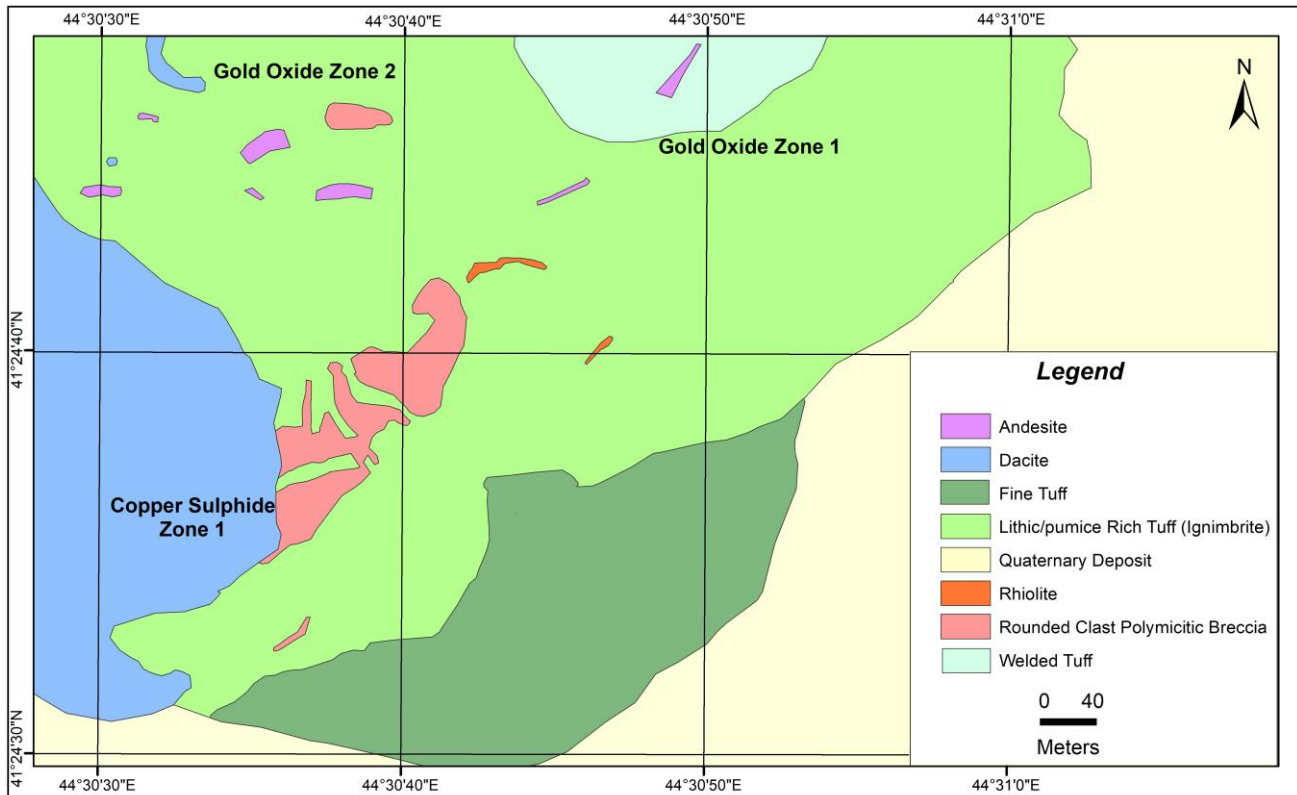


**Figure 1.** Location of the Bolnisi district within the Tethyan orogenic belt (modified from Yigit, 2012). Abbreviations: SAB – South Armenian block; SASZ - Sevan-Akera suture zone; SKB – Somkheto-Karabagh belt; KB - Kapan Block.

also has the Dambludi, Tseteli Sopeli, Tamarisi and Balichi prospects under investigation. The main aims of our work are to understand the lithological and structural controls for the development of the main ore zones in order to understand the distribution and anatomy of the Cu-Au mineralization.

## 2 Regional geology and stratigraphy

The Lesser Caucasus extends over the territories of Armenia, Azerbaijan and Georgia. It consists of three



**Figure 2.** Simplified geological map of the Kvemo Bolnisi prospect. Modified from Davies (2017), Georgian Minong Corporation) (unpublished material)

tectonic zones (Sosson et al. 2010), which are from SW to NE: (1) the South Armenian Block (SAB), (2) the Amasia-Sevan-Akera suture zone (ASASZ) and (3) the southern Eurasian plate margin consisting of the Somkheto-Karabagh belt (SKB) and the Kapan block (KB) (Fig. 1). The Somkheto-Karabagh belt is known in Georgia as the Artvin-Bolnisi zone (Yilmaz et al. 2000). The host rocks for the ore deposits and prospects in the Bolnisi district are composed of Late Cretaceous volcanic and volcano-sedimentary rocks emplaced into a depression between the basement rocks of the Khrami and Loki massifs (Zakariadze et al. 2007). Predominant Late Cretaceous volcanic and pyroclastic rocks in this region include rhyodacitic ignimbrite, ash fall and density current deposits with a phreatomagmatic origin (Popkhadze et al. 2017). The distribution of rhyodacitic to basaltic lava domes has led to speculation that a central caldera may have played a role in the localization of the Cu-Au exploration prospects in the vicinity of Kvemo Bolnisi. Based on lithological and paleontological data, Late Cretaceous volcanic and volcano-sedimentary rocks in this region are subdivided into six volcanogenic suites, and are Cenomanian to Campanian and Maastrichtian in age (Gambashidze 1984). Ore deposits in this region are associated with Late Cretaceous explosive volcanic events in different stratigraphic levels. According to Gugushvili (2004), deposits/prospects from the eastern part of the district, including: Madneuli, Kvemo Bolnisi, Tsiteli Sopeli, Mushevani and David-Gareji are hosted by

stratigraphically older rocks of the late Turonian to early Santonian Mashavera suite. A second group of ore deposits/prospects, including: Sakdrisi, Darbazi, Imedi, Beqtakari, Bnelikhevi and Samgereti are hosted by stratigraphically younger rocks of the Campanian Gasandami suite.

### 3. Geology of Kvemo Bolnisi

#### 3.1 Host rock facies architecture of the Kvemo Bolnisi prospect

This study has focused upon the physical volcanology and facies analyses during a mapping program, together with detailed drill core logging and interpretations. The complete data set including correlation of outcrop and drill core samples allows us to distinguish the following facies types in Kvemo Bolnisi area: lithic/pumice-rich tuff or non-welded ignimbrite, fine-grained tuff, columnar-jointed dacite dome, polymictic breccia, a bedded volcano-sedimentary sequence and welded ignimbrite. The detailed description and interpretation of the Kvemo Bolnisi east polymictic breccia pipe allow us to constrain the stratigraphy of the host rocks of this area (Fig. 2). The stratigraphically upper lithic/pumice tuff is strongly oxidized, fractured and in some areas silicified. The highly porous, permeable and glassy pumice/lithic tuff was affected by pervasive argillic (illite) alteration (Fig. 3a). During the petrographic investigation, it was difficult to recognize pumice or lithic clasts in the tuff, as they

are affected by argillic alteration. In some places, remnants of pumice clasts were identified. The lower stratigraphic unit consists of welded (fiamme) ignimbrite (Fig. 3b). In some cases, this fiamme might be considered as a fiamme in secondary welded pumice-rich facies, produced by secondary welding of pumice-rich clastic facies. The formation of such fiammes is possible in contact with hot lava or an intrusion. Sometimes, fiamme produced by secondary welding of fiamme-rich clastic facies are virtually indistinguishable from fiamme in conventional primary welded pyroclastic facies (McPhie and Hunns, 1995).



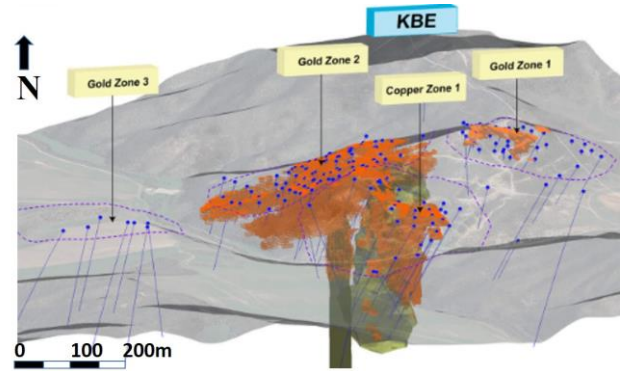
**Figure 3.** The host rock architecture from KB area: a - lithic/pumice-rich tuff; b - welded (fiamme) ignimbrite; c - fine and medium-grained, bedded volcano-sedimentary tuff, with classical slide-slump units; d - mineralized polymictic breccia; e - margin of breccia pipe showing the mixture of wall rock - with breccia clasts.

The fine- and medium-grained, bedded volcano-sedimentary tuff, with classical slide-slump unit crop out at the contact with non-welded ignimbrite and might be interpreted as an older stratigraphically unit in this sequence (Fig. 3c). The mineralized polymictic breccia pipe is cross-cutting all previously mentioned host rock sequences, including felsic dikes (Fig. 3d). While a columnar-jointed post-ore dacite dome represents the last volcanic event in the Kvemo Bolnisi area (Fig. 3e). The polymictic breccia pipe crops out in the western part of the Kvemo Bolnisi prospect, as a matrix-rich to clast-supported breccia of well rounded, milled clasts of fine tuff, less silicified ignimbrite, and also clasts of felsic dikes and other silicified clasts. In the Kvemo Bolnisi the polymictic breccia pipe margin is discernible in outcrop and drill hole intercepts as a mixture of wall rock – lithic/pumice tuff (ignimbrite) with breccia clasts (Fig. 3f).

### 3.2 Ore zones and lithological controls at Kvemo Bolnisi

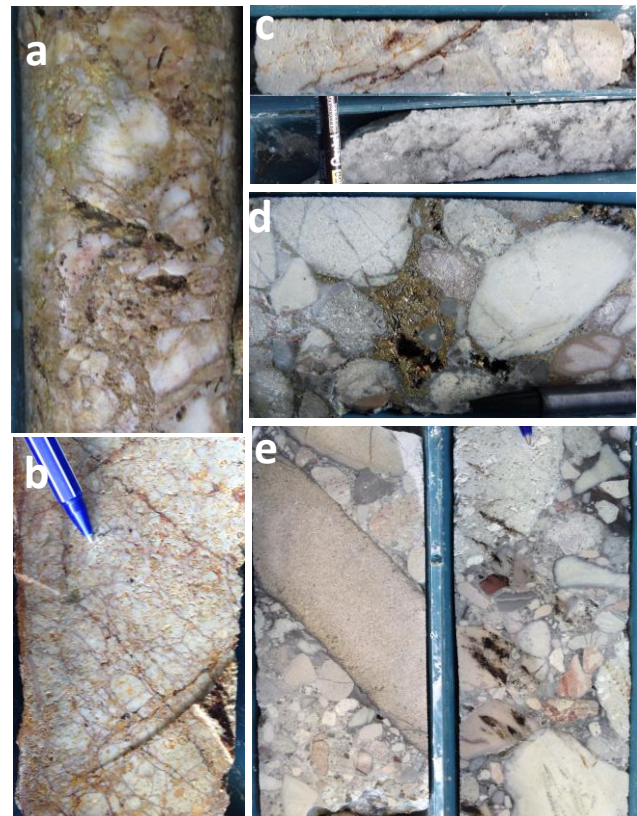
The Kvemo Bolnisi project includes different ore zones, including (Fig. 4): Kvemo Bolnisi west, which is the gold zone 3 characterized by polymetallic-gold-silver mineralization; Kvemo Bolnisi south, which includes the copper zone 1, where the breccia pipe and other structures are identified. Gold zones 1 and 2 represent

the gold oxide ore, developed from the surface to the base of the oxidation zone, between a depth of 40 and 70m (<https://www.georgianmining.com/projects/>).



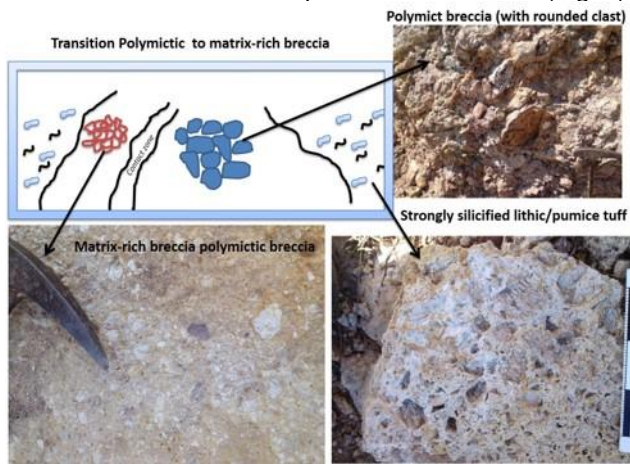
**Figure 4.** Model of the Kvemo Bolnisi prospect, including different copper and gold mineralized zones (Source: Georgian Mining corporation).

The gold zones 1 and 2 represent the upper stratigraphic level, consist of strongly oxidized lithic/pumice tuff (non-welded ignimbrite) with shallow supergene Au mineralization (Fig. 5a, b).



**Figure 5.** Characteristic features of ore at the Kvemo Bolnisi copper-gold prospect: a,b strongly silicified, crackle fractured lithic/pumice tuff cross cut by quartz-iron oxide veinlets; c – iron oxide veinlet above the redox boundary zone with chalcocite in the transition zone; d – clast-supported open space polymictic breccia filled with quartz-pyrite-chalcopyrite; e – clast-supported subrounded to rounded breccia. Pyrite and chalcopyrite are in the matrix.

This zone extends down to the base of the oxidation zone, which is clearly identified in nearly all drill holes. Chalcocite is present coating pre-existing sulphides and veinlets in the transition zone below the base of oxidation (Fig. 5c). The copper zone 1 includes the welded fiamme ignimbrite of the lower stratigraphic unit, below the redox boundary, with copper-gold and mostly with copper mineralization and the mineralized polymictic breccia (Fig. 5d, e). The breccia (Fig. 5d) contains rounded to sub-rounded, mostly silicified and mineralized clasts of pumice tuff. Some clasts host vein mineralization formed prior to brecciation which does not extend in the matrix. The open space in the polymictic breccia between the clasts is filled by a magmatic hydrothermal ore assemblage including quartz, pyrite and chalcopyrite. Relationships in outcrop suggest there is a transition from the central polymictic breccia with rounded clasts, to a matrix-rich portion, followed by a contact with the silicified pumice tuff host rock (Fig. 6).



**Figure 6.** The scheme showing the transition zone from clast-rich to matrix-rich polymictic breccia and contacts with lithic/pumice tuff.

The transitional breccia is less silicified and more affected by argillic alteration, and it contains a juvenile clast.

## 4 Conclusions

The permeability of host rock units in the Bolnisi district, including: non-welded ignimbrite, lithic/pumice tuff and different types of breccia, provides a favorable environment for fluid migration and ore formation. The existence of mineralized polymictic breccia in the Kvemo Bolnisi area provides an attractive exploration target. Different stages of ore formation and fluid migration are overprinted in polymictic breccia. Most of the clasts in this breccia are mineralized, which indicates there has been an early stage of ore formation which is overprinted by a later breccia infill mineralization. The breccia pipe is interpreted to have evolved from a magmatic hydrothermal to a more phreatomagmatic nature with an associated change in mainly breccia matrix-hosted mineralization low sulphidation Cu-rich quartz-sulphide Au±Cu style to Au rich carbonate-base metal Au mineralization, as typical of these types of

breccia deposits. The key controls on the mineralization is the breccia pipes, which are mineralized with hypogene auriferous pyrite and chalcopyrite. In the supergene environment the sulphides are oxidized giving rise to a classic sequence of oxidized and enriched gold mineralization where copper mineralization is mobilized and redeposited at the base of oxidation giving rise to strongly enriched chalcocite mineralization overprinting primary sulphides.

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