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Conference Paper

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Publication date:
2003-08

Permanent link:
https://doi.org/10.3929/ethz-b-000052302

THE MAGMATIC TO HYDROTHERMAL TRANSITION: MIOCENE DEVA PORPHYRY COPPER-GOLD DEPOSIT, SOUTH APUSENI MTS, ROMANIA

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ABSTRACT: The Deva copper-gold deposit represents the richest porphyry-type ore deposit in the Miocene South Apuseni Mountains metallogenic district, West Romania. It consist of cylindrical 0.5 km diameter breccia hosted subvolcanic stock, that is mineralized over more than 1 km vertically, most of which is mined to date. The mineralisation is associated with the latest Hbl-Bt andesite and consists of bornite-cpy-mgt stringers and impregnations, producing ore grades as high as 2 wt-% Cu. Detailed petrography together with field observations have allowed to define the evolutionary sequence of events. This forms the basis to constrain the chemical evolution of this magmatic-hydrothermal system on the basis of EMP, microthermometric and LA-ICPMS analyses of phenocrysts, hydrothermal mineral parageneses and silicate and sulphide melt and fluid inclusion assemblages that are currently in progress. These data will be used to reconstruct the magmatic to hydrothermal evolution of the rich Deva porphyry-Cu-Au deposit and help in determining the key-processes responsible for the genesis of highly economic porphyry-type ore deposits.
Keywords: calc-alkaline, porphyry Cu-Au, bornite, melt and fluid inclusions, LA-ICPMS, Deva, Apuseni

INTRODUCTION

Processes in magma chambers beneath volcano-plutonic centers such as magma mixing, saturation of a sulphide melt or of a magmatic volatile phase play a key role in determining whether or not a rich porphyry-type ore deposit may form (e.g., Cline and Bodnar 1991, Halter et al. 2002,), besides the chemistry of the magmas themselves, notably initial ore metal and chlorine contents (e.g., Audetat and Pettke, 2003). The large-scale tectonic framework on the other hand is essential in determining where ore districts may actually form (e.g., Tosdal & Richards 2001) as exemplified by the Cu-Au ore district of the Apuseni Mountains in Romania.

Our study focuses on the Deva porphyry-Cu-Au deposit and related magmatic system as an example of a rich Miocene deposit in the Apuseni Mountains. Unequivocal magmatic affiliation and minimal overprint make the Deva system very suitable for a detailed study of the magmatic-hydrothermal transition in porphyry-type ore environments. A detailed sequence of the intrusive events together with a paragenetic succession of melt and fluid inclusion assemblages associated with the porphyry mineralisation forms the basis for our LA-ICPMS analytical work on single melt and fluid inclusions. The chemical evolution of the entire magmatic-hydrothermal system then allows discussion of the magmatic processes that may prove essential for the formation of rich porphyry-type ore deposits.

GEOLOGICAL SETTING

The Deva porphyry-type ore deposit is located in the southern part of famous South Apuseni Mountains Neogene ore district, also known as "Gold Quadrangle", with continuous mining activity from pre-roman times. Similar porphyry Cu-Au systems are ubiquitous in the area (e.g., Bolcana, Rosia Poeni, Valea Morii, Musariu, Rovina, Tarnita, Voia) and related to calc-alkaline Hbt ± Bt andesite-microdiorite porphyries. High sulphidation and intermediate to low sulphidation epithermal systems generally occur as steep vein arrays (e.g., Barza, Musariu-Dealu Fetii, Trestia-Troita, Hanes-Larga, Bucium-Arama) or as disseminated breccias (e.g. Rosia Montana, Bocsa, Metesan), both of which are spatially and genetically related to Miocene volcano-plutonic activity (Udubasa et al. 2001, Ivascanu et al. 2002).

The South Apuseni Mountains district represent an internal realm of the Carpatho-Pannonian Cenozoic calc-alkaline belt the paleoposition of which is controversial. This district could have been as far as 200 km behind the Carpathian subduction front. As for several other "internal magmatic fields" of the belt (e.g., Central Slovakian Volcanic Field, Matra Mountains) the emplacement of magmatic rocks and associated porphyry type and epithermal deposits is controlled by strike-slip to pull-apart tectonic features in response to collision and microplate rearrangements (Drew & Berger 2001).

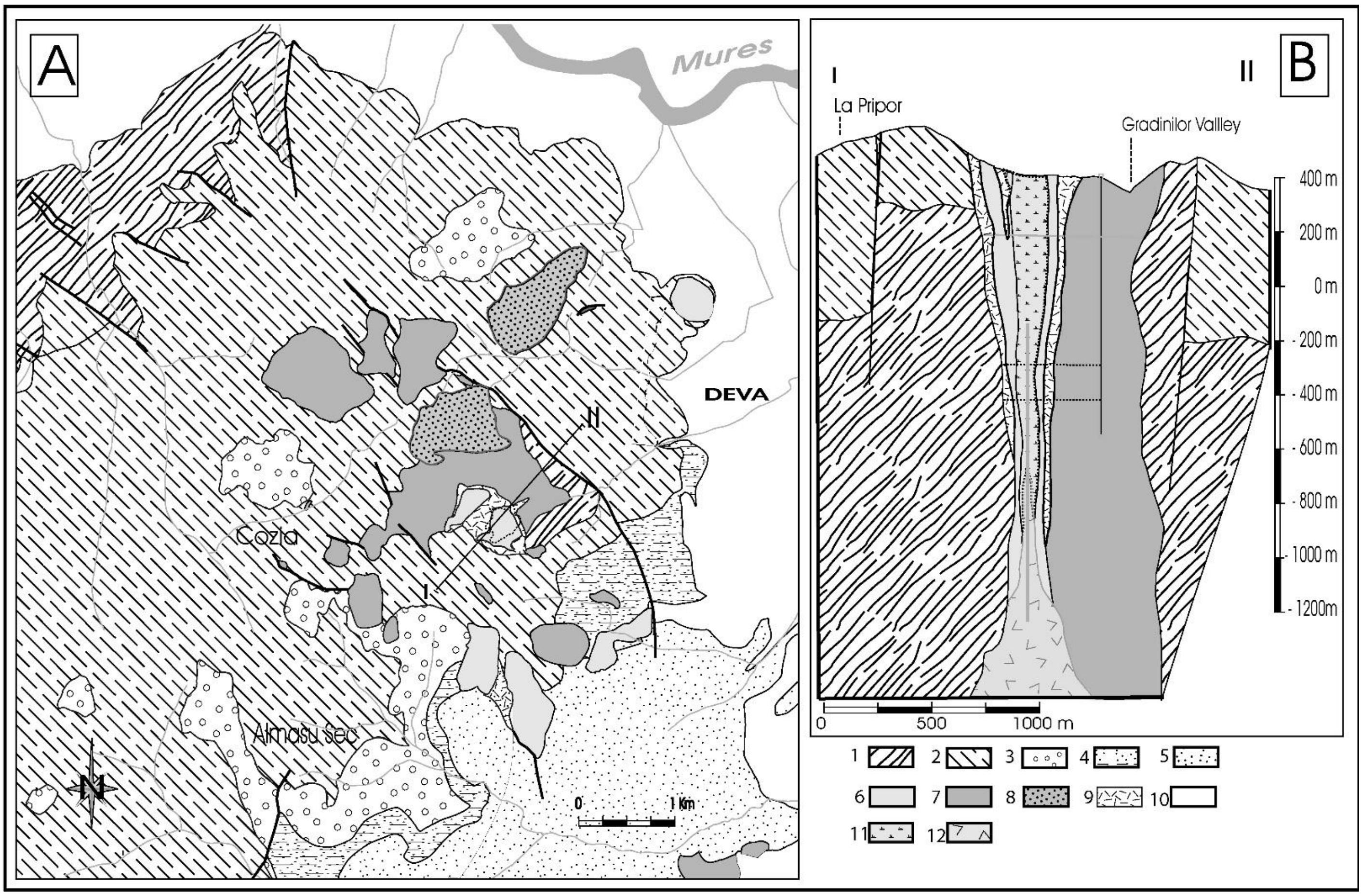

Figure 1. A - Geological map of the Deva magmatic structure (modified after Bostinescu & Savu 1996). **B**- Schematic cros-ssection of the ore deposit. 1) metamorphic basement (Paleozoic), 2) sedimentary cover (Kretacic), 3) basin sediments (Lower Miocene), 4) basin sediments (Middle Miocene), 5) basin sediments (Upper Miocene), 6) Hbl + Bt andesite, 7) Hlb ± Bt andesite, 8) Hbl plagioclase porphyry, 9) polymictic igneous breccia, 10) Quaternary, 11) economic limit (~1% Cu) of Deva porphyry copper-gold deposit and 12) microdiorite porphyry (transitional).

In the South Apuseni Mountains area several basins hosting volcano-plutonic structures have been recognized (e.g., Rosia Montana- Bucium, Zlatna, Brad-Sacaramb, Zarand, Deva-Mures).

The Deva intrusive complex consists of subvolcanic bodies and stocks, intruded in Paleozoic crystalline schists and Mesozoic clastic sediments, that form a ~30 km^2 large ring-like structure, hosting the porphyry Cu-Au deposit in its center (Fig. 1, A). This configuration suggests the presence of a feeder magma chamber at depth. Deep drilling reveal the presence of a dioritic pluton at depth that gradually changes into andesite to porphyry microdiorite (Bostinescu & Savu 1996). Microdioritic xenoliths are widespread in the later andesitic intrusions. Intrusive contacts are often brecciated.

The basement to the Deva complex is formed by Carboniferous-Devonian Pades series, representing the north-eastern extension of the Poiana Rusca Massif. It consists mainly of quartz-sericite and quartz-sericite-chlorite schists, with rare intercalations of marbles and graphitic schists. The crystalline basement is covered by a ~400 m thick middle to upper Mesozoic sedimentary formation, known as the “Deva Strata”, which consists of a marl-sandstone sequence, discordantly overlain by coarse-grained Lower Miocene (?) sediments (pebbles, marls, sandstones) and by Middle to Upper Miocene marls, clays, marly limestones, sands, gravels and tuffs.

The tectonic position of the Deva magmatic structure is peculiar because it is situated south of the main transcrustal shear zone of Mures Valley, separating ophiolitic sequences of the former Tethyan ocean from the Poiana Rusca Massif that hosts the Deva complex. It is north of this lineament where all the other mineralized intrusive complexes of the Apuseni Mountains are situated, suggesting that most of the transform fault activity predated the formation of the Miocene volcano-plutonic Apuseni Mountains province.

PETROGRAPHY

The Miocene volcano-plutonic complexes of the Apuseni Mountains consist of andesites, dacites and basaltic andesites, some of which show

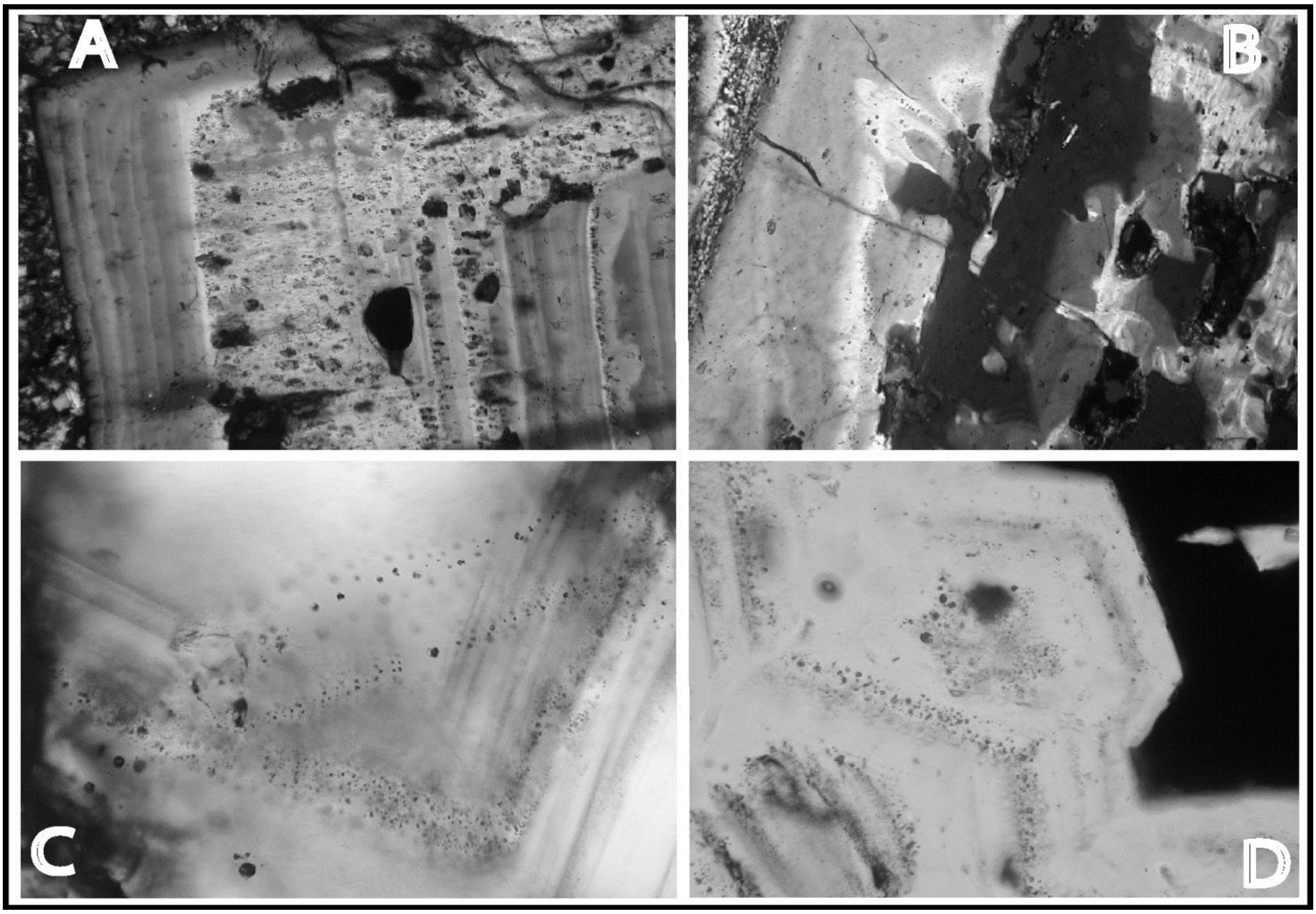

Figure 2. Microphotographs illustrating the melt inclusions assemblages presents in Deva magmatic to porphyry ore stage (all 200 microns wide). **A**) Dusty -like sieve texture in plagioclase, follow by normal zoning to the rim - left side, **B**) Patchy -like melt inclusion rich areas - light color to the right - and chemical zonation of plagioclase, **C**) Melt (within grow zones) and brine inclusions (boiling trails, late) in ore related quartz ,and **D** (primary melt inclusions in quartz within porphyry vein, predating ore minerals – bornite - cpy on top, right.

alkaline affinity (Rosu et al. 2001). The main ore-related rocks are Hbl ± Bt ± Px andesites with medium K content (Rosu et al. 2001, Ivascanu et al. 2002). For Deva, three varieties of andesites are distinguished on the basis of petrography and textures.

Hbl-plagioclase porhpyry (K-Ar age is 12.8 ± 0.5 Ma; Rosu et al. 2001) are porphyritic rocks with up to 4cm large pinkish plagioclase (An 35-50) and dark-green amphibole (<3mm) phenocrysts in a dark-grey microcrystalline groundmass. Microscopic observations reveal sieve textures on feldspars resulting from extreme enrichment of melt inclusions (Fig 2. A). Chemical zonation of plagioclase around melt inclusion rich areas is also common. Crystal rims are conspicuously poor in melt inclusions, as are plagioclase laths <2mm in the matrix. The hornblende phenocrysts are also chemically zoned and sometimes rimmed by minor chlorite and magnetite. Magnetite intergrown with ilmenite and accessory apatite are common.

Hbl andesites (K-Ar age is 12.6 ± 0.5 Ma, Rosu et al. 1997) are massive porphyritic andesites with zoned plagioclase (0.5 cm large; An 35-40) and brown elongated hornblende (0.5 cm) phenocrysts. Plagioclase phenocrysts often form aggregates (up to 2 cm), and the crystals contain a sieve texture in the core rich in melt inclusions, followed by zones that are poor in melt inclusions (Fig 2. B). Accessory minerals are apatite, magnetite and rare ilmenite. Traces of biotite can be observed.

Hbl+Bt andesites (K-Ar age is 11.8 ±0.5 Ma, , Rosu et al. 1997) can be distinguished from the Hbl-andesistes by the presence of biotite phenocrysts of up to 3mm in size. Plagioclase (An 20-50) is characterized by melt inclusion poor phenocrysts of up to 1cm and brown amphibole laths of up to 1cm. Vapor-rich fluid inclusions together with melt inclusions occur on late primary grow zones in both plagioclase and amphibole, suggesting the presence of an exsolved fluid late in the crystallization history of this rock. Accessory minerals include apatite and magnetite-ilmenite, also found as inclusions in the phenocrysts.

MINERALIZATION

The porphyry-Cu-Au deposit consists of a cylindrical, nearly vertical, 0.5 km wide mineralized stock of a subvolcanic Hbl+Bt andesite that gradually changes into a porphyritic microdiorite-diorite at depth. This stock is enveloped by polymictic magmatic breccias (clasts of andesite and porphyritic microdiorite, sediments and metamorphic country rocks). Mineralisation is restricted to the intrusive stock (up to 2% Cu) while the breccia has remained sub-economic. The ore stage is exclusively associated with potassic alteration and is represented by <1mm veinlets and impregnations in the rock. These include bornite with subordinate calcopyrite (and ISS equivalents), chalcocite, digenite and native gold, together with magnetite, K feldspar, biotite and small amounts of quartz and scarce late zeolite and anhydrite. Quartz predating the bulk of bornite precipitation hosts crystallized melt inclusions (Fig. 2, D) together with highly saline brine inclusion. Minor quartz-calcopyrite-bornite-calcite veins (several mm up to 2 cm) associated with K-feldspar alteration cut the ore stage mineralisation and have quartz that hosts coeval melt and vapor inclusions associated with later brine – vapor boiling assemblages (Fig. 2. C), that homogenize to the liquid at around 450-650°C (Th halite). Pyrite, molybdenite, clausthalite, hematite (specularite), tetrahedrite and secondary copper minerals are described from the upper parts of the deposit (Petrulian et al. 1965) now mined. Trace of pyrite associated with calcopyrite is found within the intrusive breccia envelope or in hornfels at the current levels of mining.

OUTLOOK

Based on the detailed field observations and paragenetic sequence of magmatic and hydrothermal crystallization EMP and LA-ICPMS analyses of phenocrysts, homogenized and crystallized melt inclusions and fluid inclusions are in progress to constrain:

- Fo_2 of the magmatic system by Mgt – Ilm,
- melt inclusion, mineral inclusions and phenocryst composition to trace the chemical evolution of the magmatic system,
- the significance of the exsolution of a sulphide melt for the genesis of the ore deposit, and
- the chemistry of the ore-forming fluid by microthermometry and LA-ICPMS analyses of melt and fluid inclusions.

Such data will help to better constrain the key-processes in the genesis of the Deva porphyry-Cu-Au deposit and the relation of this complex to others currently studied in the Apuseni Mountains (Kouzmanov et al. 2003).

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