

Geochemical Characteristics of Ore and Alteration Minerals from an Intrusion-Related Gold System in the Tran Region, W Bulgaria: Combined SEM, QEMSCAN and LA-ICP-MS Study

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Mineral and geochemical signatures are crucial for characterization of ore deposits and their definition as a specific genetic type. Besides the conventional methods for mineral identification, techniques such as QEMSCAN® and LA-ICP-MS can be jointly used for quantitative mineralogical and elemental distribution analyses. In this contribution, we report results from a combined use of both techniques to study the Au-Ag-W deposits in the Tran region of western Bulgaria. The study is focused on the Nadezhda, Logo, and Ruy deposits that form a cluster in the Carboniferous Ruy pluton and its lower Paleozoic low-metamorphic basement. The main features of the deposits define them as an intrusion-related gold system (IRGS). These are (i) association with the reduced Ruy pluton, (ii) structural control on the intrusion and mineralization, (iii) Au-Bi correlation, (iv) approximately coeval magmatism and mineralization (330–333 Ma), (v) low sulfide content, and (vi) presence of CO₂ in the hydrothermal fluids. Although age dating of magmatism and hydrothermal molybdenite and rutile point to a Variscan age of the system, late Alpine (Eocene) magmatic and hydrothermal activity overprinted the region, making the discrimination of hydrothermal processes complicated. In order to establish geochemical criteria for the distinction of the two hydrothermal events, electron microprobe, SEM, and LA-ICP-MS analyses on hydrothermal white micas and pyrite from mineralized (pluton and metamorphic rocks) and barren (Eocene subvolcanic dikes) samples have been performed.

Our results reveal gold is present mainly as native gold or electrum, varying in size (from 10 µm to macroscopic). In the intrusion-hosted deposits (Nadezhda and Ruy), it is associated with quartz, white micas, and pyrite—attached or in fractures. In the metamorphic-hosted ores, gold is present mainly in fractures, attached or “locked” in pyrite crystals. Only 6 vol % of the gold is submicroscopic. These features are important for future gold extraction using environmental-friendly technologies. Pyrite in the Eocene dikes is trace, small in size, and often irregular in shape. Positive gold grades in the dikes are uncommon and the element is present only as nanoinclusions in pyrite. A specific feature here is the high As content that correlates positively with Au, while in the Paleozoic rocks pyrites are low in As.

The hydrothermal white mica is a common alteration mineral in the deposits. QEMSCAN analyses provide quantitative data on its distribution in both hosts: the pluton and the Eocene dikes. In the intrusive rocks, the main K-bearing mineral is K-feldspar, reaching up to 40 vol %. White mica is a concurrent alteration mineral with 10 and 20 vol %. Quartz is another major mineral varying between 19 and 75 vol %. In the Eocene dikes, K-feldspar is almost absent, whereas white mica ranges from 27 to 29%, and quartz from 57 to 61%. Significant compositional differences of hydrothermal white micas (e.g., F and Ba content) have been identified between the Variscan and the Eocene events. This first combined application of QEMSCAN with LA-ICP-MS analyses of ore samples from an

IRGS in Bulgaria reveals the potential of these techniques in solving scientific and industry-oriented problems.