

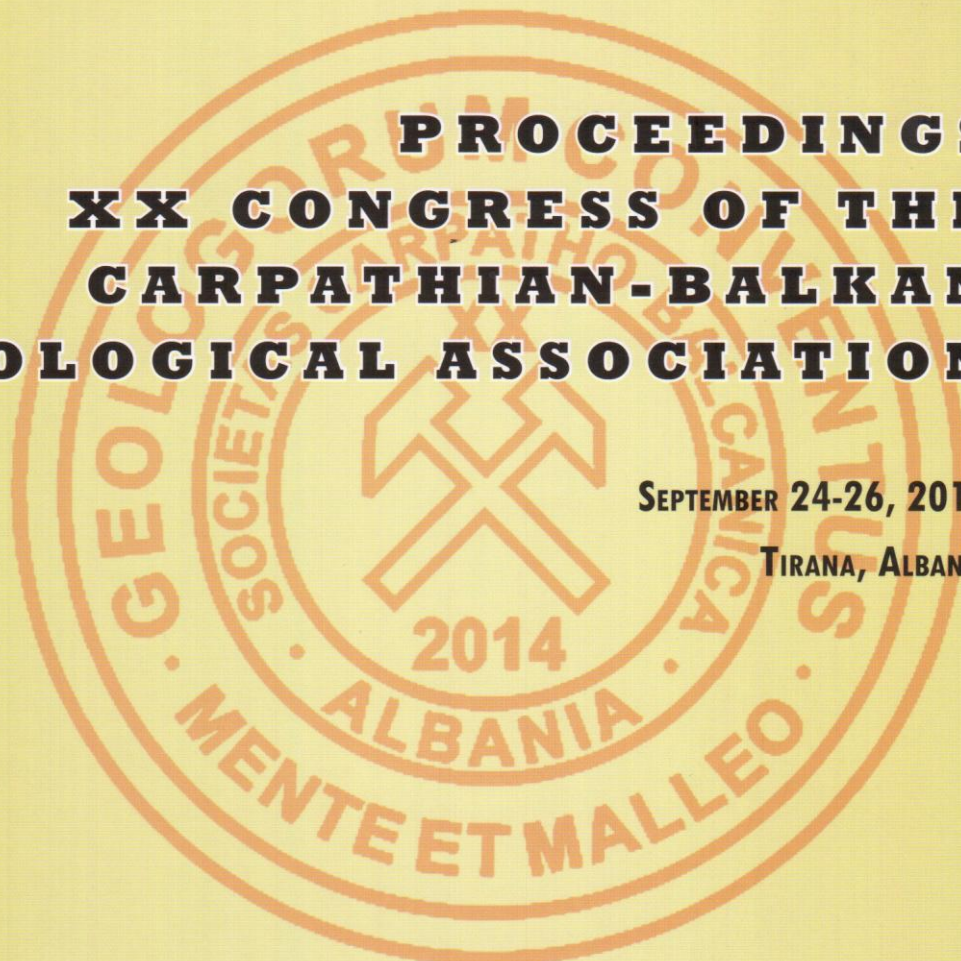


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## MINERALOGICAL, FLUID INCLUSION AND STABLE ISOTOPE CHARACTERISTICS OF THE SASA Pb-ZN SKARN DEPOSIT, REPUBLIC OF MACEDONIA

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### Abstract

The Sasa Pb-Zn skarn deposit (10 Mt of ore at 7.5% Pb+Zn) is situated in the Serbo-Macedonian massif (SMM), approximately 100 km east from Skopje, Republic of Macedonia. The SMM is the N-S extending zone, situated between the Vardar ophiolite zone in the west and the Rhodope massif in the east. It comprises an Upper (low-grade) and a Lower (medium to high-grade) unit. The protoliths of both units are reported as volcano-sedimentary series of Precambrian to Paleozoic age, metamorphosed up to green schist and amphibolite facies. During the Cretaceous and Tertiary time, the SMM was penetrated by andesitic to trachytic volcanic rocks. Associated ore deposits could be subdivided into two distinct groups: 1) Porphyry Cu-Mo-Au and subordinated epithermal gold deposits, and 2) Pb-Zn(-Ag) hydrothermal deposits.

In the Sasa Pb-Zn deposit the mineralization is represented by skarn and hydrothermal mineral parageneses that are hosted in medium to coarse grained cipollino marble of late Paleozoic age. The skarn parageneses comprise anhydrous Ca-Fe-Mn silicate minerals, such as pyroxenes and pyroxenoids (a prograde skarn assemblage), and hydrous silicates, such as epidote and chlorites, accompanied with magnetite, carbonates and quartz (a retrograde skarn assemblage). The hydrothermal parageneses are characterized by the presence of galena, sphalerite, pyrite and chalcopyrite. Carbonates and quartz are the most abundant hydrothermal gangue minerals. The mineralogical composition of the skarn and hydrothermal parageneses is estimated combining transmitted and reflected light microscopy with XRD analyses.

The mineral paragenetic sequence as well as fluid inclusion and stable isotope data distinguished three major mineralization stages

preceded by the stage of isochemical metamorphism of country rocks. The isotope composition of the host cipollino marble overlaps with values published for marine carbonates worldwide ( $\delta^{13}\text{C} \ll -1.4 \text{‰}$ ;  $\delta^{18}\text{O} \ll -26.3 \text{‰}$ ) suggesting that original geochemical features were not disturbed by metamorphism and supports an isochemical character of the process. The prograde stage (Stage 1) is characterized by metasomatic replacement of the host marble with anhydrous Ca-Fe-Mn silicates. Fluid inclusions hosted by pyroxene are moderate saline (14.5-16.4 wt % NaCl equiv.) with homogenization temperatures ( $T_{\text{H}}$ ) between 400° and 420°C. Formation temperatures above 400°C and the presence of anhydrous minerals suggest formation in a ductile lithostatic system insulated from significant infiltration of connate and meteoric waters. According to the isotope composition of hydrothermal gangue carbonates ( $\delta^{13}\text{C} = -5.0 \text{‰}$  -  $-6.4 \text{‰}$ ;  $\delta^{18}\text{O} = 8.4 \text{‰}$  -  $14.8 \text{‰}$ ) and fluid inclusion data ( $T_{\text{H}} = 270^{\circ}\text{-}300^{\circ}\text{C}$ ; salinity=6.3-7.9 wt % NaCl equiv.), hydrothermal alterations of anhydrous skarn minerals followed by precipitation of ore and gangue minerals resulted from the mixing of magmatic and meteoric fluids during the retrograde stage (Stage 2). Cooling of the country rocks below 400°C may move the system from the ductile to brittle fashion and allowed infiltration of meteoric water which would contribute to the increase in oxygen fugacity. Consequently prograde minerals are altered by mixture of hydrous silicates and magnetite. At the same time, the pressure drop from a lithostatic to hydrostatic value would favored sulfur degassing from the cooling magmatic body. The increased sulfur fugacity resulted with the sulfide deposition. The post-ore stage (Stage 3) deposited gangue minerals, mostly carbonates, from cooler ( $T_{\text{H}} = 125^{\circ}\text{-}233^{\circ}\text{C}$ ) and slightly diluted fluids (5.5-6.2 wt % NaCl equiv.).