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Geochemical characteristics of the St. Jakob (Croatia) Pb-Zn mineral deposit – a connection between the Alps and the Dinarides

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The Pb and Zn ore deposit of St. Jakob (ore paragenesis: galena, sphalerite, pyrite) is situated on Mt. Medvednica (Croatia), within the Palaeozoic-Triassic magmatic-sedimentary complex, a unit overprinted by Early-Cretaceous middle-grade metamorphism. The epigenetic ore is hosted in unmetamorphosed dolomites, which do not belong, lithologically or genetically, to the underlying Palaeozoic-Triassic complex. The host dolomites consist of ooids and sparite cement, indicators of a shallow marine environment. This associates them with a series of Norian dolomites that are part of the Triassic clastite and platform carbonates nappe, situated several kilometers away. The identification of the ore dolomites as a separate unit suggests that the Triassic carbonate nappe once covered a larger area, most of which is now eroded with the dolomites remaining as a klippe. The dolomites have enriched LREE and depleted HREE. Negative Eu and Ce anomalies indicate formation in an anoxic marine environment. Four types of fluid inclusions were identified in quartz veins syngeneic with the ore in the dolomites. Quartz veins from the adjacent sheeted marbles (part of the Palaeozoic-Triassic complex) contained only three fluid inclusion types. The primary ore fluid, present only in the ore dolomites, is represented by two-phase inclusions with a methane-rich vapour phase, and H_2O-NaCl-KCl-CaCl2 liquid phase with a salinity of 5 wt. % NaCl eqv. The secondary fluid, present in quartz veins from both rocks, is represented by two-phase inclusions with a CO_2 rich vapour phase and H_2O liquid phase with a salinity of 4 wt. % NaCl eqv. Very high homogenisation temperatures indicate leakage (and subsequent healing) of inclusions. Fluid inclusions provide more evidence for the distinction of ore dolomites from the Palaeozoic-Triassic complex, but also reveal their partly common history, possibly from after the emplacement of the nappe. X-ray diffraction revealed these secondary ore minerals: smithsonite, montmorillonite, chlorite and muscovite. Lead isotope patterns from St. Jakob showed anomalous lead characteristics, but they are in perfect accordance with the lead isotope values for Mežica, a member of the Alpine Mississippi-valley type Pb-Zn ore deposits. The origins of lead are probably deep basement rocks, remains from a previous orogeny. The simple paragenesis, host rock type, epigenetic nature and anomalous lead values of the St. Jakob Pb-Zn deposit are strong evidence for its characterization as a MVT ore deposit. Both the Mežica and St. Jakob deposits were not formed during a compressive regime, but during an extensive one, emplaced during the advanced rifting stage of the Tethys Ocean, which classifies them as Bleiberg (Alpine) subtype of MVT deposits. Their numerous similarities and a slight shift in time of formation (St. Jakob has a presumed, but not yet proven, middle to late Triassic age, placed in the Loferite facies) suggest a strong connection between the Alps and the Dinarides, and is a step towards clarifying the evolution of the Tethys Ocean in the now very tectonised Internal Dinarides.