Alpine metallogensis – reloaded

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The metallogenetic development of the Eastern Alps has been controversially discussed for over 100 years. A new model over the course of a modified Wilson cycle over the past 300 million years (Ma) is based on radiometric dating of ores, the resolution of the tectonic structure of the Eastern Alps, the paleogeographic relationships between the tectonic units and the application of geodynamic models. The post-Variscan “Alpidic” metallogenetic development of the Eastern Alps can be divided into an extension phase during Permian to Jurassic, and a compression phase starting in the Late Cretaceous. The formation of mineral deposits was controlled by a high geothermal gradient, fluid circulation along deep-crustal structures and suitable traps in Paleozoic and Mesozoic rocks. The formation of a heat dome underneath the passive continental margin of Pangaea by crustal thinning led to the formation of anatectic pegmatites and leucogranites from crustal melts in the bedrock of today`s Austroalpine nappes. Less than 1 % of the pegmatites are enriched in elements such as lithium, beryllium, tantalum or tin. By radiometric dating of garnet, cassiterite, columbite, spodumene and zircon, this phase can be bracketed to a period from 290 to 240 Ma. In the Triassic, pre-Variscan bedrocks as well as Upper Carboniferous to Lower Triassic clastic and evaporitic sediments were superimposed by very thick carbonate sequences on a facies-differentiated, extensive shelf at the margin of the Neo-Tethys. The high heat flow caused by persistent extension tectonics led to the circulation of saline formation waters from the Triassic sequence to the bedrock. These fluids were focused in deep-crustal fracture systems and led to the metasomatic replacement of carbonate rocks. Sm-Nd isotope dating documents the formation of magnesite and siderite in the Upper Triassic (230–208 Ma), occasionally also in the Permian. The radiometric dating of sphalerite from the Bleiberg-Kreuth deposit using Rb-Sr isotope analysis shows that the main phase of the formation of Austroalpine carbonate-hosted Pb-Zn ores in the stratigraphic levels of the Anisian and Carnian from saline, low-temperature fluids took place at the Triassic/Jurassic transition (about 200 Ma). In the Penninic Ocean (Alpine Tethys), small-scale pyrite-dominated „Kieserze” were formed during the Jurassic and Early Cretaceous, which are to be regarded as equivalents of volcanogenic massive sulphide deposits. In pelagic sediments of the Austroalpine and the Penninic realms, manganese-rich sediments were also deposited. In the Cretaceous there was a change from extension to compression tectonics with subduction of the Meliata Ocean and subsequent collision and nappe stacking in the Austroalpine, as well as the beginning subduction of the Alpine Tethys. At the Eoalpine peak of metamorphism (90 Ma), structure-controlled vein mineralization (Mitterberg/Hochkönig) and metasomatic deposits in carbonate rocks (siderite at Hüttenberg) were formed. Furthermore, sulphide ores were remobilized in higher metamorphic areas. In the course of the Neoalpine continent-continent collision and subsequent uplift and extrusion of large parts of the Eastern Alps, shear zone-hosted deposits such as the hematite deposit Waldenstein (approx. 46 Ma) in Austroalpine, and the “Tauern gold veins” (approx. 27 Ma) in Subpenninic and Penninic nappe systems were formed.