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The Lindgren Classification and Postcollisional Metallogeny: A Case Study from the Western Tethyan Metallogenic Belt

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The Tethyan Metallogenic Belt is a 12,000-km-long orogenic belt that extends from the Alps in Central Europe to Indochina (Fig. 1). The belt hosts numerous metallogenic provinces formed in different stages of the Wilson cycle from Permo-Triassic to Recent times.

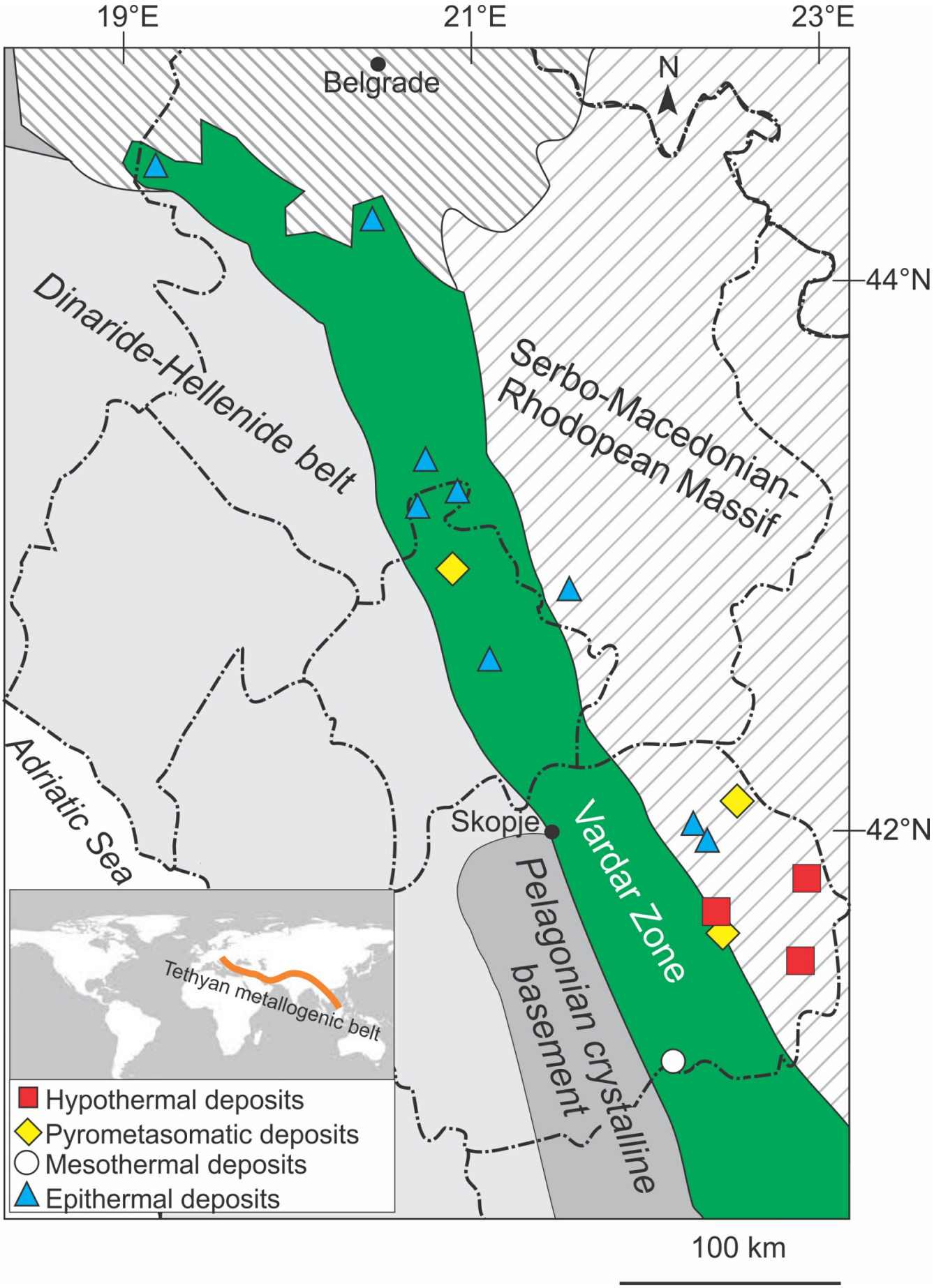
The postcollisional magmatism and associated ore deposits are well exposed along the Balkan Peninsula where, during the Oligocene-Pliocene period (31.0–1.8 Ma), calc-alkaline to shoshonitic magmatism affected the Vardar Zone (VZ) and the Serbo-Macedonian Massif (SMM). The volcanic to subvolcanic magmatism in an extensional tectonic setting was accompanied by widespread hydrothermal activity that produced numerous hypothermal, pyrometasomatic, mesothermal, and epithermal ore deposits (Fig. 1).

The hypothermal ore deposits (e.g., Buchim, Borov Dol, Kadica, Ilovica) are mostly spatially and temporary related to subvolcanic intrusions of the latitic and latitic-andesitic composition that intruded Precambrian gneisses, mica-schists and amphibolites of SMM. The mineralization occurs in forms of stockworks and disseminations along contacts of the intrusions and their host rocks. Chalcopyrite, bornite, and cubanite are the main ore minerals, associated with variable amounts of pyrite, magnetite, hematite, and native Au. The available fluid inclusion data accompanied by various geothermometers have revealed that the mineralization was formed in a temperature range between 380° and 680°C, at depths from 6 to 12 km, and from highly saline fluids (25-75 wt % NaCl equiv).

The pyrometasomatic ore deposits include proximal and distal skarn deposits. The proximal skarn deposits (e.g., Damjan), formed in a direct interaction of the Oligocene magmatism and carbonate-rich flysch lithologies of VZ, are characterized by the magnetite- and hematite-rich mineralogy, associated with abundant retrograde skarn minerals (epidote, amphiboles, chlorites, quartz, and carbonates) and minor amounts of pyrite and pyrrhotite. In contrast, distal skarns formed by infiltration of magmatic fluids through Paleozoic marbles of SMM (e.g., Sasa, Toranica) and Upper Triassic limestones of VZ (e.g., Trepca), host Pb-Zn-Ag-sulfide mineralization that overprints prograde (anhydrous), and retrograde (hydrous) Ca-Fe-Mg-Mn-silicate mineral assemblages. The distal skarns were formed at temperatures between 350° and 475°C, depths of 1-4 km, from moderate salinity aqueous fluids (4-12 wt % NaCl equiv) under conditions of progressive increase in water activity and sulfur fugacity.

The Carlin-like Allchar deposit is a typical example of mesothermal mineralization in the area. The deposit is predominately hosted in calcareous sedimentary rocks at intersections of high-angle faults in permeable stratigraphy of VZ. The mineralization is spatially and temporally associated with a Pliocene high-K calc-alkaline to shoshonitic volcano-plutonic center. The Au-As-Sb-Tl-rich mineralization formed at temperatures >200°C from moderate salinity aqueous-carbonic fluids (3-21 wt % NaCl equiv).

The epithermal ore deposits are common. In general, these deposits occur as Pb-Zn-sulfide-quartz ± carbonate veins (e.g., Zletovo) or as Cu-Au dissemination (e.g., Plavica) in shallow portions of postcollisional volcanic rocks. They were formed at temperatures <300°C from low- to moderate-saline aqueous fluids (<15 wt % NaCl equiv).


19°E
21°E
23°E
Belgrade
N
44°N
42°N
Dinaride-Hellenide belt
Serbo-Macedonian-
Rhodopean Massif
Adriatic Sea
Skopje
Vardar Zone
Pelagonian crystalline
basement
Tethyan metallogenic belt
Hypothermal deposits
Pyrometasomatic deposits
Mesothermal deposits
Epithermal deposits
100 km