

Magmatic and Metallogenic Framework of Au-Cu Porphyry and Polymetallic Carbonate-Hosted Replacement Deposits of the Kassandra Mining District, Northern Greece

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The Kassandra mining district in the eastern Chalkidiki peninsula of northern Greece contains >12 Moz Au in porphyry and polymetallic carbonate-hosted replacement sulfide orebodies. Collectively, these deposits represent the most economically significant mining camp in the Serbo-Macedonian metallogenic province.

Zircon U-Pb geochronology defines two distinct magmatic episodes in the late Oligocene (25–27 Ma) and early Miocene (19–20 Ma). Both suites are characterized by high-K calc-alkaline magmas with the younger early Miocene porphyritic stocks and dikes having a moderate shoshonitic geochemistry. Normalized rare earth element patterns support plagioclase fractionation among the late Oligocene suite, while amphibole or garnet fractionation is more likely for early Miocene porphyries. Both suites may have interacted with previously enriched, subduction-modified subcontinental lithosphere during ascent into the upper crust.

Carbonate replacement mineralization is hosted in marble contained within the semibrittle Stratoni fault zone. Mineralization varies along the 12-km strike length of the fault zone from Cu-bearing skarn adjacent to the late Oligocene Stratoni granodiorite stock westward into Au-Ag-Pb-Zn-Cu carbonate replacement deposits at Madem Lakkos and Mavres Petres. Piavitsa, at the western end of the exposed fault zone, hosts siliceous Mn-rich replacement bodies associated with crustiform Au-rich quartz-rhodochrosite veins. Structural and alteration relationships suggest that carbonate replacement mineralization is syn- to post-emplacement of the late Oligocene Stratoni granodiorite stock at 25.4 ± 0.2 Ma. An unaltered 19.2 ± 0.2 Ma porphyry dike at Vathilakkos cuts the Stratoni fault zone and the Madem Lakkos massive sulfide orebody, constraining mineralization to predate early Miocene magmatism. The Olympias Au-Ag-Pb-Zn carbonate replacement deposit is located 8 km north of the Stratoni fault zone. Mineralization at Olympias is hosted in marble and associated semibrittle structures. While broadly similar to the Madem Lakkos and Mavres Petres deposits, the precise timing and source for mineralization at Olympias remains unresolved.

Early Miocene Au-Cu mineralization at Skouries, 8 km south of the Stratoni fault zone, is associated with a narrow pipe-like multiphase porphyry stock (20.6 ± 0.5 Ma) emplaced into the hinge zone of a regional antiform. Mineralization is hosted by multiple sets of porphyry-related quartz and quartz-magnetite veins associated with pervasive potassic alteration in the porphyry stock and adjacent wall-rock gneiss and schist.

Late Oligocene and early Miocene magmatism overlaps spatially within the district but defines distinct petrogenetic events separated by about 5 m.y. Both episodes are associated with

Au-rich mineralization. Carbonate replacement deposits are interpreted to have formed in association with high-K calc-alkaline late Oligocene magmatism, whereas the Skouries porphyry system is hosted by an early Miocene porphyry stock showing characteristics similar to subalkaline and shoshonitic porphyry deposits elsewhere. Carbonate replacement massive sulfide deposition was largely controlled by an extensional structure and receptive host rocks within the fault zone, whereas a major regional fold axis localized the Skouries porphyry system. The changing character of mineralization with time in the Kassandra district may reflect a combination of factors, including structural preconditioning, magmatic-hydrothermal processes, and the availability of reactive host rocks.