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Mesozoic magmatism and metallogeny in Philippine: Insight from the Atlas giant porphyry Cu-Au deposit, Cebu Island

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Porphyry deposits are the world's important source of many metals such as Cu, Mo, and Au. Most of these deposits are distributed along convergent margins related with active subduction zones, predominantly in the circum-Pacifc. As an important part of the Pacific margin, the Philippine Mobile Belt is bound to the east and west by subduction zones. The developed subduction zones have generated abundant Cenozoic porphyry deposits in the Philippines. The Atlas giant porphyry Cu–Au deposit (1,420 Mt total resources and reserves @ 0.45% Cu and @ 0.24 g/t Au), Cebu Island, Philippines, is thought to be the oldest Philippine porphyry deposit based on the whole-rock Rb–Sr and K–Ar ages (108 ± 1 Ma) of ore-related porphyry. However, more robust U–Pb dating of zircons is still absent. Moreover, the research on the exact ore-forming process, the direct and precise mineralization age, and the nature of ore-related magmatism for the Atlas deposit have not been investigated, which obviously affects the further understanding of the Atlas deposit, and even the Mesozoic magmatism and metallogeny in the Philippines.

Zircon grains from the Atlas ore-related quartz diorite porphyry yielded a weighted mean age of 108.5 ± 1.6 Ma (MSWD = 0.81). Pyrite from quartz-sulfide ores and anhydrite-sulfide ores yielded Re–Os isochron ages of 110.2 ± 5.6 Ma (MSWD = 0.79) and 100.3 ± 2.7 Ma (MSWD= 26), respectively. These ages indicate that the Atlas giant porphyry Cu–Au deposit formed in the Early Cretaceous with possible multiple pulses and is different from most of the Philippine porphyry deposits that formed in the Cenozoic. The ore-related porphyry at Atlas shows an adakite affinity (Sr/Y = 54 – 69, La/Yb = 13 – 16), and is characterized by pronounced depletions of Nb, Ta, and Ti, and lack of zircon xenocrysts. Therefore, the ore-related porphyry was most likely generated from subducted oceanic crust. The Nb/Ta ratios (11.7 – 18.0) and the εHf(t) values (3.4 – 10.0) indicate that the magma primarily contains mantle material, consistent with the Sr–Nd isotope composition (ISr = 0.703734 – 0.703815; εNd(t) values = 2.4 – 3.4). The Mg# (49 – 53), Ni (Avg. 7 ppm), and Cr (Avg. 14 ppm) contents indicate that the magma is probably a product of various degrees of fractional crystallization after mantle melting with residue olivine and clinopyroxene, similar to the volcanic suites in the Cebu Island region. The nature of the ore-related porphyry at Atlas shows the obvious features leading to development of porphyry Cu–Au mineralization. These include the high oxygen fugacity condition (high zircon Ce^{4+}/Ce^{3+} values (avg. 531) and abundant magnetite and anhydrite), the relatively hydrated magma (low Ti-in-zircon temperatures that avg. 670 °C), abundant amphibole phenocrysts in the ore-related porphyry, and the remarkable geochemical features of adakites.