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# Archean Layered Mafic-Ultramafic Intrusions in the West Pilbara Craton, Western Australia: A Synthesis of Some of the Oldest Orthomagmatic Mineralizing Systems in the World

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## Abstract

Considerable exploration interest has been generated by the platinum-group element (PGE) and Ni-Cu potential of the Archean layered mafic-ultramafic intrusions in the West Pilbara Craton, Western Australia. The Munni Munni intrusion contains the largest resource of PGE associated with a layered intrusion in Australia, and the Radio Hill and Mount Sholl intrusions host significant resources of Ni-Cu-Co sulfides. Titaniferous magnetite layers, remobilized sulfides, and structurally controlled hydrothermal polymetallic deposits have also been a focus for exploration in recent years.

The ca. 2.9 Ga Munni Munni, Andover, Radio Hill, Mount Sholl, and Sherlock layered intrusions are a cogenetic suite of high-level (<5 kbars) bodies that represent some of the oldest mineralizing systems of their type in the world. Although they display similar field relationships and mineralogical, geochemical, and isotopic features, their contrasting chalcophile metal distribution patterns show that the timing and mechanism of the S saturation event were critical for the development of PGE-enriched sulfide-bearing layers and basal segregations of base metal sulfides.

The intrusions form thick (>5.5 km) dikelike bodies or relatively thin (0.5–2 km) sheets and sills emplaced at different levels along major lithological discontinuities in the upper crust. Rhythmically layered ultramafic components are generally thinner than, and occur along the northern sides of, more massive overlying mafic components. The ultramafic zones consist of dunite, lherzolite, wehrlite, olivine websterite, clinopyroxenite, and websterite. Inverted pigeonite gabbronorite, magnetite gabbro, olivine gabbro, anorthositic gabbro, and anorthosite comprise the mafic sequences. Olivine and clinopyroxene were generally the first minerals to crystallize, except in the Andover intrusion, where orthopyroxene preceded clinopyroxene and possibly reflects greater contamination of the parent magma by felsic crustal material. The crystallization of chromite was inhibited in the ultramafic zones by the partitioning of Cr into early crystallizing clinopyroxene, thus downgrading the potential for PGE-chromite associations.

The PGE mineralization in the Munni Munni intrusion occurs in the upper levels of a porphyritic plagioclase websterite orthocumulate layer directly below the ultramafic-gabbroic zone contact. Mineral compositional trends and Nd isotope data indicate that a Pd-Pt-Au-enriched S-undersaturated magnesian basaltic magma was frequently injected into a small magma chamber during formation of the ultramafic zone. A major influx of more fractionated, S-saturated tholeiitic gabbroic magma related to the resident magnesian magma, rapidly inflated the chamber, and induced turbulent magma mixing that resulted in the formation of the PGE-bearing porphyritic websterite layer. In contrast, the parent magmas that formed the Mount Sholl, Radio Hill, Andover, and Maitland intrusions were saturated in S before they were emplaced into the magma chambers. In these intrusions gravitational and structural controls were important for the concentration of PGE-poor (5–400 ppb Pt + Pd + Au) massive Ni-Cu-Co sulfides in depressions and structural embayments along the basal contacts beneath the thickest sequences of mafic-ultramafic cumulates.

The parent magmas to the West Pilbara intrusions were siliceous high magnesian basalts of Al-depleted komatiitic affinity (Barberton-type) with 9 to 12 percent MgO, 15 to 25 ppm Sc, 12 to 18 ppm Y, low $Al_2O_3/TiO_2$ (ca. 11 or half chondrite ratios), and light rare earth enrichment (chondrite-normalized La/Sm = 2.7, La/Lu = 9.0). They were generated with garnet in the residual asthenospheric mantle with probable involvement of a pre-3.0 Ga subduction-modified lithospheric mantle. Isotopic and geochemical modeling suggests that the magmas were contaminated by ca. 3.0 to 3.3 Ga Archean tonalitic to granodioritic crust before being emplaced into high-level magma chambers.