

The Archean Amphibolite Facies Coolgardie Goldfield, Yilgarn Craton, Western Australia: Nature, Controls, and Gold Field-Scale Patterns of Hydrothermal Wall-Rock Alteration

JOSEPH T. KNIGHT,

BHP Minerals Discovery Group, BHP World Minerals, 3 Plain Street, East Perth, W.A. 6004, Australia

JOHN R. RIDLEY,

GEMOC, Department of Earth and Planetary Sciences, Macquarie University, NSW 2109, Australia

AND DAVID I. GROVES

Centre for Teaching and Research in Strategic Mineral Deposits, Department of Geology and Geophysics, University of Western Australia, Nedlands, W.A. 6907, Australia

Abstract

The late Archean Coolgardie Goldfield at the western margin of the Norseman-Wiluna belt, Yilgarn craton, comprises an arcuate belt of deformed mafic, ultramafic, and sedimentary rocks which is bounded to the west by the syntectonic Calooli monzogranite. Greenstones at Coolgardie preserve a broad metamorphic gradient, with peak metamorphic temperature varying from $480^{\circ} \pm 50^{\circ}\text{C}$ at the center of the gold field to $545^{\circ} \pm 50^{\circ}\text{C}$ adjacent to the western granitoid-greenstone contact, at an approximate pressure of 3 to 4 kbar.

Gold field-scale variations in the gangue and ore mineralogy of zoned wallrock alteration assemblages around lodes, the ore geochemistry, and the isotope chemistry of vein minerals at Coolgardie are correlated with plan-view distance from the Calooli monzogranite. Evidence supporting synpeak metamorphic gold mineralization in the Coolgardie Goldfield includes the equilibrium textural relationships between gold, sulfides, and high-temperature silicate gangue; the occurrence of undeformed auriferous quartz veins, enveloped by garnethornblende-plagioclase-calcite alteration, which crosscut peak-metamorphic fabrics; and the siting of variably deformed gold ores in synpeak-metamorphic structures. Conditions of gold mineralization at deposits less than 1 to 2 km from the Calooli monzogranite are determined from geothermometry and barometry to be $510^{\circ} \pm 50^{\circ}\text{C}$ to $590^{\circ} \pm 25^{\circ}\text{C}$ at 3 to 4 kbar, whereas those at greater distances from the monzogranite are 490° to $525^{\circ} \pm 50^{\circ}\text{C}$ at 3 to 4 kbar.

Alteration assemblages in mafic host rocks can be divided into garnet-bearing (garnet-hornblende-plagioclase-calcite) and garnet-absent (biotite-amphibole-plagioclase-calcite). The presence or absence of garnet is mainly controlled by the Mg number of the host mafic rocks. Ore in deposits with garnet-bearing alteration is enriched in Ag, Na, Pb, S, and W, but only weakly enriched or depleted in K_2O and other large ion lithophile elements, CO_2 , As, Mo, Sb, and Te, whereas deposits with biotite-amphibole-plagioclase-calcite alteration are strongly enriched in Ag, As, S, Sb, W, CO_2 , and large ion lithophile elements. Sulfide-oxide assemblages are regionally zoned from pyrite-ilmenite in deposits in granitoids and adjacent to the granitoid-greenstone contact, through pyrrhotite-ilmenite \pm pyrite in garnet-bearing alteration 1 to 2 km from the contact, to arsenopyrite-pyrrhotite-ilmenite assemblages in biotite-bearing alteration >2 km from the greenstone-granitoid contact. This variation is potentially related to gradients in fluid f_{O_2} away from the granitoids.

Isotopic compositions of oxygen in quartz ($\delta^{18}\text{O} = 10.8\text{--}12.4\text{‰}$), scheelite ($\delta^{18}\text{O} = 4.0\text{--}4.1\text{‰}$), and oxygen and carbon in calcite ($\delta^{18}\text{O} = 8.9\text{--}13.2\text{‰}$, $\text{TM}_{13}\text{C} = -0.5$ to -5.3‰) are generally more positive in deposits with garnet-bearing alteration than in those with biotite-bearing alteration ($\delta^{18}\text{O}_{\text{quartz}} = 6.6\text{--}11.8\text{‰}$, $\delta^{18}\text{O}_{\text{scheelite}} = 2.3\text{--}4.6\text{‰}$, $\delta^{18}\text{O}_{\text{calcite}} = 8.7\text{--}11.4\text{‰}$, $\delta^{13}\text{C}_{\text{calcite}} = -4.3$ to -8.4‰), whereas both alteration styles have $\delta\text{D}_{\text{biotite}}$ and $\delta\text{D}_{\text{amphibole}}$ values in the range -65 to -86 per mil. These differences are interpreted to reflect interaction of isotopically heavy ore fluids with relatively depleted greenstone host rocks during fluid migration through structurally controlled conduits.

The gold field-scale variations in alteration mineralogy and ore chemistry are considered to be related not to initial ore-fluid composition but to temperature, to host-rock composition, and to changes in fluid composition resulting from reaction with greenstone-belt rocks. The correlation between the calculated temperature of alteration and distance from the western granitoid-greenstone contact suggests that the

Calooli monzogranite played some genetic role in determining the nature of hydrothermal alteration across Coolgardie.