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Sources of Metals and Fluids in Orogenic Gold Deposits: Insights from the Otago and Alpine Schists, New Zealand

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Abstract

The Otago and Alpine schists of the South Island of New Zealand form a young (<200 Ma), lithologically monotonous, metasedimentary belt with exposures ranging from unmetamorphosed graywackes to amphibolite facies rocks. The belt contains abundant orogenic gold deposits, including the 125-t Au Macraes deposit. As such, the schist belt is an ideal geologic setting for investigation of the sources of metals and fluids responsible for formation of metamorphic rock-hosted gold deposits.

A large suite of samples representative of the lithologic and metamorphic variation in the Otago and Alpine schists was collected and analyzed for a comprehensive suite of elements. The aim was to identify any rock type or metamorphic setting that may be depleted in the suite of ore-forming elements (Au, Ag, As, Sb, Hg, Mo, and W) relative to unmetamorphosed protoliths, perhaps representing the source for the enrichments observed in the Otago ore deposits. Gold, Ag, As, Sb, Hg, Mo, and W were found to have significantly lower concentrations in higher grade metamorphic rocks compared to unmetamorphosed protolith samples. These were the only elements in a suite of 12 major and 50 trace elements to show systematic depletions with metamorphic grade. Investigation of the trace element chemistry of sulfide minerals indicates that the whole-rock depletions are caused by the disappearance between greenschist and amphibolite facies conditions of pyrite, galena, sphalerite, and cobaltite, the major host phases for the ore-forming elements. More than 95 percent of upper greenschist and amphibolite facies samples are significantly depleted in the ore-forming elements. Such regional-scale depletions require pervasive, grain-boundary fluid flow throughout these rocks. The leaching is most likely to have been caused by metamorphic fluid produced by dehydration reactions at the greenschist-amphibolite boundary.

The suite of elements depleted in mid- to high-grade Otago and Alpine schists is almost identical to those enriched in the orogenic gold deposits in Otago. Furthermore, the vertical zonation in depletions is similar to the vertical zonation in enrichments that occurs in the Otago deposits. Mass-balance calculations suggest that 2 metric tons (t) Au and 24,000 t As was leached from 1 km^3 of amphibolite facies rock and that the Macraes deposit could have been formed by leaching of a 5- × 5- × 5-km cube of amphibolite facies rock. We propose that the orogenic gold deposits in Otago, such as Macraes, were formed directly from metal-rich metamorphic fluid produced during prograde metamorphism at depth. The contribution of other fluid and metal sources in the formation of these deposits, such as magmatic fluids, cannot be ruled out, but there is no direct evidence to support their involvement. Infiltration of meteoric water, such as occurs currently in the Southern Alps of New Zealand may have contributed to the formation of the late-stage deposits that formed at shallow level during uplift of the Otago schists.

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