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The Role of Sulfate-Sulfide-Oxide-Silicate Equilibria in the Metamorphism of Hydrothermal Alteration at the Hemlo Gold Deposit, Ontario

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Abstract

The Hemlo Au (-Mo) deposit is an example of atypical, greenstone-hosted, mesothermal mineralization from the Superior province of north-central Ontario. The ore is shear hosted and consists primarily of disseminated native gold in several mineralized zones near the contact between quartz-feldspar porphyry and metasedimentary rocks. Metsasedimentary rocks (i.e., pelite, graywacke, arenite, marl, mafic fragmental rocks, and baritic sediment) host most of the ore. The dominant alteration is potassic and is characterized by a central zone of granoblastic microcline-quartz-(barite-muscovite-biotite-pyrite) rocks, surrounded by muscovite-quartz-pyrite schists. Regional, amphibolite-facies metamorphism (~630°C, 5–7 kbars) overprinted the ore zones and recrystallized the alteration assemblages. Unaltered metasedimentary wall rocks contain the assemblages biotite-garnet-staurolite-kyanite and/or sillimanite (metapelite) and amphibole-plagioclase (mafic fragmental rocks and marly sediment). As the ore zones are approached, the proportions of muscovite and K-feldspar and the mole fraction of pyrope in garnet increase, garnet, staurolite, and kyanite gradually disappear, biotite becomes Mg rich, ilmenite is replaced by rutile, and pyrrhotite is replaced by pyrite. In altered and mineralized mafic fragmental rocks, biotite replaced amphibole, which indicates that amphibole was present prior to alteration and that gold mineralization occurred at pressure-temperature conditions equivalent to those of the greenschist facies (400°–500°C, 3–5 kbars).

The presence of garnet and staurolite in unaltered metasedimentary rocks, but not in the ore zones, is consistent with phase equilibria which indicate that only Mg-rich silicates can coexist with pyrite, and that Mg-rich end members of garnet and staurolite are only stable at temperatures and pressures considerably higher than those of peak metamorphism. This change in mineral assemblage is due primarily to the very high f_{S_2} during alteration and gold mineralization, which caused iron to partition preferentially into pyrite, and is supported by the decrease in the Fe/Mg ratio of garnet and biotite toward the ore zones. Similarly, the absence of kyanite in the ore zones, despite its common occurrence in the immediately adjacent wall rocks, can be attributed directly to the high activity of potassium, which stabilized the assemblage muscovite-microcline in favor of the assemblage kyanite-muscovite. The combined effects of sulfidation and potassic alteration ensured that all phases in the ore zones participated directly or indirectly in metamorphic reactions. The evolution of such rocks therefore differs significantly from those of normal metasedimentary rocks. In general, typical peak metamorphic assemblages do not develop, and thus timing relationships of mineralization hosted by amphibolite-grade rocks are obscured. However, the disappearance of metamorphic index minerals, modification of mineral assemblages, and mineralogical changes in sulfides and oxides that are recognizable on an outcrop scale at Hemlo serve as important vectors to economic mineralization.

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