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Gold in Sedimentary Pyrite and its Implications for Ore-forming Processes in the World-class Timmins-Porcupine Au Camp and its Surroundings, Abitibi Greenstone Belt, Canada

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Orogenic gold deposits of the world-class Timmins-Porcupine gold camp in the Archean Abitibi greenstone belt are commonly found in proximity to sequences of fine-grained sedimentary rocks. These contain diagenetic and epigenetically recrystallized pyrite nodules, in which gold tenors can vary from below ~10 ppb to more than 10 ppm. Given the proximity of these nodule-rich sequences to gold systems, important questions regarding their potential role in the ore-forming processes have to be addressed (e.g., one potential source of gold). Hence, this study examines in detail the petrographic, geochemical, and isotopic characteristics of diagenetic and epigenetic pyrite with the aim to: 1) establish factors controlling the primary enrichment of gold in pyrite nodules; and 2) interrogate the possible genetic implications for auriferous ore-forming processes.

Investigation of over 120 rock samples from seven distinct volcanic-sedimentary assemblages, including samples within, proximal to (<100 m), and distal (>100 m) to gold mineralization reveals many regional textural commonalities within pyrite nodules, such as polycrystalline nodule cores and acicular rims. In situ multi-element analyses (*n* = 454) by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) show that gold content is largely refractory and decreases systematically towards the acicular rim to near barren values. The trace elements Ni, As, Ag, Sn, Sb, Te, Pb, and Bi in pyrite co-vary positively with Au, whereas Mo and Tl generally behave antithetically with Au. Measurements of the same elements in epigenetic pyrite porphyroblasts, euhedral overgrowths, and granoblasts within the same samples show clear distinctions in chemical assemblages and compositions with, for instance, Tl tenors being >100 times greater in nodules (typically >1 ppm Tl).

Possible factors controlling gold abundance in nodule cores were examined by comparing geochemical proxies from whole-rock lithogeochemical analyses of the sedimentary host. In nodules collected from the Kidd-Munro, Tisdale, and Porcupine assemblages, gold shows consistent co-variations with proxies for provenance, with the highest abundances found in more mafic/juvenile rock-derived sediments (e.g., lower La/Sc, higher V/Al and Co/Th).

In situ sulfur isotope ratio ($^{34}S/^{32}S$, $^{33}S/^{32}S$) measurements on pyrite nodules show significant variations in composition ($\delta^{34}S$ = -18.3 to +8.7‰; $\Delta^{33}S$ = -2.1 to +4.2‰), with negative correlations between $\delta^{34}S$ and $\Delta^{33}S$ and, overall, suggest that the nodules formed through processes involving both mass-dependent and mass-independent sulfur isotope fractionation. Metamorphic pyrite unrelated to ore revealed mainly positive $\delta^{34}S$ and $\Delta^{33}S$ values ranging from -1.0 to +11.3‰ and -1.8 to +4.6‰, respectively, whereas ore-associated metamorphic pyrite in three gold deposits (Bradshaw, Bell Creek, and Pamour) show a restricted range in $\delta^{34}S$ values (+0.3 to +3.8‰) with slightly positive mass-independent fractionation signatures ($\Delta^{33}S$ = -0.3 to +0.6‰). These preliminary results suggest that at least some of the sulfur in the ore-forming fluids was atmospheric and was likely sequestered in sedimentary (± volcanic) rocks that now reside at depth. By liberation processes during metamorphism, and given that sulfur is an important transport ligand for gold, it is possible that some gold was also derived from diagenetic pyrite and incorporated into the ore-forming hydrothermal system.