Geophysical Research Abstracts
Vol. 19, EGU2017-248-2, 2017
EGU General Assembly 2017

Pyrite deformation and connections to gold mobility: insight from micro-structural analysis and trace element mapping

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Pyrite is an important and ubiquitous gold-bearing phase in many orogenic gold deposits making the study of its deformation behaviour under metamorphic conditions crucial to the understanding of gold (re)mobilization. However, pyrite deformation mechanisms and their influence on the retention or release of trace elements during deformation and metamorphism remain poorly understood. We propose a syn- to post-peak metamorphic and deformation driven gold upgrading model where gold is remobilized through deformation-induced diffusion pathways in the form of substructures in pyrite. The middle amphibolite facies assemblage (actinolite-biotite-plagioclase-almandine) of the Detour Lake deposit (Canada) makes it an ideal study area due to maximum temperatures reaching 550°C, exceeding the conditions for plastic deformation in pyrite (450°C). The world-class Detour Lake deposit, containing 16.4 Moz of Au at 1 g/t, is a Neoarchean orogenic gold ore body located in the northern Abitibi district within the Superior Province. The mine is situated along the high strain, sub-vertical ductile-brittle Sunday Lake Deformation Zone (SLDZ) parallel to the broadly E-W trending Abitibi greenstone belt. Herein we combine orientation contrast (OC) forescatter imaging, electron backscatter diffraction (EBSD) and 2D laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) trace element pyrite mapping to evaluate the influence of pyrite brittle and plastic deformation on the release of trace elements during syn-metamorphic gold remobilization. Local misorientation patterns in pyrite exhibit parallel bands that can be described by continuous rotation around one of the <100> axes, whereas higher strain areas reveal more heterogeneous misorientation patterns and the development of low-angle grain boundaries with late fractures indicative of dislocation creep and strain hardening. These late fractures are an important micro-structural setting for gold and clusters of precious-metal mineral inclusions (telluride minerals). Minor recrystallization processes can also be observed along phase boundaries between pyrite and more competent amphibole crystals. LA-ICP-MS trace element maps document primary, syn-metamorphic oscillatory zoning of some chalcophile and siderophile elements during crystallization of pyrite porphyroblasts. These primary pyrite features are cut by late metal-rich fractures suggesting that remobilization of gold occurred with trace element enrichment of other chalcophile and siderophile elements (Cu, Pb, Zn, Ag, Bi, Te), which post-dates the main period of syn-metamorphic pyrite crystallization at the margins of pre- to syn-deformation, high-grade gold veins. Pyrite grain boundaries and subgrains are also base and precious metal rich, suggesting that late gold remobilization also occurred during pyrite recrystallization. Additional trace element mapping will help determine to what extent pyrite plastic deformation facilitates the diffusion of gold and other trace elements during gold precipitation and remobilization, which, in turn, will inform the source to sink pathways of ore deposition.