Economic Geology
Vol. 95, 2000, pp. 1657-1671

Re-Os Dating of Low-Level Highly Radiogenic (LLHR) Sulfides: The Harnäs Gold Deposit, Southwest Sweden, Records Continental-Scale Tectonic Events

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Abstract

To obtain geologically meaningful and precise results on low-level sulfides that are highly radiogenic, blank corrections that account for the extreme difference in the Os isotope composition of sample and blank are necessary, and the resulting data is best plotted in ^{187}Re-^{187}Os space, much like the approach used for molybdenites. We here introduce the acronym LLHR as a means of characterizing low-level and highly radiogenic sulfides. Use of the traditional $^{187}Re/^{188}Os$ vs. $^{187}Os/^{188}Os$ plot for LLHR sulfides leads to large analytical uncertainties and highly correlated errors, as ^{188}Os is poorly determined and can generally be accounted for by the blank. We now recognize that LLHR sulfides, such as those encountered at the Harnäs Au deposit, are a common occurrence and characteristic of many crustally affiliated ore systems.

The Harnäs Au deposit in southwest Sweden is located in the Mjøsa-Vänern mineral belt that transects, from northwest to southeast, the prominent geologic fabric of the Sveconorwegian province including the Mylonite Zone. The deposit is hosted in a strongly sheared and locally brecciated sulfide-bearing quartz vein that crosscuts the foliation of orthogneisses belonging to the ~1600 Ma Åmål granitoid suite. A ^{187}Re-^{187}Os isochron of 973 ± 34 Ma (2s) for samples of pyrite and chalcopyrite from outcrops of the Harnäs, Alma, and Silvergruvan veins was obtained. The Harnäs and subsidiary Alma veins are Au bearing, whereas the Silvergruvan, ~2.5 km to the southeast, is not of the Au-bearing type. Four replicate analyses of an additional pyrite sample from the Harnäs vein yield a model age of 616 ± 40 Ma (95% C.L.). In all samples, Re and ^{187}Os concentrations are extremely low, 0.35 to 7.1 and 0.005 to 0.074 ppb, respectively, and total common Os (0.002–0.028 ppb) is less than half the calculated radiogenic ^{187}Os. Two samples of galena from the Harnäs vein yielded blank level Re and Os.

Neither the ~973 nor ~616 Ma time of mineralization is related to development of the Mylonite Zone at ~920 Ma or intrusion of the anorogenic Bohus-Blomskog granites at ~920 to 900 Ma, previously proposed sources for generating Mjøsa-Vänern mineral belt ore fluids. An age of ~973 Ma for Harnäs-Alma-Silvergruvan suggests that sulfide deposition was associated with the waning stages (0.97–0.90 Ga) of the Sveconorwegian (Grenvillian) orogeny (1.15–0.90 Ga), postdating metamorphism and deformation that produced a regionally overthickened crust. In the northern part of the Sveconorwegian province, the vein systems for these and numerous other small deposits in the Mjøsa-Vänern mineral belt could have resulted from regional exhumation in the Late Sveconorwegian with associated extension and the development of fracture systems at cooler middle to upper crustal levels. In the southern part of the Sveconorwegian province, dominated by granulitic facies rocks, no mineralization is present, perhaps due only to increased exhumation and erosion that has exposed deeper crustal levels.

The Late Sveconorwegian age (~973 Ma) records the main period of sulfide deposition for the Harnäs-Alma-Silvergruvan vein systems and indicates the robustness of the chronometer within tectonically complex terranes. The Late Neoproterozoic age (~616 Ma) records a later time of pyrite deposition, probably associated with shearing and reopening of the Harnäs vein system. Because the Au mineralization at Harnäs has been described as

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associated with shearing and occurring in fracture fillings in early pyrite, we suggest that part or all of the Au mineralization could have been introduced at ~616 Ma during reactivation of the vein system. The 616 Ma age for pyrite suggests a previously unrecognized and much younger mineralizing episode in the Harnäs region, most likely reflecting continental-scale extension and the Late Neoproterozoic opening of the Iapetus ocean.