

Direct Dating of Epigenetic Hydrothermal Gold Deposits in Newfoundland using Re-Os Pyrite Geochronology

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Summary

It is not easy to obtain precise and useful ages for epigenetic hydrothermal mineralization, including most types of gold deposits. The ideal solution to this problem is to date minerals that are directly associated with the gold, such as pyrite and arsenopyrite. Under some circumstances, these minerals are amenable to direct dating using the Re-Os system, but the low concentrations of Re and Os complicate such analysis. The application of this method to gold deposits in Newfoundland was successful in two out of three cases. In the third case, the results were enigmatic, possibly due to complications involving an earlier generation of syngenetic sulphide in the host rocks, and subsequent loss of Re.

Introduction

Epigenetic hydrothermal mineral deposits, such as most gold deposits, present significant problems for geochronological studies. Radiometric ages obtained from the host rocks using conventional methods (e.g., U-Pb) provide only maximum age constraints, and the mineralized veins and associated replacement deposits rarely contain mineral assemblages amenable to such dating methods. Geochronological data from associated alteration minerals, typically through Ar-Ar methods, are not always easy to interpret, as the links between the dated alteration and mineralization may be subjective. Direct dating of the minerals associated with the gold provides the ideal solution.

Geological and Geochronological Background

The Re-Os geochronometer, well-known through its use to date molybdenite, can be applied under some circumstances to other sulphide minerals, including pyrite and arsenopyrite, both of which are commonly associated with epigenetic gold mineralization. These sulphides typically contain very low concentrations of Re (1 to 100 ppb) and their Os concentrations are typically measured in parts-per-trillion (ppt). However, in many cases the Os contained in such minerals is of exclusively radiogenic origin, and so useful ages can be obtained through model age calculations akin to those employed in molybdenite dating, or through direct regression of daughter (^{187}Os) versus parent (^{187}Re). Such sulphide minerals are termed “low-level highly radiogenic” (LLHR; Stein et al., 2000), and they provide the most promising route towards direct

dating of epigenetic hydrothermal gold deposits, and perhaps other deposit classes. This paper outlines the successful use of Re-Os geochronology on LLHR pyrites from two important gold deposits on the Baie Verte Peninsula in northwestern Newfoundland, and also discusses unresolved problems revealed by results from a third gold deposit. The deposits in question include vein-style and replacement-style mineralization, and show a strong association between gold and epigenetic pyrite; gold typically occurs as microscopic inclusions within the latter. The Stog'er Tight and Pine Cove deposits appear to contain only a single generation of pyrite; however, the Nugget Pond deposit is hosted by sedimentary rocks that locally contain significant syngenetic or diagenetic pyrite. The geological background for the study is outlined by Kerr and Selby (2010).

Results and Discussion

Pyrite separates from the Stog'er Tight and Pine Cove gold deposits proved to be typical LLHR sulphides, in which > 95% of the contained Os is of radiogenic origin. They have low Re contents (0.7 to 26 ppb) and extremely low Os contents (3 to 115 ppt). Nevertheless, the data from both deposits are amenable to Re-Os model age calculations or to isochron regression. The Re-Os model ages for the Stog'er Tight deposit and Pine Cove deposits are 411 +/- 7 Ma and 420 +/- 7 Ma, respectively. Direct regression of ^{187}Os versus ^{187}Re yields a slightly younger age for Stog'er Tight (~399 Ma) and an identical age for Pine Cove, albeit with slightly larger uncertainties of ~ 20 Ma. In the case of Stog'er Tight, the results are in agreement with a previous U-Pb age of 420 +/- 5 Ma from "hydrothermal" zircons in alteration assemblages spatially associated with high-grade mineralization. The Pine Cove deposit has not previously been dated, but its general similarity in age to Stog'er Tight is consistent with the strong geological similarities between the two. The results suggest that using the Re-Os technique on LLHR sulphides may provide a viable technique to better understand the temporal distribution of epigenetic gold mineralization in the Newfoundland Appalachians, and perhaps elsewhere. In the case of these mid-Paleozoic deposits, Re contents of > 3 ppb are ideally required to generate radiogenic Os sufficient for precise age determinations. Results show that Re concentrations in pyrites from single gold deposits vary by as much as one order of magnitude, which implies that "screening" of sulphides for the feasibility of dating via single Re analyses may be inconclusive.

The Re-Os geochronological data on pyrite separates from the Nugget Pond gold deposit are not so easily interpreted. Some samples have significant amounts of common Os, and others yield Re-Os model ages of 549 to 511 Ma that are older than the inferred age of the sedimentary host rocks to the mineralization. The Re-Os model ages are also inconsistent with a previous U-Pb age of 374 +/- 8 Ma obtained from xenotime in a cross-cutting sulphide-bearing vein. These enigmatic results may reflect the incorporation of older Re-rich syngenetic (sedimentary) sulphides, followed by net loss of Re, during later epigenetic gold mineralization. Preliminary numerical models suggest that such a process can explain the observed results, with reasonable assumptions, but this does not prove that this answer is correct. However, further investigation of this problem is warranted, because interaction between hydrothermal fluids and pre-existing sulphides is known to be an important metallogenic process in many other settings, and such effects could compromise attempts at direct dating of mixed assemblages.

Conclusions

In conjunction with the only previous Re-Os study of epigenetic hydrothermal gold mineralization in the Appalachians (Morelli et al., 2005) and with other studies by Stein et al. (2000) and Arne et al. (2001), results indicate that direct dating of such deposits is feasible if they contain LLHR sulphides. The final proof of such methods lies in their wider application, and in the consistency of results in the context of other geochronological data and regional geological constraints.

References

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