Re-Os isotopic study of komatiitic volcanism and magmatic sulphide formation in the southern Abitibi greenstone belt, Canada

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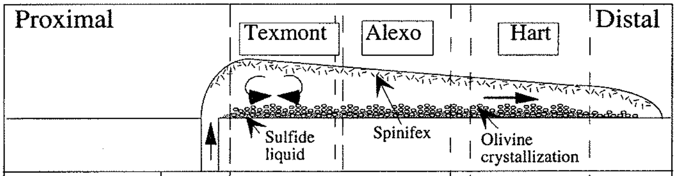
The giant nickel sulphide ore deposits of Archaean greenstone belts are associated with komatiitic lavas. The formation of this style of ore deposit is dependent on the host komatiite lava attaining sulphide saturation. Because komatiites are thought to be sulphide-undersaturated on eruption, crustal contamination of turbulently flowing, high temperature komatiites via thermal erosion or "ground melting" of sulphidic sediments has been proposed as a mechanism by which sulphide saturation was achieved (Groves, *et al.* 1986). Recent studies on komatiite lavas and ores in Western Australia have demonstrated near-chondritic initial Os isotopic compositions, but only in less altered and deformed portions of the ore systems (Foster, *et al.* 1996). This rather controversial result from Western Australia needs to be corroborated by Re-Os isotopic analyses of similar komatiites and ores from other Archaean cratons. In order to refine the ground melting model and evaluate the superimposed effects of metamorphism and hydrothermal alteration on ore environments and non-ore environments, we have investigated the Re-Os isotope geochemistry of 2.7 Ga komatiitic flows from Alexo, Texmont and Hart in the Abitibi greenstone belt (Canada) that have been extensively studied (Barnes and Naldrett 1987).

Methods

Re and Os concentrations and Os isotopic compositions were obtained on 10 samples using a low-blank Carius tube acid digestion method followed by double distillation for Os, and ion exchange chromatography for Re. Isotopic compositions were obtained using a Finnigan MAT 262 negative thermal ionisation mass spectrometry. During this study, total chemistry and mass spectrometry blanks were 6 pg for Re and 2 pg for Os. Analyses over a period of three years of an Os isotopic mass spectrometer standard provided by the Carnegie Institution of Washington (DTM) yield a mean $^{187}Os/^{188}Os = 0.17367 + 0.00058$ (external reproducibility at the 2σ level), within error of the DTM value of $0.17429 + 0.00055$ (Shirey 1997). Internal precision on SRM WPR1 ($n = 7$) was $\pm$ 0.5% on $^{187}Os/^{188}Os$.

Results

The disseminated and net textured ore samples from Texmont are characterised by high Os concentrations (2418 and 1359 ppb, respectively) and low Re/Os (0.13-0.09), consistent with a R-factors of 800 to 1400 (defined as the effective mass of silicate magma with which a given mass of sulphide magma has equilibrated, calculated using a $D_{Os} = 30{,}000$). The two net-textured and massive ore samples from Hart are characterised by low Os concentrations (7 to 49 ppb), higher Re/Os (0.09-0.2), and low R-factors (20-80). Four net-textured and disseminated ore samples as well as two silicate samples (upper chill margin and olivine cumulate) have been analysed from Alexo. Ore samples are characterised by lower Os concentrations (7 to 49 ppb), higher Re/Os (0.3-0.8), and low R factors (80 to 120). The upper chill, assumed to be representative of the initial komatiite liquid, yields very similar concentrations to those from a komatiite flow from Kambalda (Foster, *et al.* 1996) with an Os concentration of 1.79 ppb and a slightly higher Re concentration of 0.9 ppb. Ore samples from Texmont yield near-chondritic initial



R factor		1400 - 800	120-80	80-20
γ_{Os}		0-3	20-140	70-135
Possible Flow Regime		Turbulent		Laminar ?
Metamorphisme		Low Greenschist	Prehnite Pumpellyite	Low Greenschist

FIG. 1. Model for the development of the Western Abitibi ore. Modified from Barnes and Naldrett (1987).

Os isotopic compositions (γ_{Os} = 0 to +3). However, ore samples from Hart and Alexo yield more radiogenic initial Os isotopic compositions (γ_{Os} = +35 to +142). Even the upper chilled margin of the Alexo flow yields a radiogenic initial Os isotopic composition (γ_{Os} = +35) in comparison to the chondritic initial defined by Foster *et al.* (1996) for the Kambalda komatiite and ores (γ_{Os} = +0.5).

Discussion

Re-Os isotopic data from the Abitibi flow do not yield an isochron, potentially the result of at least two processes: (i) crustal contamination followed by variations in R-factor or (ii) remobilisation of Re and/or Os during secondary hydrothermal events.

(i) High R-factor is more likely to be found in highly dynamic magmatic systems. If this process is operative in contaminated ore systems, a direct correlation should be observed between R-factor and the initial γ_{Os} values for the samples (Foster *et al.*, 1996). This correlation would be a reflection of the dynamic nature of komatiitic flow systems. Figure 1 shows a model of the development of a typical nickel sulphide deposit in a komatiite, assuming that the three flows studied belong to the same system. The Abitibi komatiite may have been contaminated by surrounding felsic rocks which is consistent with the radiogenic γ_{Os} value in the upper chill at Alexo. This radiogenic isotopic signature would have only been preserved in distal environments (low R-factor) where the flow regime is more likely to be laminar. More proximal environments (higher R-factor) would have erased all evidence of contamination because of the dilution effect in the turbulent portion of the lava field (Lesher and Campbell 1993).

(ii) These flows display a wide range of metamorphic P, T, x conditions. The Texmont ores have experienced a simple hydration in the lower greenschist facies whereas ores from Hart have experienced intense carbonation leading to PGE remobilisation (Pt and Au anomalies). Although the Alexo flow is considered to be exceptionally well preserved by Archaean standards, detailed alteration studies have shown that the flow top has experienced sulphur addition whereas the rest of the flow has suffered intense hydration as well as incomplete Proterozoic rodingitisation (Lahaye and Arndt 1996). There are several lines of evidence that lead us to question a ground melting interpretation for the radiogenic Os isotopic composition of the Alexo whole rocks: (a) the isotopic difference between our data for the upper chilled margin of the Alexo flow (γ_{Os} = +35) and the value obtained on the KAL1 komatiite standard (γ_{Os} = −10) which represents a larger sample from the upper part of the same flow. This isotopic heterogeneity is consistent with Re redistribution on a large scale within the flow; (b) the presence of radiogenic Os in carbonated samples from Hart.

In order to isolate the primary signature of the flow and to evaluate crustal contamination vs. alteration processes as the cause of the radiogenic Os, further analyses will be performed on primary sulphide and silicate minerals.

References

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