Origin of early hydrothermal fluids associated with the Sudbury structure deduced from individual fluid inclusion Sr isotope analysis

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Early quartz-epidote-calcite-sulfide veins and stockworks in the Archean footwall of the Sudbury Igneous Complex contain inclusions of ore metal-bearing (Cu-Ag-Pt-Bi-Au) aqueous brine (Ca-Na-Cl) with high Sr and relatively low Rb bulk concentrations (4400 μg/g Sr; 110 μg/g Rb; Sr/Rb = 40; n = 18) in addition to wt% concentrations of K, Fe, Mn, Zn, Pb and Ba[1]. Inclusions were trapped in the veins at ~ 0.5 kbar; 200-250ºC[1]. We have determined initial (at 1.85 Ga[2]) $^{87}Sr/^{86}Sr$ ratios in individual brine inclusions by LA-MC-ICP-MS to constrain the source of this fluid that circulated prior to magmatic sulfide deposition.

Analyses of 62 brine inclusions yielded an average initial $^{87}Sr/^{86}Sr = 0.70308 \pm 0.00020$ (1SE). Tentatively, we suggest that the data are most consistent with this early, metalliferous hydrothermal fluid containing a significant endowment of regional Proterozoic seawater ($^{87}Sr/^{86}Sr = 0.70296$[3]) which covered the target area at the time of impact and subsequent formation of the melt sheet. Suspected major crustal reservoirs in the area had initial $^{87}Sr/^{86}Sr$ too radiogenic to have been an exclusive source for the Sr in the inclusions; these include the gneissic country rocks hosting the veins and their associated groundwaters (initial $^{87}Sr/^{86}Sr$ = 0.71008-0.71092[3]) and magmatic fluids derived from the main igneous units of the Sudbury Igneous Complex itself (initial $^{87}Sr/^{86}Sr$ = 0.70710-0.70742[3]). However, some individual inclusions of assemblages show significant variation in composition (e.g., for 3 inclusions: initial $^{87}Sr/^{86}Sr$ ranges from 0.7018 to 0.7046). A standard deviation for all inclusions analyzed (1σ on mean) of $\pm$ 0.001540 suggests the inclusions have trapped pulses of a poorly mixed fluid involving mainly seawater, and a minor component from an additional source, either magmatic and/or groundwater. Scatter due to analytical bias is also being investigated.

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Pairing Re-Os geochronology and biostratigraphy – Dating fossils

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With hard-earned insights in sampling strategies and improvements in analytical precision, Re-Os geochronology of organic material in sedimentary rocks is now an established method for placing time pins in the stratigraphic record. Age uncertainties better than 1% are routine, and as low as 0.5% not uncommon. We are now able to address a range of questions using Re-Os geochronology where age constraints were previously lacking. For example, Re-Os shale geochronology can assist uncertain biostratigraphic correlations, and provide ages where biota are absent. We have established the timing of tectonic events in the southern Superior province with a 2695 ± 14 Ma age in a supracrustal sequence [1]. We have confirmed correlation of Anisian-Ladinian (Middle Triassic) biozones between Boreal and Tethyan terranes, where there are no common fossil assemblages and U-Pb geochronology is limited to the Tethyan realm [2]. Further work on the Boreal Triassic section (Xu *et al*., this meeting) affirms the proposed "Alternate" Triassic time scale. Similarly, tight time constraints on the Permo-Triassic extinction were previously limited to the Meishan area in Tethys. We have extended that extinction timeline to the Boreal, with remarkably precise Re-Os isochrons from opposing sides of the Norwegian Sea [3].

An obvious next step is direct dating of fossil organic remains. The Lower and Middle Ordovician sections in western Newfoundland display sequences of well-defined graptolite zones, but lack radiometric age constraints. Re-Os analysis of *Archiclimacograptus* sp., hand-picked from Table Cove Fm shales (Table Head Group) yields 11.4 ppb Re and 0.540 ppb Os. Isotopic ratios are reasonable for the proposed biostratigraphic age. Detailed age constraints from multiple graptolite horizons can delimit durations of biozones, refine the Ordovician time scale, and confirm global correlations. Ultimately, we can assign absolute ages to stratigraphic key surfaces and system tracts, reflected in environmentally sensitive graptolite assemblages, to improve precision of the sea-level curve for the Lower and Middle Ordovician.

Funded by U.S. NSF grant EAR-0844213

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