

Re-Os isotope systematics of massive Cu-Ni-PGE mineralization, Duluth Complex, Midcontinent Rift System, USA

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The presence of sulfidic country rock and sulfur isotope ratios point to the importance of contamination of mafic magmas by Proterozoic footwall rocks in the generation of Cu-Ni-PGE mineralization associated with the ~1.1 Ga Duluth Complex. Massive sulfide mineralization of the Partridge River intrusion consists of pyrrhotite, cubanite, chalcopyrite and pentlandite, and may occur either in gabbroic/troctolitic rocks or within pelitic footwall rocks of the Virginia Formation.

Massive sulfide samples have variable Re concentrations (37-253 ppb) and more restricted Os concentrations (0.92-15.74 ppb). Results of Re and Os isotopic studies strongly support the premise that contamination by country rocks has played a pivotal role in the formation of the sulfide mineralization. γ_{Os} values at 1.1 Ga are extremely elevated ranging from 982 to 1433. The Os isotopic compositions of the massive sulfides are consistent with mixing between chondritic mafic magmas and highly radiogenic, carbonaceous country rock at 1.1 Ga. Mixing calculations suggests that a minimum of 40% of Os in the massive sulfides was of crustal derivation. However, the S and Os isotope compositions of the sulfides and the presence of major amounts of mineralization in the country rocks lead to another possible alternative.

A sulfide melt may have been derived from the sulfidic pelites during contact metamorphism, or from sulfidic country rock xenoliths. The massive sulfides are characterized by relatively low Ni abundances and Cu/Ni ratios in excess of 5, suggesting limited interaction with mafic magma prior to the crystallization of Ni-bearing olivine. The massive sulfides plot below the ~1.85 Ga isochron for the Virginia Formation indicating some interaction with a low $^{187}Os/^{188}Os$ material (presumably the Duluth Complex magmas at 1.1 Ga).

A third possible interpretation is that Re-Os isotopic compositions have been variably perturbed by much later hydrothermal processes. However, little or no evidence exists for hydrothermal events that occurred significantly after 1.1 Ga, and we suggest that anomalies in the Os isotopic composition of massive sulfides are related to events directly linked to emplacement of the Duluth Complex magmas.

Temporal variations in the iron isotopic compositions of Pacific hydrogenetic Fe-Mn crusts

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We report high-resolution iron isotope ($\delta^{57/54}Fe$) studies of two well characterised Fe-Mn crusts sampled from the central equatorial Pacific ocean (F10-89-CP D11-1 and F7-86-HW CD29-2). Both crusts have been dated using Os isotope stratigraphy [1-3] and for CD29-2, Fe isotope data were obtained on the same sample splits for which Os isotopes were determined. From the late Cretaceous to the earliest Cenozoic, CD29-2 displays variable but generally negative $\delta^{57/54}Fe$ ratios (0.0 to -1.2 permil). A smooth shift to positive $\delta^{57/54}Fe$ at ~55 Ma occurs in CD29-2, followed by a period characterised by highly variable, generally positive $\delta^{57/54}Fe$ values. The shift to positive $\delta^{57/54}Fe$ at ~55 Ma in CD29-2 is mirrored in D11-1, but more data are required to confirm this. From ~16 Ma to present, both crusts show isotopically light $\delta^{57/54}Fe$ values that are essentially invariant and within error of modern surface-water values [4].

One explanation for the $\delta^{57/54}Fe$ variations is diagenetic phosphatisation. However, the depths at which phosphates first appear in both crusts [5] do not show clear $\delta^{57/54}Fe$ excursions. Other explanations include processes such as complexation of Fe by organic siderophore-like ligands [6] and changes to the Fe inputs to the oceans [7]. In the latter case, there are no relationships between $\delta^{57/54}Fe$ and proxies of dust/aerosol deposition such as Pb isotopes [5]. Moreover, $\delta^{57/54}Fe$ varies very little between ~16 Ma to present despite the major build up of dust in the Pacific that occurred from ~10 Ma [8]. Given the short ocean residence time of Fe (100-200 years), it is likely that the crusts record both first and second-order $\delta^{57/54}Fe$ variations. If the shift to positive $\delta^{57/54}Fe$ at 55 Ma in CD29-2 can be confirmed for D11-1, which is >3000km away, this argues for the involvement of large-scale as well as more transient local processes in controlling $\delta^{57/54}Fe$ variations.

[1] Burton (2006) *J. Geochem. Explor.* **88**. [2] Klemm (2005) *EPSL* **238**. [3] Nielsen (2009) *EPSL* **279**. [4] Levasseur (2004) *EPSL* **224**. [5] Ling (1997) *EPSL* **146**. [6] Dideriksen (2008) *EPSL* **269**. [7] Chu (2006) *EPSL* **245**. [8] Kyte (1993) *GCA* **57**.