

Komatiites, kimberlites and boninites

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When the mantle melts, it produces ultramafic magma instead of the more usual mafic magma, if (a) the site of melting is unusually deep, (b) the degree of melting is unusually high, or (c) the source is unusually refractory. For this to happen, the source must be unusually hot, or it must contain a high volatile content. Just as with basalts, different conditions of mantle melting produce a spectrum of ultramafic magma types.

Komatiites form by relatively high degrees of melting, at great depths, of an essentially anhydrous source. Barberton-type (or Al-depleted) komatiites are high-degree batch melts from a particularly hot source. The combination of high-degree melting and a garnet-subtraction geochemical signature requires that these melts formed at extreme depths (>300 km) from a source that may have been molten as it crossed the transition zone. Munro-type (Al-undepleted) komatiites lack the garnet-subtraction signature and are depleted in incompatible trace elements. They form through high-degrees of fractional melting from a slightly cooler source, at less extreme depths.

Kimberlites and meimechites are highly mafic to ultramafic alkaline magmas that form through low-degree melting, also at great depth, of sources that are enriched in incompatible elements and in CO₂ + H₂O. Their enormous trace-element concentrations and lithospheric or asthenospheric isotope compositions are not explained simply by partial melting. These magmas probably attain their final geochemical compositions during subsequent interaction with overlying asthenospheric or lithospheric mantle.

Boninites are highly mafic siliceous magmas produced by hydrous melting of metasomatised, originally depleted mantle wedge above a subduction zone.

Just like basalts, the different types of ultramafic magma, and their contrasting modes of formation, are readily distinguished using a combination of major and trace element characteristics.

Oxygenation of Proterozoic oceans: Insight from molybdenum isotopes

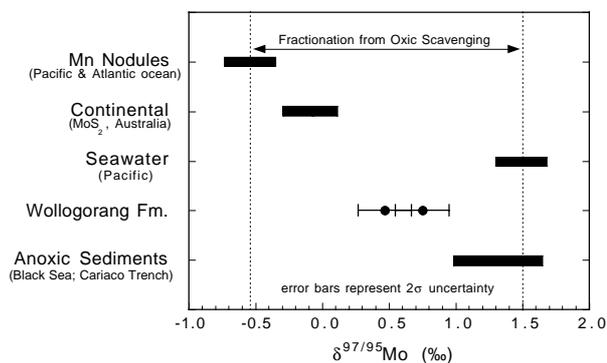
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The oceans in the mid-Proterozoic are classically thought of as fully oxygenated. However, S-isotope data suggest widespread sulfidic conditions (Canfield, 1998). Mo isotopes may provide insight to this debate.

Previously, we observed a systematic Mo isotope fractionation ($\delta^{97/95}\text{Mo}$) between recent oxic and anoxic sediments (Barling et al., 2001; Arnold et al., 2001; Fig. 1; data relative to laboratory standard). $\delta^{97/95}\text{Mo}$ of seawater and anoxic sediments are essentially the same, suggesting Mo isotope fractionation during removal to oxic sediments. Laboratory experiments support this suggestion (Barling and Anbar, 2001). Therefore, $\delta^{97/95}\text{Mo}_{\text{seawater}}$ may reflect the global balance between Mo removal to oxic and anoxic sediments and changes in this balance should be recorded as changes in $\delta^{97/95}\text{Mo}_{\text{anoxic}}$. If the proportion of seafloor under sulfidic waters were larger in the past, $\delta^{97/95}\text{Mo}_{\text{anoxic}}$ should shift toward lighter values. Assuming steady-state mass balance and data to date as representative, $\delta^{97/95}\text{Mo}_{\text{anoxic}} \sim 1.98 - 2.05 \times f_{\text{anoxic}}$.

Figure 1: $\delta^{97/95}\text{Mo}$ in geological materials



Preliminary investigation of ~ 1.73 Ga Mo-rich black shales from the Wollongorag Fm. (McArthur Basin, Australia) reveals unusually light $\delta^{97/95}\text{Mo}_{\text{anoxic}}$ (0.47 to 0.75 ‰). Mo in these sediments is primarily authigenic. These data suggest $f_{\text{anoxic}} = 0.60$ to 0.74 vs. ~ 0.22 today, consistent with more extensive sulfidic deposition in mid-Proterozoic oceans.

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