Simulating the climatic impact of Large Igneous Provinces using a mid-Miocene case-study

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Large Igneous Provinces (LIPs) have occurred throughout Earth's history, erupting great quantities (>10^4 km^3) of lava in long-lived (>10^5 y) events that have been linked to major environmental disruptions [1]. While the largest LIP eruptions are widely considered to have had a significant impact on global climate through basalt CO_2 degassing [2–4], the impact of the more numerous smaller LIPs is disputed [5–7]. Here we test the hypothesis that LIPs had a greater impact on Earth's climate history than previously estimated because of the degassing not only of erupted basalts but also intruded, underplated and pyroxenite-enriched magma [1, 4, 8]. We use biogeochemical box models to investigate the potential impact of the Columbia River Basalts (CRB) during the mid-Miocene, as a more rigorous model-data comparison is enabled by the better palaeorecords from this relatively geologically recent event. Comparison of our simulations to palaeorecords [5, 9, 10] of mid-Miocene changes in oceanic carbonate compensation depth (CCD), $\delta^{13}C$ in benthic foraminifera and atmospheric pCO_2 suggests that an emission of ~2000-4000 Pg of carbon between ~16.2 and 15.8 Ma is required to reproduce the palaeorecords, although additional mechanisms are required to match the CCD palaeorecord beyond ~15.8 Ma. This flux is within the estimated range of potential carbon emissions when including non-extrusive sources. Our results indicate that with these additional CO_2 sources the CRB could have played a significant role in the mid-Miocene Climatic Optimum, and implies that other LIPs could have also had a greater climatic impact than currently estimated.

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Constraining the history of the Mojavian lithosphere with Sr, Nd, Hf, and Os isotopes of peridotite xenoliths from Dish Hill, California

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The $^{187}Os/^{188}Os$ ratios in mantle xenoliths have been used to constrain continental growth histories [e.g. 1]. However, there is debate over the degree to which model Os ages reflect large-scale mantle melting linked to continental growth [2], or averaged-out end members after a multi-stage-history of partial melting, melt-rock interaction and metasomatism [3]. Combining different isotopic systematics can help constrain the nature and timing of melt extraction and secondary melt or fluid interactions in subcontinental lithospheric mantle.

A suite of 16 spinel-bearing Cr-diopside peridotite xenoliths from Dish Hill, CA, a Plio-Pleistocene cinder cone in the Mojave Desert were first characterized for major and trace elements (bulk-rock and main phases), then analysed for Os, Hf, Nd and Sr isotopes, with the lithophile isotopic analyses being obtained on cpx separates.

The $^{187}Os/^{188}Os$ ratios fall on two aluminachron [4] trends, with T_{PUM} at 2.12±0.08 Ga and 1.39±0.10 Ga. These two distinct trends are supported in correlations of $^{187}Os/^{188}Os$ versus melt depletion indicies such as Cr# in spinel This signal of two mantle melting events is not present in the Hf isotope data. The correlations between εHf and melt depletion indicies are weak. There is also evidence that Hf is decoupled from Nd as the peridotites that lie off the εHf-εNd terrestrial array of [5] also display LREE enrichments. High Nb/Zr and La/Lu ratios in cpx in one of the peridotites suggest a HFSE-LREE metasomatic component.

The combined isotopic data points to the lithosphere mantle under Dish Hill being formed in two ancient mantle melting events, and overprinted by at least two metasomatic components. There is no evidence in this xenolith suite of underlying Farallon oceanic lithosphere as proposed by [6].

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