Hafnium - Osmium Systematics of Cretaceous Group II Kimberlites from India

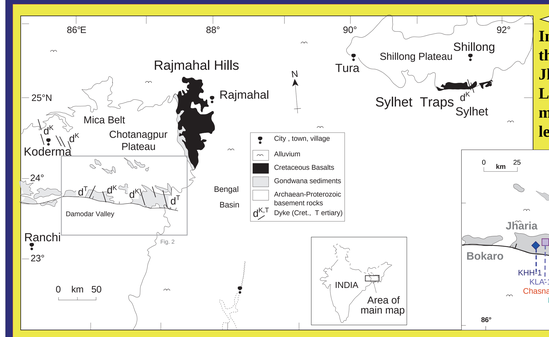
R.W. Kent[a], S. Ingle[b], N. Mattielli[c], P.D. Kempton[d], A. Saunders[e], K. Suzuki[f]

[a] Loughborough University, United Kingdom
[b] Tokyo Institute of Technology, Japan
[c] Université Libre de Bruxelles, Belgium
[d] NERC, Swindon, United Kingdom
[e] University of Leicester, United Kingdom
[f] IFREE - JAMSTEC, Yokosuka, Japan

Rationale for study

Orangeite (Group II Kimberlite) magma is generated from garnet-bearing mantle at depths in excess of 150 km, and may transport diamond to the surface. The petrogenesis of orangeite magma is not well understood, but it appears that orangeites are hybrid rocks consisting of variable proportions of xenocrysts (principally olivine macrocrysts derived from disaggregated peridotite) plus phenocrysts and interstitial phases, representing extensive crystal fractionation from a mafic alkalic melt.

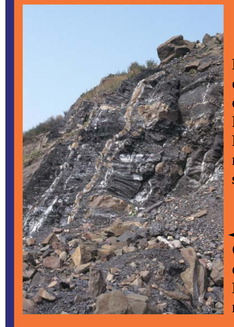
We have collected Hf and Os isotope data for orangeite samples from the Damodar Valley of eastern India. These data complement our major element, trace element and Sr-Nd-Pb isotopic studies. We propose to use these data to place constraints on the nature of the mantle source(s) of orangeite, which has been the subject of recent debate.



Map of eastern India showing locations of the Damodar Valley, Jharkhand, West Bengal. Location of the main sedimentary basins in the valley and sample locales.

Ramnagar Colliery, Raniganj Basin Eastern Damodar Valley

Cylindrical sills of orangeite cutting Permian Barakar Formation coal and sandstone.



Large orangeite sill emplaced into Permian Barakar Formation coal seams.

Orangeite dykes cutting Permian sediments.

Ramnagar Colliery, Raniganj Basin Eastern Damodar Valley

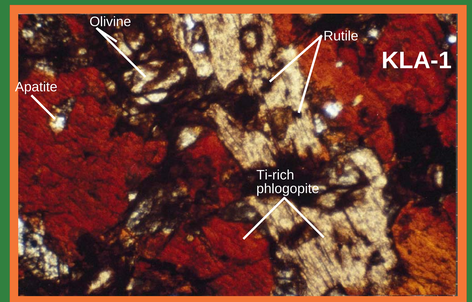
Large eliptical orangeite sills (bleached white) intruding Barakar Formation coal.

Orangeite cylinder with small dyke-like apophyses intruding sandstone and coal.

Kustore Colliery, Jharia Basin Central Damodar Valley

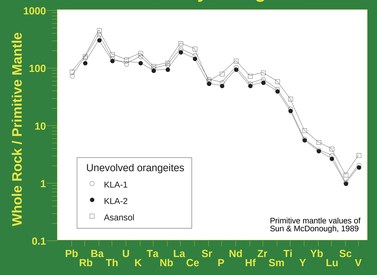
Small cylindrical sills of orangeite some exposed in longitudinal section, intruding Barakar Formation coal and sandstone.

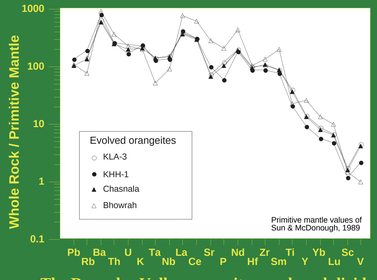
Petrogenesis of Group II Kimberlites



Cross-polars photomicrograph (x100)

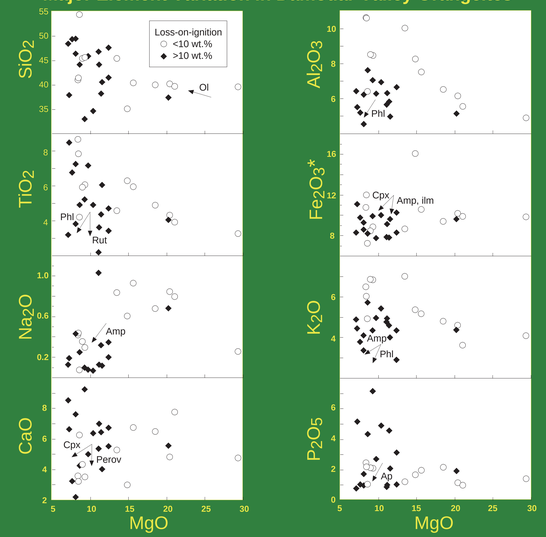
Trace Element Variation in Damodar Valley Orangeites





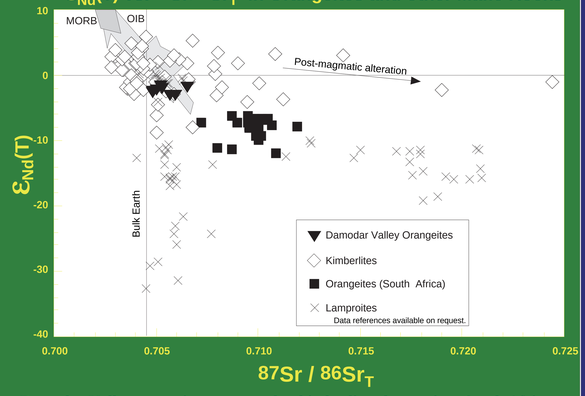
The Damodar Valley orangeites can be subdivided into two groups based on the mineralogy / trace elements (after Mitchell, 1995): Unevolved and Evolved orangeites.

Major Element Variation in Damodar Valley Orangeites



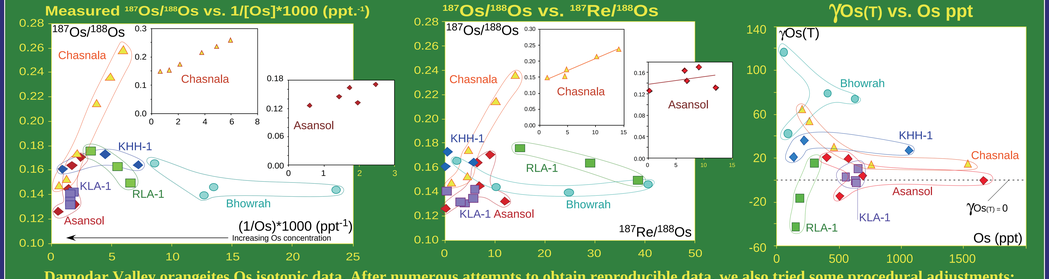
Effects of crystal fractionation - primarily olivine (ol) and phlogopite (Phl), but also clinopyroxene (Cpx), rutile (Rut). Alteration (carbonation) is extensive in some samples (>10% LOI).

$\varepsilon_{Nd}(T)$ vs. $^{87}Sr/^{86}Sr_T$ in Orangeites and other Mafic Rocks



Damodar Valley orangeites compared to kimberlites, lamproites, South African orangeites, mid-ocean ridge basalts (MORB) and ocean island basalts (OIB).

Os Isotope Results

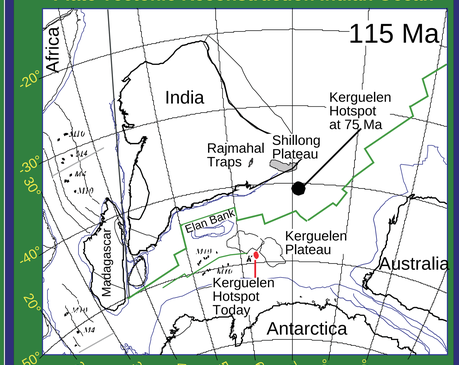


Damodar Valley orangeites Os isotopic data. After numerous attempts to obtain reproducible data, we also tried some procedural adjustments: reproducibility was not improved. Therefore, we suggest that these orangeite samples are extremely heterogeneous and small phases (<30µm) probably host the high Os concentrations.

A Kerguelen Connection?

The Kerguelen hotspot is linked in space and time with the eruption of east India orangeites. Compositional similarities also exist, particularly in isotopes. Could they be connected?

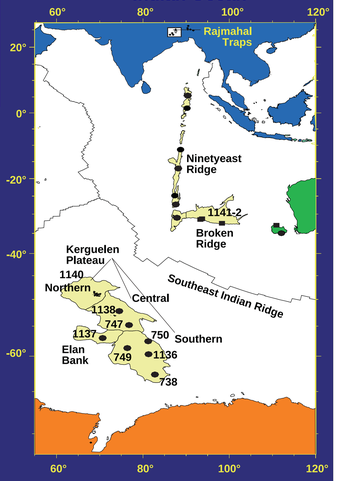
Plate Tectonic Reconstruction Indian Ocean



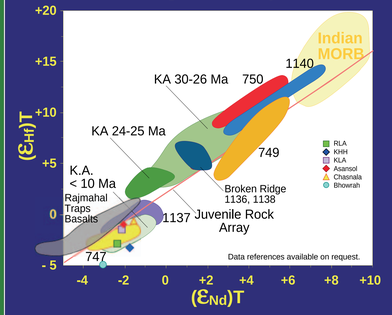
Reconstruction from Kent et al. 2002, using mantle convection code derived by Steinberger & O'Connell, 1998. Relative southward motion of the Kerguelen hotspot is based on Antretter et al. 2002.

At 115 Ma, eastern India was near the inferred location of the Kerguelen hotspot (calculated back to 75 Ma). At present, the hotspot is near 49°S but has likely drifted southward over time. Damodar Valley orangeites were emplaced just to the south of the Rajmahal Hills, where flood basalts were contemporaneously emplaced. Rajmahal basalts and Damodar Valley orangeites may form two parts of the same magmatic episode, which might have coincided with early Kerguelen plume activity. Below, we compare data for these three volcanic events.

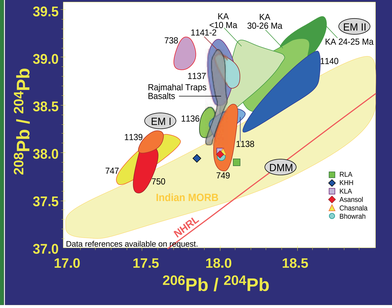
Present-day map of the Indian Ocean



Isotopic compositions of Orangeites and Kerguelen hotspot lavas



Damodar Valley orangeites compared to Rajmahal Traps lavas, Kerguelen hotspot lavas, Indian mid-ocean ridge basalts (MORB), and the mantle 'endmembers'. Also shown is the Northern Hemisphere Reference Line, a regression through oceanic basalts north of the equator (in Pb plot).



Conclusions

Indian orangeites (115 Ma) lie on or just below the mantle array in Hf-Nd isotope space, comparable to some Rajmahal Traps and Kerguelen basalts; similarities that are present in Pb isotopes too. These characteristics, when combined with mineralogical and other geochemical data, imply derivation of the orangeites from a garnet-bearing source. Subsequent interaction with Indian lithosphere and/or lower crust is likely. Plate tectonic reconstructions and isotopic overlap with Kerguelen hotspot-derived lavas permit a contribution from the Kerguelen plume in the orangeites.