Temporal isotopic variations in the Kerguelen plume: evidence from the Kerguelen Archipelago

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An understanding of the origin and evolution of mantle plumes and their interactions with surrounding mantle is required in order to understand the evolution of the Earth's heterogeneous mantle. The Hawaiian and Kerguelen plumes are two major long-lived plumes that are geochemically very different and evolved in different tectonic settings. The Kerguelen plume is important because: (a) its Sr, Nd and Pb isotopic characteristics are near one of the extremes for ocean island basalts and (b) it has a very long record of volcanism beginning with a very large Cretaceous igneous province (the ~85 to 115 Ma Kerguelen Plateau-Broken Ridge system), continuing with a ~82 to 38 Ma year hotspot track (Ninetyeast Ridge) and concluding with oceanic islands (the long-lived 38 myr Kerguelen Archipelago and the recent, < 2 Ma, Heard Island).

Although much of this plume-related volcanism was subaerial, the lavas that erupted from ~115 to 38 Ma now form the submarine Kerguelen Plateau-Broken Ridge complex and the Ninetyeast Ridge. Lavas from these large submarine provinces were recovered by DSDP and ODP drilling (Legs 22, 26, 119, 120 and 121) and the uppermost portions of these thick volcanic structures (e.g. the Kerguelen Plateau is 21 to 25 km thick) are tholeiitic basalt (Mahoney *et al.*, 1995). The only directly accessible lavas related to the Kerguelen Plume are those erupted on islands such as those forming the 6500 km^2 Kerguelen Archipelago on the Antarctic plate. We have obtained Sr, Nd and Pb isotopic data from five 380 to 978 meter stratigraphic sections of the flood basalts (ages ranging from 22 to 30 Ma, Nicolaysen *et al.*, 1996), forming this archipelago. These basalts form a nearly horizontal plateau and represent >85% of the archipelago. Their compositions range from transitional in the oldest sections (~30 Ma) to slightly alkalic in the young sections (~22 Ma). At <22 my the eruption rate decreased dramatically and highly evolved lavas, such as trachytes and phonolites, are common. These long-term trends within the archipelago are interpreted as reflecting a temporal decrease in extent of melting, an increase in pressure of melt segregation, and frequent stagnation of magmas within the crust (Weis *et al.*, 1998).

Four of the five stratigraphic sections are dominated by lavas with $(^{87}Sr/^{86}Sr)_i = 0.70515 \pm 12$ and $(^{143}Nd/^{144}Nd)_i = 0.51259 \pm 5$. This range defined by >100 samples includes that inferred for the Kerguelen Plume from studies of the youngest, Miocene to Pleistocene, lavas in the archipelago (Weis *et al.*, 1993, 1998). Both parental and evolved lavas have similar isotopic ratios. Two sections from the north-central part of the archipelago contain a few lavas (~15%), the group D lavas (for depleted), with lower $^{87}Sr/^{86}Sr$ and higher $^{143}Nd/^{144}Nd$; these lavas are interpreted to contain a component derived from older oceanic crust (Yang *et al.*, 1998). One lava section (Mont Tourmente) from the central part of the archipelago has isotopically homogeneous transitional (older) and alkalic (younger) lavas that have lower $^{87}Sr/^{86}Sr$ (0.70476 ± 5) and higher $^{143}Nd/^{144}Nd$ (0.51272 ± 1) than the dominant isotopic signature present in the other four sections.

Despite the similarity of Sr and Nd isotopic ratios in four of the five sections, there are distinct differences between all sections in Pb isotopic ratios; each section has a distinct Pb signature. For example, basalts from the older and northernmost sections have lower $^{206}Pb/^{204}Pb$ (<18.3) than those from the east and central archipelago. The $^{206}Pb/^{204}Pb$ variation is not a simple temporal trend as younger post-flood basalts in the Southeast Province (<10 Ma) and Ross Volcano (<2 Ma) also have relatively low $^{206}Pb/^{204}Pb$. Plutonic rocks, except at Mt. Ross, of widely varying age (39 to 4 Ma) have $^{206}Pb/^{204}Pb$ >18.3. Clearly, the Pb isotopic

variations that occur on a relatively small spatial scale provide information not available in the Sr and Nd isotopic systems. Lavas recovered from the southern Kerguelen Plateau (115–85 Ma) by drilling range widely in Sr and Nd and overlap with the Kerguelen Archipelago lavas field (< 30 Ma) but the Kerguelen Plateau lavas are offset to lower $^{206}Pb/^{204}Pb$ and lower $^{208}Pb/^{204}Pb$. At ODP Site 738, such low $^{206}Pb/^{204}Pb$ ratios are accompanied by very high $^{87}Sr/^{86}Sr$, $^{207}Pb/^{204}Pb$, $^{208}Pb/^{204}Pb$ and low $^{143}Nd/^{144}Nd$ and this isotopic signature is interpreted to reflect a continental lithosphere component (Mahoney *et al.*, 1995). There is no evidence for a continental component in Archipelago and Ninetyeast Ridge lavas but it is present in a few peridotite xenoliths in archipelago lavas.

In summary, our study of lava sections leads to the following conclusions:

1. The temporal evolution in the archipelago is from older transitional to younger alkalic lavas, but there is no simple temporal evolution in isotopic ratios of Sr and Nd; i.e. relatively high $^{87}Sr/^{86}Sr$ and low $^{143}Nd/^{144}Nd$ are characteristic of recent <1 Ma alkalic lavas from Mt. Ross, and ~29 Ma transitional lavas in the flood basalt sequence. This enriched isotopic signature is the dominant component represented in lavas of the Kerguelen Archipelago and defines the characteristics of the Kerguelen Plume.

2. Pb isotopic ratios vary with location; each lava section on the archipelago has a distinctive Pb isotopic signature. Most of the Kerguelen Plateau lavas have Pb isotopic ratios that do not overlap with Kerguelen Archipelago lavas. The array for lavas from Heard Island is also different (Barling *et al.*, 1994). Some of the Pb isotopic variability may reflect a role for oceanic crust or its mantle source, but this interpretation does not explain the full range or the provinciality of the Pb isotopic data. A satisfactory explanation for the Pb isotopic variations remains a major goal.

3. A continental component with relatively high $^{207}Pb/^{204}Pb$ and depletion in Nb and Ta abundances is present in some of the oldest, >80 Ma, lavas associated with the Kerguelen plume, but there is no evidence for this component in lavas from the Kerguelen Archipelago. In contrast to Heard Island, the Kerguelen Archipelago may not be underlain by Cretaceous Kerguelen Plateau lithosphere; this difference may explain the differences in isotopic mixing trends defined by lavas from these islands that are only 440 km apart.

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