THE LIFE CYCLE OF MANTLE PLUMES

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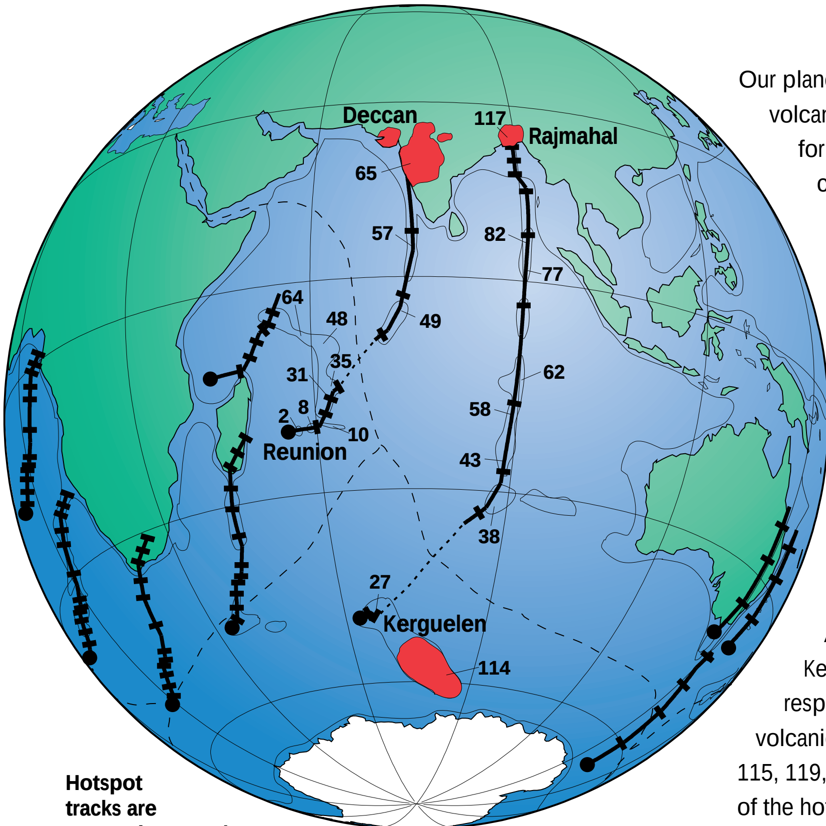

Hotspot tracks are mapped across the Indian Ocean by a computer model that incorporates known tectonic plate motions and assumes hotspot immobility. The tracks match observed volcanic ridges, seamounts and islands remarkably well. Radiometrically-determined ages (numbers in m.y.) of ODP samples and terrestrial rocks also fit with model-predicted ages (ticks at 10 m.y. increments). Enormous accumulations of flood basalts at the northern ends of the Reunion and Kerguelen tracks, and the southern Kerguelen plateau (stippled areas) were erupted when mantle plume activity initiated.

Our planet's surface is dotted with hotspots, which are focused volcanic areas, approximately 100-200 km wide, that persist for tens of millions of years. Because these volcanic centers appear to remain at a fixed position beneath the moving tectonic plates throughout their long lifetimes, it is speculated that hotspots are connected to a stable pattern of upwardly flowing plumes of warmer than average material from deep levels of the mantle. This convective circulation may be the major way that heat moves from Earth's interior to its surface. We study these features to better understand the dynamics, kinematics, chemistry, and thermal histories of these fascinating conduits. Nowhere is their behavior more clearly seen than in the Indian Ocean (see figure). Here, drift of the African, Indian, Australian and Antarctic plates over the Reunion and Kerguelen hotspots (formed at about 65 and 117 Ma, respectively) produced linear, age-progressive chains of volcanic ridges, islands and seamounts. Data from ODP Legs 115, 119, 120 and 121 document the continuity and immobility of the hotspots, which provide us with a direct and simple frame of reference to reconstruct plate motions during the opening of the Indian Ocean. The Reunion and Kerguelen hotspots began with extraordinarily extensive eruptions of lava flows that cooled into thick volcanic platforms, called flood basalts, both on continental and oceanic lithosphere. The original eruption rate from these hotspots was at least 10 to 100 times greater than today at the most active hotspots, such as Hawaii and Iceland. This enormous flux was most likely related to new, surfacing plumes that disgorged large volumes of high temperature mantle material. The timing of flood basalt volcanism correlates with environmental crises, such as global warming, ocean anoxia and mass extinctions, implying a strong link between mantle activity and Earth's surface. Hotspots also provide "windows" into the deep mantle. The compositions of volcanic rocks along hotspot trails change with time and reflect varying contributions from the deep vs. the shallow mantle. The compositional variation along the Reunion hotspot trail is consistent with early entrainment of shallow material within the rising plume, and subsequent gradual increase in the proportion of deep material in the source for hotspot melting. A similar evolution in Kerguelen hotspot magmas is observed, with compositional changes related to varying proportions of upper and deep mantle mixing, correlated with the plate tectonic setting. Both hotspots are now located well away from plate boundaries but earlier lay near or at spreading ridges.

References:
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