Plume Flux, Spreading Rate, and Obliquity of Seafloor Spreading

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Most of Earth’ s surface is created by seafloor spreading, a fundamental global tectonic process. While most seafloor spreading is orthogonal, i.e., the strike of mid-ocean ridge (MOR) segments is perpendicular to transform faults, obliquity of up to ~45° occurs. Here, building on the work of DeMets et al. [2010] we investigate the global relationship between obliquity of seafloor spreading, spreading rates, and the flux of nearby plumes. While we confirm the well-known tendency for obliquity to decrease with increasing spreading rate [Atwater and Macdonald, 1977], we find exceptions at both intermediate (up to 18°) and ultra-fast (up to 12°) rates of spreading. Thus, factors other than the minimization of power dissipation across mid-ocean ridges and transform faults [Stein, 1978] may influence the amount of obliquity.

Abelson & Agnon [1997] modeled spreading centers as fluid-filled cracks and found that the variation of segment orientation depends on the ratio of the magma overpressure to the remote tectonic tension that drives plate separation. A high ratio promotes oblique spreading and a low ratio promotes segmentation that results in orthogonal spreading. They further argued that if a hotspot lies near a MOR segment, the hotspot contributes to magma overpressure along the segment. We quantify their argument as follows: (1) that magma overpressure increases with increasing flux of a plume. (2) that effective magma overpressure decreases with increasing distance between a MOR segment and a plume. From this we estimate the effective plume flux delivered to each mid-ocean ridge using published plume flux estimates.

Not only does obliquity tend to decrease with increasing spreading rate, but also it tends to increase with increasing effective plume flux delivered to a MOR segment. Many exceptions occur, however. Along slow spreading centers, many segments are less oblique than along the Reykjanes Ridge and western Gulf of Aden despite having higher effective plume flux. Similarly, along intermediate spreading centers, some ridge segments are less oblique than along the western Galapagos spreading center, despite having greater effective plume flux. We conclude that neither the minimum power dissipation model nor the hotspot proximity model fully explain the globally observed variations of oblique spreading.

Keywords: Plume Flux, Obliquity of Seafloor Spreading

Dispersion of hotspot trends: A tool for estimating motion between groups of hotspotsDispersion of hotspot trends: A tool for estimating motion between groups of hotspots

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It is widely believed that groups of hotspots in different regions of the world are in relative motion at rates of 10 to 30 mm a^{-1} or more. Recent work on plate motions over the past ≈50 Ma indicate no significant motion between hotspots and place an upper bound on such motion of ≈10 mm a^{-1}. Here we present a new method for analyzing geologically current motion between groups of hotspots beneath different plates. In an inversion of 56 globally distributed, equally weighted hotspot trends, misfit magnitudes range from 0° to 86° (median= 9°; standard deviation =23°). The dispersion is dominated by differences in trend between different plates rather than dispersion within plates, lending support to the notion that groups of hotspots beneath different plates do indeed move relative to one another. The absolute value of mean angular difference for a given plate decreases significantly with increasing absolute plate speed. When these angular misfits are converted to vperp, the rate of hotspot motion perpendicular to the direction of absolute plate motion, there is no significant dependence on absolute plate speed. Moreover, vperp differs significantly from zero for only two of ten plates and then by no more than 1 mm a^{-1}. Thus, motion between groups of hotspots may be as low as 1 mm a^{-1} and perhaps even slower when considering plate non-rigidity and errors in relative plate motions. The upper bound on | *vperp*| is 3.2 ±2.8 mm a^{-1}. Therefore, groups of hotspots move between 1 mm a^{-1} and 6 mm a^{-1} relative to the mean hotspot frame, substantially slower than found in some prior work.

Keywords: Hotspot fixity, Absolute plate velocity

Can Seismic Tomography See Mantle Plumes?

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Seismic tomography is often used to study the three-dimensional structure of the upper and lower mantle, and is the most powerful tool for imaging structure beneath "hot spots". Tomography experiments have often found regions of low wave speed beneath hot spots (and elsewhere) that might be an effect of high temperatures such as thermal plumes, but such results are seldom reproducible from one study to another. The basic reason for this difficulty is the sparseness and unevenness of the sampling of the Earth by seismic waves, a consequence of the sparse geographical distribution of earthquakes and seismometers. An infinite number of three-dimensional models are consistent with any real data set. The common practice of inverting seismic data to derive one such model is thus not informative, since the results are so highly non-unique.

The North Atlantic Ocean provides a good illustration of these difficulties. This region is sampled relatively well by seismic waves, due to the abundance of seismometers in Europe and North America and on Iceland and other islands, and to a favorable distribution of seismicity (compared to the central Pacific Ocean, for example). Nevertheless, derived mantle models differ in seeing or not seeing features that can be interpreted as mantle plumes. The locations, orientations, etc. of these features also differ from study to study.

Despite the shortcomings of real data sets, however, they do usually contain useful information. Even though an infinite number of conceivable models are consistent with available data, even more models are inconsistent with the data. A useful way forward is to use data to test hypothetical models, seeking to rule out some of the competing hypotheses about the Earth, as suggested by Tarantola (2006).

Keywords: seismic tomography, plumes, resolution

Low CaO olivine phenocrysts in picritic rocks formed in back-arc area, Japan.

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Low-CaO core (<0.17 wt.%) of olivine phenocrysts are found from Miocene picritic rocks distributed in back-arc area, Japan Sea. Picritic dolerite of Ogi Basalt, Sado island, Japan, has MgO content ranging from 12 to 34 (wt.%), which is controlled by olivine accumulation. Based on c.a. 50 line profiles, the large phenocrysts show reverse zoning, and Fo content of the core varies grain by grain, in the range Fo 90 to 82, rimmed with normal-zoned rim (Fo90 to 87). Composition of high-Fo core has low-CaO contents (0.1-0.15 wt.%) and continue to that of low-Fo core with high-CaO contents ($\geq$0.15 wt.%), illustrating a sequencial trend of composition. The compositional trend is similar to that of olivine phenocrysts crystallized from high-CaO boninitic magma. NiO contents of all the olivine phenocrysts are no more than 0.28 (wt.%). Xenocrystic origin of olivine core of the phenocrysts is suggested as captured from dunitic cumulate rather than from mantle lerzolite. High-CaO boninitic magma could be parental to form this dunitic cumulate body. Similar core of olivine phenocrysts can be found in picritic basalt of Miocene Mishima Volcanic Rocks, Mishima Island. Though any boninitic rocks has not been known in the back-arc area, boninitic magmatism could not be denied from these facts. Although high Mg andesite is not popular in back area, there are some adakitic dacite and high Mg andesite reported from the Japan Sea side in Neogene to Miocene age. Associated with back-arc spreading, boninitic magma could have been originated by decompressional melting of upwelled hot mantle, or by melting of depleted mantle source reacted with slab melts.

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