ANTIPODAL HOTSPOTS ON EARTH: ARE MAJOR DEEP-OCEAN IMPACTS THE CAUSE? J. T. Hagstrum, U. S. Geological Survey, 345 Middlefield Road, MS 937, Menlo Park, CA 94025, jhag@usgs.gov

Introduction: Hotspot volcanism on Earth is restricted to relatively small areas, on the order of 100 km in diameter, and is generally believed to result from narrow upwellings of hot mantle material called 'plumes'. At first glance, hotspots appear randomly distributed. General associations with geoid highs and divergent plate margins have been noted [1], and hotspots tend to occur in provinces separated by spotless areas [2]. Matyska [3] investigated angular symmetries of hotspot distributions, and showed that the highest maxima were obtained with 180° rotations. Rampino and Caldeira [4] also conducted a statistical analysis of large and small data sets and found that more hotspots occur as nearly antipodal pairs than would be expected from random distributions.

The rise of antipodal plumes from the core-mantle boundary through a convecting mantle seems unlikely, but axial focusing of an impact's energy by the spherical Earth might underlie the antipodal pairing of hotspots [5, 6]. Such a focusing mechanism has been proposed to explain seismically disrupted terrains antipodal to major impact basins on the Moon and Mercury [7], and to explain formation of fractured crust on Mars opposite the Hellas basin—perhaps later exploited as a conduit for volcanism at Alba Patera [8]. First-order problems with this model for Earth, however, include the expected low seismic efficiency of impacts [7] and the lack of any volcanic features opposite large continental impact structures (e.g. Chicxulub).

Antipodal Hotspots: Although as many as 122 hotspots have been proposed [9], the number most commonly discussed is between 40 and 50. In a recent compilation of hotspots (plus 3) totaling 52 [10], 30 form antipodal pairs (~58%) with angular distances ranging from 168° to 179°. Deviations from 180° might be explained by an observed drift rate between hotspots of ~10 to 20 mm/yr [11].

One test of antipodal formation due to impact and focusing of seismic waves is to determine whether hotspots of a given pair began simultaneously. Tectonic recycling of oceanic crust, however, has made this impossible for most of the older pairs. For a few younger hotspot pairs, estimated initiation ages are roughly contemporaneous. Both Aitu (Cook Islands) and Tibesti (175°) are Late Miocene in age; Kerguelen and the Columbia River basalts (Yellowstone; 175°) are Early Miocene in age; the Marquesas hotspot track and Ethiopian flood basalts (Afar; 179°) are ~30 Ma in age; and the Balleny track indicates an age >40 Ma consistent with Iceland's (178°) age of ~55 Ma.

Individual hotspot pairs can generally be divided between one associated with initial flood basalts and rifting (e.g. Afar), and the other with oceanic affinities and no flood volcanism (e.g. Marquesas). It is hypothesized that the oceanic hotspots represent impact sites and those associated with voluminous volcanism the antipodal sites. Moreover, the geographic distribution of a large (122) hotspot compilation [9] shows that hotspot provinces are generally opposite oceans and that spotless areas are opposite continents [2].

Deep-Ocean Impacts: If these observations are correct, what process would cause oceanic impacts to form hotspot pairs, and continents to apparently shield their formation? A significant difference between continental and oceanic impacts is the formation of a high-pressure steam cloud above the oceanic impact site [12]. The pressure of the steam cloud might 'cap' the explosive release of energy from the seafloor impact, causing significantly more energy to be directed downwards.

A simple analog of deep-ocean impacts might be the surface blasting technique for secondary rock breaking known as 'mudcapping'. Mudcapping works due to the impulse action of explosives, which is proportional to the detonation pressure and its time of application on a rock burden [13]. A mudcap maintains the impulse pressure over a longer period of time, and the coupling effect depends partly on the amount of mudcap being used. In contrast, in a continental impact much of the energy released is likely directed upward and away from the land surface, resulting in a much lower seismic efficiency.

Conclusions: Although few impacts in the deep oceans are known, these events might have important consequences in the formation of hotspots, flood basalt provinces, and the breaking up of continental masses on Earth. Moreover, oceanic impacts, megatsunami waves, and antipodal continental flood basalts could be a major cause of global mass extinctions, and could explain rapid sea-level and abrupt ocean chemistry changes at extinction boundaries. Few models of deep-ocean impacts have been made, and it is suggested that a needed modification is the consideration of pressure effects from the steam cloud above the site upon energy release from the seafloor impact below.

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