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Deep Crustal Structure beneath Large Igneous Provinces and the Petrologic Evolution of Flood Basalts

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We present a review of seismological constraints on deep crustal structures underlying large igneous provinces (LIPs), largely from wide-angle seismic refraction surveys. The main purpose of this review is to ascertain whether this seismic evidence is consistent with, or contrary to, petrological models for the genesis of flood basalt lavas. Where high-quality data are available beneath continental flood basalt (CFB) provinces (Emeishan, Columbia River, Deccan, Siberia), high-velocity structures (Vp $\sim$6.9-7.5 km/sec) are typically found immediately overlying the Moho in layers of order $\sim$5-15 km thick. Oceanic plateau (OP) LIPs exhibit similar layers, with a conspicuous layer of very high crustal velocity (Vp$\sim$7.7 km/sec) beneath the enormous Ontong-Java plateau. These structures are similar to inferred ultramafic underplating structures seen beneath active hotspots such as Hawaii, the Marquesas, and La Reunion. Petrogenetic models for flood basalt volcanism based on hot plume melting beneath mature lithosphere suggest that these deep seismic structures may consist in large part of cumulate bodies of olivine and clinopyroxene which result from ponding and deep-crustal fractionation of ultramafic primary melts. Such fractionation is necessary to produce basalts with typical MgO contents of $\sim$6-8%, as observed for the vast bulk of observed flood basalts, from primary melts with MgO contents of order $\sim$15-18% (or greater) such as result from hot, deep melting beneath the lithosphere. The volumes of cumulate bodies and ultramafic intrusions in the lowermost crust, often described in the literature as “underplating,” are comparable to those of the overlying basaltic formations, also consistent with petrological models. Further definition of the deep seismic structure beneath such prominent LIPs as the Ontong-Java Plateau could place better constraints on flood basalt petrogenesis by determining the relative volumes of ultramafic bodies and basaltic lavas, thereby better constraining the overall process of LIP emplacement.