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Surface Waves from the Hawaiian PLUME Project Trace Anomalously Slow Lithosphere and Asthenosphere

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During the two-stage Hawaiian PLUME (Plume-Lithosphere Undersea Melt Experiment) deployment, we collected continuous seismic data at ten land stations and nearly 70 ocean bottom sites from 2005 through mid-2007. In the first stage from January 2005 through January 2006, 35 sites were occupied in an elongated array centered on the island of Hawaii, with a station spacing of roughly 75 km and an aperture of 500 km. In the second stage from May 2006 through June 2007, 37 sites were occupied in a larger array with a station spacing of roughly 200 km. Most of the sites were occupied with broad-band seismometers. This allows for an analysis of surface waves in a broad frequency band.

Our current analysis concentrates on long-period teleseismic Rayleigh waves. During the first stage, we collected records from upward of 95 suitable shallow earthquakes (source depth less than 200 km) with surface wave magnitudes of 5.6 or larger. We also identified and analyzed 70 smaller events. The initial data set of the second stage is quite a bit larger, and our initial analysis concentrates on 163 larger earthquakes. Our set of 5000 unique single-station phase measurements for the first stage and 3100 for the second form the basis to obtain two-station path-averaged phase velocity curves. Each curve is well constrained by many earthquakes (typically 10-20). The data are internally consistent between 15 and 80 s, allowing us to image the lithosphere and upper asthenosphere. Some larger events provide constraints beyond 100 s which allows us to reach deeper. Using these dispersion curves we invert for phase velocity maps at fixed frequency but also for path-averaged depth profiles, and ultimately for a full 3D model. For the two deployment stages, we currently have over 300 and 200 two-station paths respectively.

Compared to 100-million year old upper mantle, our analysis reveals a roughly 30 km thick low-velocity anomaly in the lower lithosphere, surrounding the island of Hawaii, that is a clear manifest of rejuvenation. This anomaly may extend as far as Maui but not much beyond and is no more than 300 km wide. We also find a narrower, 100-km wide low-velocity anomaly in the asthenosphere that is clearly limited to the immediate vicinity west of Hawaii. These results are consistent with those from the 1997/98 SWELL pilot experiment that covered an area in the southwestern corner of the PLUME array. A second, possibly isolated low-velocity anomaly is found to the south of Oahu and is most likely confined to the lithosphere.

We have also begun to determine group velocities. These will provide additional and somewhat independent constraints and improve the depth resolution of the crust and mantle. Group velocities have larger error bars but the signal from the expected anomalies are also larger. Our analysis is still ongoing but initial maps will be presented at this meeting.