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The structure of earth's dynamic deep mantle and core-mantle boundary region

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In recent years, Earth's deep mantle has been shown to play an integral role in whole mantle dynamics, with connections made between lower mantle seismic velocities (and layering) with surface locations of subduction zones, hot spot volcanism, and even possible reversal paths of Earth's magnetic field (e.g., Lay et al., 1998). At long wavelengths (> 2000–3000 km), high velocities in the deep mantle underlie past and present subduction; low velocities are geogaphically correlated with hot spots (see Fig. 1). Also, inferences for whole mantle convection have been made from global seismic tomography (e.g., Su et al., 1994; Grand et al., 1997). It has been noted that the shallowest and deepest mantle contain the strongest seismic heterogeneity, and that in the deepest mantle, compressional and shear velocity heterogeneity do not correlate well (e.g., Masters et al., 2000). Hence, we are motivated to look at deep mantle structure in greater detail.

Deep mantle structure is also intriguing at shorter wavelengths (100–1000 km), and phenomena seen in the lithosphere, such as seismic wavespeed anisotropy and interesting boundary layering, has also been detected in places. For example, analysis of shear waves that either graze, reflect off of, or diffract around the core of the Earth reveals arrival time differences between the horizontal and vertically polarized shear waves. While it is now accepted in the global seismology community that lowermost mantle anisotropy causes the observed shear wave splitting, there is little consensus as to the cause or type of anisotropy due to lack of constraints. Our work has focused on documenting the magnitude and geographic pattern of shear wave splitting, as well as the feasibility of lamellae versus transverse isotropy models explaining the data (see Fig. 2).

Detailed investigations of the core-mantle boundary have revealed an ultra-low velocity zone (ULVZ) in places, where compressional and shear velocities may be reduced by up to 10 and 30%, respectively (e.g., Garnero et al., 1998). This thin (5–50 km) zone may have origin of partial melt, implying ULVZ may be earth's largest magma chamber, as well as a source of whole mantle plumes. Alternately, the ULVZ might be related to core-mantle reactions. Our recent work on CMB boundary layer structure will be presented.

Regions of the most pronounced lateral seismic velocity gradients in the deep mantle are strongly correlated with the surface location of hot spot volcanism (Thorne et al., 2001). This correlation is much stronger than that for the lowest seismic wavespeeds in the deepest mantle (Fig. 1). This argues against a thermal origin for lowest velocities in the lowermost mantle, otherwise upwellings that result in whole mantle plumes would more likely initiate from the lowest wavespeeds (owing to the highest temperatures). The strongest lateral seismic velocity gradients in the deep mantle are thus most easily explained by changes in composition, where in-

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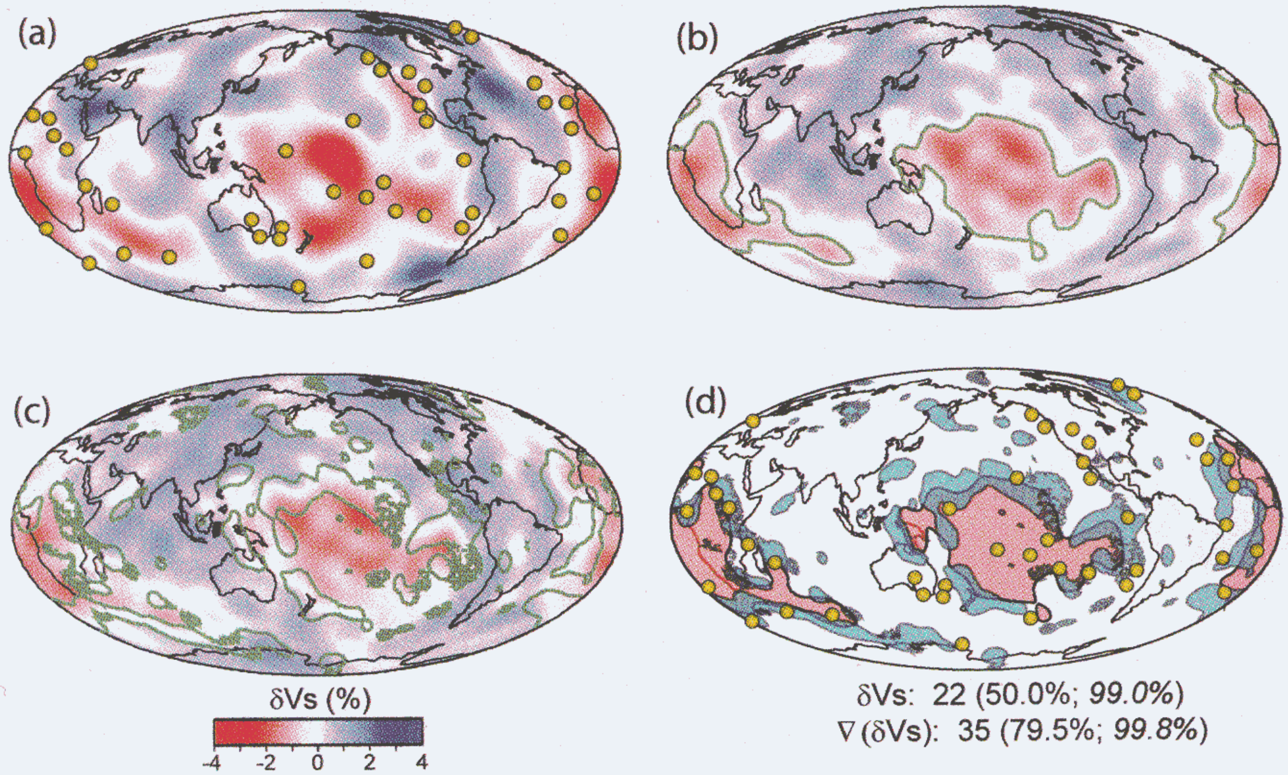
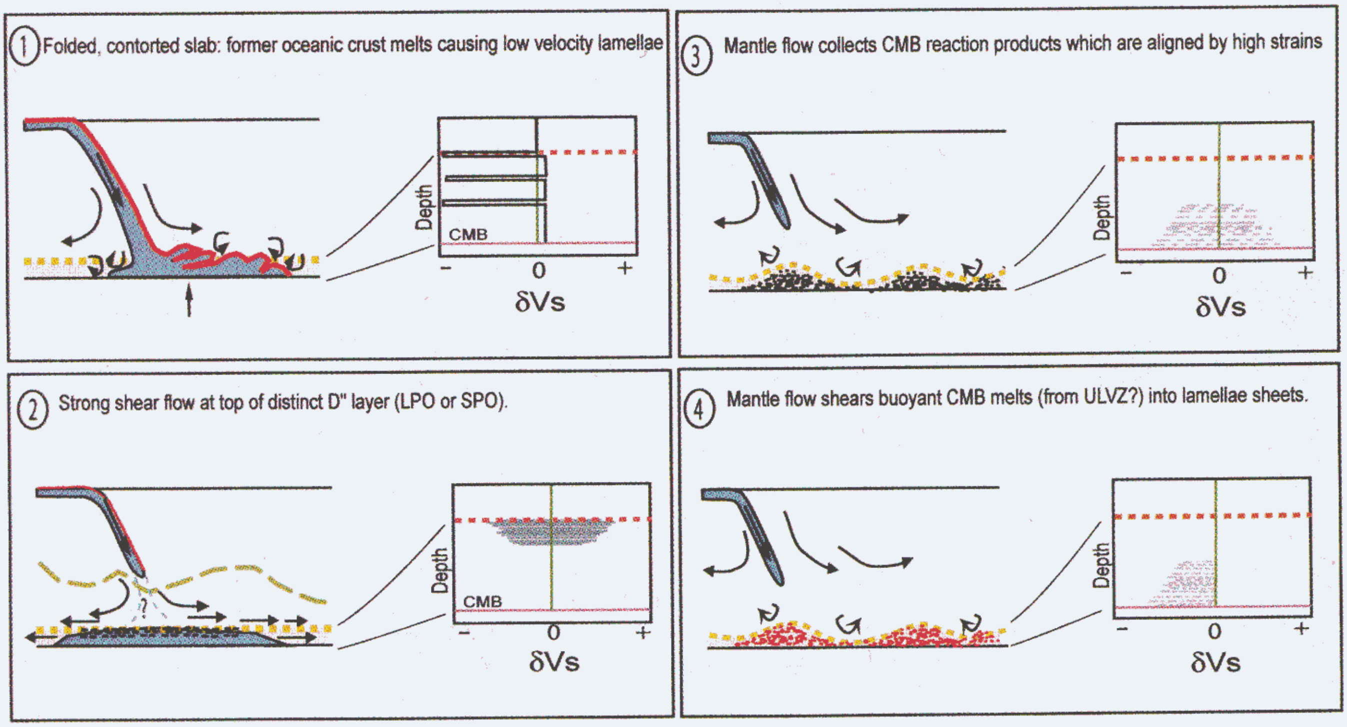


Fig. 1. **(a)** Seismic velocity heterogeneity in the lowermost 300 km of the mantle (after Kuo et al., 2000). – **(b)** The lowest velocity in the deepest mantle are shown for the Caltech model (Ritsema an Van Heijst, 2000), along with the 20% of the core-mantle boundary's surface that is occupied by the lowest velocities outlined in green. – **(c)** The same model as in (b), with the 20% of the CMB occupied by the strongest lateral velocity gradients outlined in green. – **(d)** The outlined areas of (b) and (c) are shown – the strongest gradients of the lowermost mantle (green) are compared to the lowest velocities (pink). The hot spot locations are also shown. For this model, the low velocity areas are overlain by 22 hot spots (50% of the hot spot data set), compared



stabilities have been shown to form (Zhong & Gurnis, 1997). We will present our recent progress on several deep mantle research projects, including the ultra-low velocity layer at the base of the mantle, lower mantle anisotropy, and the correlation of strong gradients and hot spots.

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Fig. 2. Four possible relationships between subduction of the oceanic lithosphere, and lowermost mantle seismic velocity anisotropy. Whether the lithosphere subducts down to the core-mantle boundary is still not-well resolved for most subduction zones. However, strong lateral shear flow due to the presence of a large thermal boundary layer is expected.