3-D STRUCTURE OF CONTINENTAL UPPER MANTLE, DERIVED FROM SEISMOGRAMS*

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EXTENDED ABSTRACT

Earth's structure beneath the crust is heterogeneous on a regional scale. Within one continent or subcontinent the structure of the upper mantle can change over several hundreds of kilometers from being relatively rigid and cold to being relatively weak and warm. The depth extent of the more rigid part also varies laterally, with the deepest extents beneath Precambrian geology. Results from studies of the upper mantle beneath four different continents: South and North America and the Africa-Eurasia plate boundary are discussed herein.

The propagation of regional seismic waves depends on properties of the material in the upper mantle through which the waves pass. Regional S and surface waves, generated by earthquakes, will travel faster through regions that are more rigid than average and slower through regions that are weaker than average. In the work presented here, I have derived images of 3-D upper mantle structure for the continents mentioned above through modeling broadband seismograms containing regional S and surface waves. This modeling technique and its development are described by Nolet (1990) and Van der Lee and Nolet (1997b). Descriptions of the data sets and modeling details can be found in Van der Lee et al. (2001b, 2002), Van der Lee (2002), Van der Lee and Nolet (1997a), Schmid et al. (2002), Goes and Van der Lee (2002), and Marone et al. (submitted manuscript, 2003).

Furthermore, I discuss the depth extent of the olivine to wadsleyite phase transition thought to take place at a depth near 410 km. This phase transition is the most likely cause of a globally observed discontinuity in the propagation velocities of seismic waves at this depth. Constraining the thickness of this phase transition is based on the analysis of S waves that converted from teleseismic P waves at this phase transition.

Our 3-D model for the South American upper mantle shows a large region that is relatively rigid within the top 200 km. This region underlies widespread Precambrian geology but continues beneath the Amazon basin, which experienced post-Proterozoic tectonism. The western margin of South America is presently deforming and our 3-D model shows that the South American mantle wedge, above the subducting Nazca plate and below the Andean crust, is particularly weak. This high level of weakness can be easily explained by a small amount of partial melting caused by the subducting Nazca plate releasing water into the mantle wedge.

Our 3-D model for the North American upper mantle shows a high-rigidity region that is larger, more rigid, and extends deeper than that for South America. This region generally coincides with Precambrian basement except beneath the Archaean Wyoming province, where the rigidity of the upper mantle is not raised. Our 3-D model indicates that a weak layer exists below this high-rigidity layer, but the viscosity of this weak layer cannot nearly be as low as that of oceanic asthenosphere. Resolving power for such upper mantle structure is particularly great where seismograms from dense arrays of broadband seismic stations have been included. Another way to enhance the resolving power is through expanding the data set with the arrival times of teleseismic S waves. Between 300 and 660 km we have imaged the subducted trailing fragments of the Farallon plate as structures of higher rigidity than average mantle at these depths. Through kinematic thermal modeling we have determined that the upper mantle contains lithosphere of the Farallon plate that subducted during the past 60 m.y. A conversion of the seismic velocity anomalies in our 3-D upper-mantle model to temperature shows that the subcrustal temperature in the western United States is near 1000 degrees higher than that in the central and eastern United States.

Our 3-D model for the region comprising the tectonic plate boundary between Africa and Eurasia shows that upper mantle structure varies laterally on the same scale as the tectonic domains at the surface. To improve resolving power of seismograms we have installed 25 new, temporary broadband seismic stations in the region. This deployment

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**Lecture delivered at the Geological Society of India at Bangalore on 3 March 2003.*

was a collaborative, international effort and was carried out under the acronym MIDSEA (Mantle Investigation of the Deep Suture between Eurasia and Africa, *see* Van der Lee et al. 2001a). We have constrained crustal thickness in the region through a combination of (1) receiver function analysis (Van der Meijde et al. 2003a) and surface wave modelling of the new MIDSEA data, and (2) all pertaining data from the accessible geophysical literature. Our map of crustal thickness (Marone et al. 2003) shows that the region is roughly in isostatic equilibrium, though the Atlantic crust seems to be significantly thicker than 6 km. Our 3-D model of upper-mantle structure shows that the deepest half is densely populated by pieces of relatively cool subducted lithosphere, which speeds up S waves. Weak regions, which slow down S waves, are found in the upper half, and are particularly shallow beneath regions presently undergoing extension. Our analysis of S waves that converted from P waves at the 410-km discontinuity shows that the 410-km discontinuity is at least 10 km thicker than the global average. We infer that the 410-km discontinuity was thickened by water, now incorporated in olivine, that was brought down by the ubiquitous subduction that characterizes the geological past of the Africa-Eurasia plate boundary region (Van der Meijde et al. 2003b).

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