2002 Fall American Geophysical Union Meeting, San Francisco, CA, USA

Reference: Bernot, C.M., and M.J. Fouch, Seismic anisotropy and mantle flow beneath Japan, *Eos Trans. AGU Suppl., 83*, 2002.

Seismic Anisotropy and Mantle Flow Beneath Japan

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The goal of this study is to provide new constraints on the strength, orientation, and location of seismic anisotropy in the vicinity of the Japan subduction zone. Determining seismic anisotropy parameters has important implications for understanding the dynamics of convergent margins and the nature of mantle flow in subduction zones. The Japan region is a tectonically unique area, as it contains several zones of active volcanism, is situated in the vicinity of two triple junctions, and therefore is a region in which multiple plates are subducting near one another. Additionally, it is an ideal region for examining seismic anisotropy, as a broad range of earthquake sources, both laterally and with depth, are recorded at numerous local stations of the FREESIA and IRIS networks.

We performed shear wave splitting analysis on local S phases recorded at a total of 70 broadband stations in the Japan area. We examined 378 local events with source depths ranging from 33 km to 506 km recorded between 1995 and 2001. Using these data, we determined 243 well-constrained shear wave splitting measurements for the region. Results from the shear wave splitting analyses provide important insights into the structural complexity of the area. First, across central and southern Honshu, fast directions demonstrate a rotation from N-S near Shikoku to the west, to E-W in Kinki, and continue to a N-S orientation across much of Chubu and Kanto to the east. This pattern of fast direction variations was also observed, although in less detail, by Fouch and Fischer [1996]. Splitting time variations for the region are also intriguing. First, we observe a general increase in splitting time with source depth, with a maximum splitting time of 1.9 s. Regional variations occur in this pattern, and appear to be related to the proportion of the raypath propagating within the mantle wedge. Second, a region of anomalously large splitting times with fast directions oriented roughly NW-SE exists slightly west of the central Japan volcanic front.

While the observed seismic anisotropy may be derived from a combination of structure in the subducted slab, mantle wedge, and overriding plate, the pattern of splitting, both laterally and with depth, strongly suggests that the bulk of the anisotropy is derived from fabric within the mantle wedge. In one possible model, complex mantle flow patterns near the triple junctions produce the bulk of the fast direction variations, marking a dramatic shift in flow direction over short spatial scales. Splitting time variations suggest that anisotropy exists to depths of at least 275 km and perhaps deeper. Additionally, the zone of large splitting times near the central Japan volcanic front may correspond to a local complex slab morphology, such as a sharp bend or tear in the slab. Our results, combined with results from several other regions, including Tonga, Kuriles, New Zealand, and South America, suggest that for many subduction zones, simple patterns of mantle flow are unlikely, and complex geometries of mantle flow must be fully assessed.