S075-016 Room: 302 Time: May 29 9:36-9:48

Crustal heterogeneity in large earthquake source areas: Effect of arc magma, fluids and slab dehydration

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http://www.epsu.jp/jmoo2003/

In this report, we present our case studies for the detailed 3-D crust and upper mantle structure under the source areas of the 1995 Kobe earthquake (M 7.2) and the 2000 Tottori earthquake (M 7.3). We first determined P and S wave velocities (Vp, Vs) using seismic tomography, then we determine Poisson's ratio (K) using the simple relation: (Vp/Vs)**2 = 2(1-K)/(1-2K). By definition, Poisson's ratio is the ratio of radial contraction to axial elongation. It is a key parameter in studying petrologic properties of crustal rocks (Christensen, 1996) and can provide compositional constraints not available with either P or S-wave velocity alone. Its values of common rock types range from 0.20 to 0.35. Poisson's ratio has proved to be very effective for the clarification of the seismogenic behavior of the crust, especially the role of crustal fluids in the nucleation and growth of earthquake rupture (Zhao et al., 1996, 2002).

Significant variations of up to 5% for seismic velocity and 10% for Poisson's ratio are revealed in the Kobe and Tottori aftershock areas. A low Vs and high Poisson's ratio anomaly exists right beneath the Kobe mainshock hypocenter at 16 km depth, which represents a fluid-filled, fractured rock matrix (Zhao et al., 1996). In the Tottori fault zone, areas with large coseismic slips and high aftershock activity are associated with high Vp, high Poisson's ratio and high electrical conductivity, which may represent the strong and competent parts of the fault zone containing fluids. The Tottori mainshock hypocenter is located in a boundary zone where both velocity and Poisson's ratio change drastically. Both Vp and Vs are lower in the lower crust under the Tottori mainshock hypocenter, and low-frequency microearthquakes were detected within the slow anomalies around the Moho discontinuity before and after the occurrence of the 2000 Tottori earthquake (Ohmi and Obara, 2002) . These results and other related evidence suggest that the strong crustal heterogeneities in the Kobe and Tottori source areas are associated with fluids, which may have influenced the nucleation and rupture process of the earthquakes. The fluids result from the dehydration reactions of the subducting Philippine Sea slab in southwest Japan.

Beneath the Japan Islands, large crustal earthquakes occur only in the upper crust, such as the Kobe and the Tottori earthquakes. No shallow earthquake occurs in the lower crust and the uppermost mantle except for a few low-frequency microearthquakes in volcanic areas (Hasegawa and Yamamoto, 1994). However, the lower crust and the uppermost mantle may play an important role in the nucleation of large crustal earthquakes because of the existence and migration of fluids and arc magma resulted from the dehydration of the subducting Pacific and Philippine Sea slabs. In other words, the generation of a shallow crustal earthquake could be controlled by a deep process in the lower crust and uppermost mantle. From this point of view, it is vital to investigate the detailed structure and processes of the lower crust and upper mantle for clarifying the seismogenesis and reducing earthquake hazards. It is insufficient to refer only to the surface distribution of active faults to predict the seismic potential of a region. Note that field surveys did not find any fault traces on the surface related to the 2000 Tottori earthquake.

Our results indicate that large earthquakes do not strike anywhere, but only anomalous areas that may be detected with geophysical methods. Higher-resolution seismic imaging and combining seismological studies with geological, geochemical and geophysical investigations would certainly provide us a better understanding of the earthquake generating process and would also contribute to the mitigation of seismic hazards.