Modeling deep structure of active faults and 3-D crustal structure in and around the Kinki district

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Summary

The goal of our research program is to construct a model of deep structure of active faults as well as a model of three dimensional crustal structure in and around the Kinki district, southwest Japan, which will contribute to estimating strong ground motions by inland large earthquakes. For these purposes we have been carrying out following three study subjects: 1) Study on deep structure of active faults, 2) Study on seismicity and focal mechanism along and around the active faults, and 3) Study on 3-dimensional crustal structure of velocity, attenuation, and gravity.

1. Introduction

In order to improve the accuracy of estimating strong ground motion caused by large inland earthquakes, it is essential to elucidate the structure of the fault plane related to the rupture process and also the crustal structure related to the propagation of seismic waves. For these purposes we have been carrying out following three study subjects in the Kinki district, southwest Japan: 1) Study on deep structure of active faults, 2) Study on seismicity and focal mechanism along and around the active faults, and 3) Study on 3-dimensional crustal structure of velocity, attenuation, and gravity. In this presentation, we discuss several preliminary results obtained at present, especially focusing on the deep structure of active faults.

2. Analyses and preliminary results

2-1 Deep structure of active faults

We take two approaches to estimate deep structure of active faults, i.e., analyses of scattered waves and fault-zone trapped waves. Scattered waves have an advantage to survey heterogeneities in a regional area and also to estimate fault geometry and along-fault heterogeneity distribution, while trapped waves can reveal detailed structure of low-velocity fault zone such as branching or discontinuity of fault-zone.

Generation of scattered waves is well recognized in the seismograms from local earthquakes as long-continuing coda waves, and the coda envelopes can be inverted to estimate a 3D heterogeneous structure in the crust (e.g., Nishigami, 1991, 2000). Nishigami (2000) applied this method to the San Andreas fault system in northern California, and showed that scattering is high along the fault system and the source areas of $M_{6-7}$ earthquakes are characterized by relatively weaker scattering than the surroundings. Asano and Hasegawa (2003) also obtained similar results in the source region of the 2000 Western Tottori earthquake. Scattering tomography seems to be effective to detect source areas of large earthquakes as weaker scattering areas, as well as to image deep geometry of active faults.

![Figure 1. Distribution of relative scattering coefficients at 10-15 km depth around the Yamasaki fault system (YF), southwest Japan. Open and solid symbols](image-url)
represent stronger and weaker scattering than the average, respectively.

We applied this method to two active fault regions, the Yamasaki fault system in southwest Japan and the Atotsugawa fault system in central Japan. The Yamasaki fault system is a typical strike-slip active fault in southwest Japan, with northwest-southeast extending for about 80 km length. We analyzed coda envelopes from 138 local earthquakes (1.7 < M < 3.7) recorded at 23 Hi-net stations. The analysis area, 220 km in horizontal and 60 km in depth, was divided into 5,800 small blocks with 10 and 5 km in horizontal and depth, respectively. Figure 1 shows the distribution of relative scattering coefficients at a depth of 10-15 km, which shows strong scattering along the Yamasaki fault system at the seismogenic depth. The resolution will be improved by adding more data including the University and JMA stations, and the deep heterogeneous structure of the fault system will be discussed, including the result of the Atotsugawa fault system.

Fault-zone trapped waves have been observed for aftershocks of large inland earthquakes (e.g., Li et al., 1994), and the analysis of trapped waves is one of effective approaches to elucidate detailed fault-zone structure. We revised a computing program of fault-zone trapped waves by 3-D finite difference method (Mamada et al., 2004) to that applicable to the earthquake data with longer hypocentral distances. Figure 2 shows an example of the simulation. The waveforms of trapped waves are almost similar for different focal mechanisms, while direct S waves strongly depend on the source radiation pattern. We observed fault-zone trapped waves at the subsurface array of the Mozumi-Sukenobu fault, one branch of the Atotsugawa fault system, and the average fault-zone structure was estimated by using 2-D structure model of Ben-Zion and Aki (Mizuno et al., 2004). We will estimate detailed fault geometry by the 3-D simulation stated above. We also analyzed the apparent velocity of direct S waves recorded at the subsurface array, and found the possibility that the low-velocity fault-zone exists at shallow depth less than ~4 km.

2-2 Seismicity and focal mechanism

We have been trying to detect heterogeneous structures on active fault, which may be related to the rupture process of large earthquakes, from analyses of detailed micro-seismicity and focal mechanisms. Complex rupture process is caused by the heterogeneous distribution of strength on the fault plane as well as the fault geometry such as branching, step-over, and so on. We may suppose lower micro-seismicity in the areas with higher strength or the areas where both sides of the fault plane strongly contact such as asperities. We may also suppose lower b-values in the areas under stress concentration (Westerhaus et al., 2002), because the fault plane is contacting more strongly and therefore under more homogeneous condition there. The area with low b-value, therefore, may become an initiation point of rupture.

We obtained detailed distribution of hypocenters around the Yamasaki fault system by a joint-hypocenter method (Figure 3), and estimated spatial variation of b-values (Figure 4). We see several areas with lower seismicity and lower b-values. These may be candidates of asperities and rupture-initiation points, respectively, in future large earthquakes. We are also analyzing focal mechanisms of
microearthquakes along and around the active faults, to estimate heterogeneous stress field on the fault plane.

![Figure 4](image4.png)

Figure 4. Distribution of $b$-values along the Yamasaki fault system. Magnitude-frequency distribution is shown for three areas.

2-3 3-D crustal structure

Detailed crustal structure is necessary in estimating strong ground motion as well as in investigating the crustal heterogeneity and seismotectonics. We have been taking the following three approaches: 1) crustal structure estimated from explosion experiment data, 2) 3-D velocity tomography using earthquake catalogue, and 3) shallow crustal structure using gravity data. Figure 5 shows preliminary result of 3-D velocity tomography in the Kinki district. P and S travel time data of ~8,800 events and ~70 stations, including University, JMA, and Hi-net, were analyzed by the program of Zhao et al. (1992), with appropriately evaluating the station corrections by the method of Hurukawa and Ohmi (1993). We will try to improve the result by evaluating the shallow crustal structure using receiver-function analyses.

We have been analyzing the gravity data to model the 3-dimensional basement structure of tectonic basins in the Kinki district. Figure 6 shows a distribution of basement depth estimated for the area including the Kyoto and Nara basins. We can find detailed relationships between basement structure and the active or buried faults in this area.

![Figure 5](image5.png)

Figure 5. A result of travel-time tomography, showing perturbation of P wave velocity at a depth of 0, 5, 10, and 15 km.

![Figure 6](image6.png)

Figure 6. Left: contour map of basement depth in the area including the Kyoto and Nara basins. Right: topography map with active faults in the same area.

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References


