

Electromagnetic imaging of fluids in the crust

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1. Introduction

Resistivity of the crustal rocks depends mainly on the existence and connectivity of fluids within the cracks, pores and grain boundaries, rather than on the resistivity of the surrounding host materials. Thus, electromagnetic sounding method can image the fluids in the crustal structure in detail. In this paper, we review case studies on the electromagnetic imaging of fluids in the active seismicity zones.

2. Methodology (Wideband magnetotelluric measurements)

We use natural electromagnetic signals in the frequency range between 0.5 mHz to 300 Hz. In 1990s, portable wide-band magnetotelluric equipments were developed and two-dimensional modeling techniques became mature by taking the near-surface three dimensional distortions of the response functions. These developments enabled detailed and reliable imaging of the crust, in particular in seismically active zones.

3. Resistivity structure of seismically active regions

We have found the following features in common in many case studies as below. The first feature is that the seismogenic regions are electrically resistive and they are underlain by distinct electrical conductors. These characteristic feature were found at Tokoku backbone regions around the Senya fault (Ogawa et al., 2001; Ogawa 2002), 1962 M6.5 Northern Miyagi Earthquake region (Mitsuhashi et al., 2001), Nagamachi-Rifu fault (Ogawa et al., 2005), Itoigawa-Shizuoka tectonic line (Ogawa et al., 2002; Ogawa & Honkura, 2004), 2007 Noto Hanto Earthquake (Yoshimura et al., 2008).

Correlations of the spatial distribution between the mid-crustal conductors and the negative dilatation were pointed out by Ogawa & Honkura (2004) in the northern part of Itoigawa-Shizuoka tectonic lines. In the Nagamachi-Rifu fault, mid-crustal conductor was located at the deep extension of the fault trace which is also consistent with the deformation model (Ogawa et al., 2005).

These correlations of the conductor to the seismicity and deformation suggest that the conductor represents zones of ductile deformation zones with abundant fluids and that the surrounding resistive region represent zones of brittle region.

The alternative interpretation is that the fluids in the conductive region enter the resistive dry region, leading to fracture by increasing the pore pressures (by decreasing effective normal stress) (e.g., Ogawa et al., 2001).

It is also important how these crustal fluids are supplied. In Kii peninsula, our electromagnetic imaging (Umeda et al., 2006a) showed that the fluid are supplied from the descending Philippine Sea Plate. At 20-40km depth, a conductor was found. The bottom corresponds to the top of the Subducting Philippine Sea Plate, where non-volcanic tremors were observed. Above the conductor, there is high crustal seismicity which is also seen in other high seismicity area.

In volcanic areas, fine correlations were found between cut of depth of the micro-seismicity and the top of the conductor (Umeda et al., 2006).

Our magnetotelluric profilings of major strike-slip faults are underway at North Anatolian fault (Turkey), Alpine fault (New Zealand) and Sumatra fault (Indonesia). North Anatolian fault at the Izmit earthquake focal area showed anticline structure of upper mantle conductor and the Izmit earthquake hypocenter is located at resistive side of the crust underlain by the mantle conductor (Tank et al., 2005). This is consistent with our interpretation for the intraplate earthquakes in Japan.

4. Conclusions

We have found that mid-crust is rather inhomogeneous and conductors presumably imply the fluid-rich zones. The top of the conductor correlate well with the cutoff depth of the seismicity. The large earthquakes may take place at the resistive zone near the edge of the conductors. The locations of the conductors correlate well with the concentrated deformation zones.