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Three-dimensional imaging of fluids under the volcanic arc, around Naruko Volcano, NE Japan

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SUMMARY

We have carried out wideband magnetotelluric measurements in order to map the distribution of fluids and melts under the volcanic arc in the NE Japan around the Naruko volcano. The area has several Quaternary calderas, such as Naruko, Onikobe, Sanzugawa and Mukaimachi calderas. The area has also high shallow seismicity and has one of the largest intraplate earthquakes, M7.0, in 2008 near the Kurikoma volcano. Thus the area is thought as a good test field to study the relation of fluids and volcanoes and intraplate earthquakes. We have 224 sites in total with average site spacing of ~5km. From the three-dimensional modelling we have imaged (1) subvertical conductors which shallows towards the active volcanic zones under Onikobe, Naruko and Sanzugawa calderas, and (2) seismic activities over the resistive zones above the crustal conductors, which implies earthquake triggering by fluid migration into the brittle crust.

Keywords: magnetotellurics, three-dimensional inversion, fluid, volcano, earthquake

INTRODUCTION

Magnetotelluric (MT) method can image the crustal and mantle structure in terms of resistivity, which is sensitive to the existence and connectivity of fluids and melts. Previous MT studies in NE Japan have successfully imaged fluid/melt distribution under the seismically active regions (Ogawa et al., 2001; Mitsuhata et al., 2001) and volcanic zones (Mishina, 2009; Asamori et al., 2010). However, these studies were restricted to two-dimensional modeling along profiles and also to depth extent of ~30km.

As part of the GEOFLUID program, we have been working on the three-dimensional electromagnetic imaging of the central part of NE Japan to a depth of upper mantle. We had two sub-projects with different scales. One is aiming at detailed crustal imaging using wide-band equipment (0.01-1000s periods) at ~3km grid stations, the other is upper mantle imaging using long period equipment (10-10,000s period) at ~20km grid stations.

In this paper, we show the crustal imaging results around the Quaternary caldera regions in the Northeastern Japan arc, covering Onikobe, Naruko, Mukaimachi and Sanzugawa calderas. These areas are suitable to study the distribution and role of fluid in relation to volcanoes and shallow earthquakes.

METHODOLOGY

We used WSINV3DMT program (Siripunvaraporn and Egbert, 2009). As for observed data, full impedance components were used. Our initial models are uniform earth of 100 ohmm together with distribution of surrounding ocean of 0.25ohmm. The initial model was also used for prior model. After several iterations we have reached minimum rms which is over 1.0. Then we adopted the model of the minimum rms as the next prior model as well as the next initial model. This gives a model with further smaller rms.

RESULTS

Onikobe caldera:
In 2009, we had 30 wideband MT stations in the Onikobe caldera, which has an oval topographic depression of 7.5km x 10km. After the three-dimensional inversion, a low resistivity body with N-S strike was found at 20km depth in the western part of the caldera. The conductor shallows locally toward the most active geothermal manifestation below 2km from the surface. Shallow earthquakes occur at resistive zone above the conductive body. This suggests the fluid triggering of earthquakes. The known fault models within the caldera(Onodera et al., 1998) distribute in the resistive part of the upper crust. Shallow seismicity is also controlled laterally by fluid in the upper crust.

Naruko volcano:
In 2010, we carried out new 30 wideband MT stations around Naruko volcano in the central part of NE-Japan.

The number of stations was 77 including the previous dataset. Fig.1 shows the EW section at Naruko volcano after the three-dimensional inversion. Backarc side of lower crust was found conductive with NNE-SSW strike, consistent with island arc directions. In the mid-crust (5-15km depth), the sub-vertical conductor appears under the volcanic zone and there is also a conductor in the forearc side. The crustal seismicity is high outside of those conductors and above the conductors, suggesting fluid rich zone is ductile. Naruko volcano is located at the sub-vertical resistivity contrast and the conductor shallows from west to east. This represents the eastward pathway of fluids to the surface, known as volcanic front.

Mukaimachi and Sanzugawa calderas:
We have inverted data at 116 stations including those from Mishna (2009) and Asamori et al. (2010). Mukaimachi and Sanzugawa calderas have high resistivity upper crust underneath the caldera depressions, which may imply the consolidated magma bodies. Underneath the central resurgent dome of Sanzugawa caldera, another sub-vertical conductor was found, corresponding to surface geothermal manifestations and a geothermal power plant.

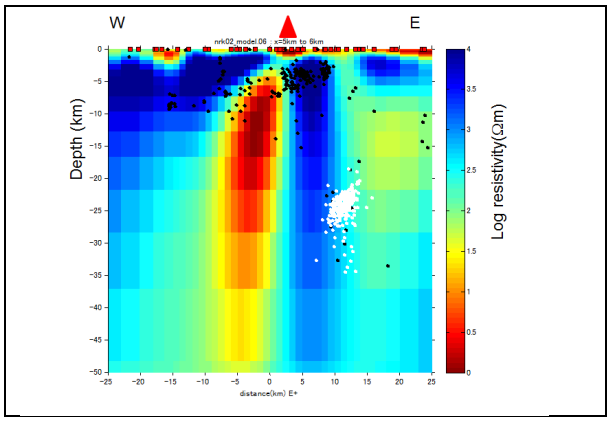

Fig. 1. *East-West cross section passing through Naruko volcano after three-dimensional inversion. The red squares denote MT stations and red triangle denote Naruko volcanoes. Black and white dots represent crustal earthquakes and long-period volcanic earthquakes.*

Conclusions

We have found lower crustal conductor and its sub-vertical connection to the upper crust beneath the volcanoes and also in the forearc. Shallow seismicity is high above the crustal conductors and surrounding regions. The resistivity of these conductors ranges between 1 and 10 ohmm. Using the Hashin-Strikman model, where conductive fluid shells cover the resistive rock matrix, the conductors will have 0.16-1.3% fluid content if we assume 0.01ohmm as fluid resistivity.

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REFERENCES

Asamori, K., K. Umeda, Y. Ogawa, and T. Oikawa, 2010, Electrical Resistivity Structure and Helium Isotopes around Naruko Volcano, Northeastern Japan and Its Implication for the Distribution of Crustal Magma, *International Journal of Geophysics*, 1–7, doi:10.1155/2010/738139.

Ogawa, Y. et al., 2001, Magnetotelluric imaging of fluids in intraplate earthquake zones, NE Japan back arc, *Geophysical Research Letters*, **28**(19), 3741–3744.

Onodera, M., Horiuchi, S., and Hasegawa, A., 1998, Three-dimensional seismic velocity structure in and around the focal area of the 1996 Onikobe earthquake based on Vp/Vs inversion, Zisin ser.2, 51(2), 265–279.

Mishina, M. 2009, Distribution of crustal fluids in Northeast Japan as inferred from resistivity surveys, *Gondwana Research*, **16**(3-4), 563–571, doi:10.1016/j.gr.2009.02.005.

Mitsuhata, Y., Y. Ogawa, M. Mishina, T. Kono, and T. Uchida, 2001, Electromagnetic heterogeneity of the seismogenic region of 1962 M6.5 Northern Miyagi Earthquake, northeastern Japan, *Geophysical Research Letters*, **28**(23), 4371–4374.

Siripunvaraporn, W., and G. Egbert, 2009, WSINV3DMT: Vertical magnetic field transfer function inversion and parallel implementation, Physics of the Earth and Planetary Interiors, 173(3-4), 317–329, doi:10.1016/j.pepi.2009.01.013.