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地殻流体のマッピングにむけて
Towards mapping of geofluids

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There are accumulating evidences indicating that geofluids in subduction zones play important roles in various phenomena, such as seismic and magmatic activities, crustal deformation, metamorphism, evolution of continental crust, and global material differentiation. However, in situ distribution of geofluids within the crust and the mantle, or even their presence, has not been identified with sufficient resolution, hence their roles in the various phenomena mentioned above remain unclear.

Low seismic velocities and/or a high electrical conductivity have conventionally been regarded as diagnostic features for presence of geofluids (e.g., Nakajima and Hasegawa, 2003). Overlapping thermal, compositional and textural variations blur the features specific to geofluids, and the number of unknown parameters apparently exceeds the number of observed variables (e.g., Watanabe, 2005). Therefore, introducing a priori information and models (e.g., thermal and petrological structures) into the analysis (i.e., deducing phase, fraction, geometry [represented by, e.g., aspect ratio] and their spatial distribution of geofluids based on the seismic velocity and electrical conductivity) is necessary. In addition, some key variable or parameter could be sensitive enough to constrain a parameter for geofluids beyond the background variations, eliminating uncertainties introduced by a priori information and models. In this paper, we discuss both aspects, i.e., (i) integration of available information, and (ii) key variables or parameters sensitive to geofluids.

In order to quantitatively identify the spatial distribution of geofluids, we combine (1) observed seismic velocity structure, (2) observed electrical conductivity structure, (3) petrological model, and (4) thermal model, for areas with well-resolved tomography of both seismic velocity and electrical conductivity. The models of (3) and (4) correspond to the point (i) above. Concerning the point (ii), we focus on the contrast between (1) and (2): for a typical case, distribution of low velocity regions coincide well with that of highly conductive regions (e.g., those beneath the northern Miyagi Prefecture area [Mitsuhata et al., 2001; Nakajima and Hasegawa, 2003]), associated with a few percent decrease in the seismic velocity and two to four orders of magnitude increase in the electrical conductivity. Inspection of all the plausible factors strongly suggests that the huge contrast in amplitude between the seismic velocity and the electrical conductivity may be resolved only when a variation of fluid fraction affects linearly the seismic velocity and nonlinearly the electrical conductivity.

This differential response may arise from the fact that the seismic velocity is approximately a linear function of fluid fraction (Takei, 2002) and is insensitive to the connectivity, whereas the electrical conductivity is sensitive to the connectivity. If the connectivity of fluid increases with its volume fraction, this causes a nonlinear increase of electrical conductivity with the fluid fraction. We thus think that the relationship between connectivity and fluid fraction is a key to interpret the observed seismic velocity and electrical conductivity. Deciphering this relationship, being combined with thermal and petrological models, could be a useful and robust approach to map geofluid distribution.