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Electrical conductivity imaging in the western Pacific subduction zone

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Oceanic plate subduction is an important process for the dynamics and evolution of the Earth's interior, as it is regarded as a typical downward flow of the mantle convection that transports materials from the near surface to the deep mantle. Recent seismological study showed evidence suggesting the transportation of a certain amount of water by subduction of old oceanic plate such as the Pacific plate down to 150-200 km depth into the back arc mantle. However it is not well clarified how deep into the mantle the water can be transported. The electromagnetic induction method to image electrical conductivity distribution is a possible tool to answer this question as it is known to be sensitive to the presence of water. Here we show recent result of observational study from the western Pacific subduction zone to examine the electrical conductivity distribution in the upper mantle and in the mantle transition zone (MTZ), which will provide implications how water distributes in the mantle.
We take two kinds of approach for imaging the mantle conductivity, (a) semi-global and (b) regional induction approaches. Result may be summarized as follows:

(a) Long (5-30 years) time series records from 8 submarine cables and 13 geomagnetic observatories in the north Pacific region were analyzed and long period magnetotelluric (MT) and geomagnetic deep sounding (GDS) responses were estimated in the period range from 1.7 to 35 days. These frequency dependent response functions were inverted to 3-dimensional conductivity distribution in the depth range between 350 and 850 km. Three major features are suggested in the MTZ depth such as, (1) a high conductivity anomaly beneath the Philippine Sea, (2) a high conductivity anomaly beneath the Hawaiian Islands, and (3) a low conductivity anomaly beneath and in the vicinity of northern Japan.
(b) A three-year long deployment of ocean bottom electro-magnetometers (OBEM's) was conducted in the Philippine Sea and west Pacific Ocean from 2005 to 2008. As a preliminary investigation, MT response functions from 20 sites in the Philippine Sea and 4 sites in the west Pacific basin in the period range between 300 and 80000 sec were respectively inverted to one-dimensional (1-D) profile of electrical conductivity by quantitatively considering the effect of the heterogeneous conductivity distribution (ocean and lands) at the surface. The resultant 1-D models show three main features: (1) Strong contrast in the conductivity for the shallower 200 km of the upper mantle depths is recognized between the two regions, which is qualitatively consistent with the difference in lithospheric age. (2) The conductivity at 200–300 km depth is more or less similar to each other at about 0.3 S /m. (3) The conductivity around the MTZ depth is higher for the Philippine Sea mantle than for the Pacific mantle, which is consistent with the implication obtained from a semi-global approach (a).

As already suggested in our previous work, the high conductivity in the MTZ below the Philippine Sea can be explained by the excess conduction due to the presence of hydrogen (water) in wadesleyite or in ringwoodite. Therefore, it implies a large scale circulation of water in the back arc mantle not only in the upper mantle but also down to the MTZ depth. However, our interpretation indicates that the high conductivity of the Philippine Sea uppermost upper mantle cannot be explained only by the effect of hydrogen conduction in olivine, but that additional conduction enhancement such as the presence of partial melt is required.