Transportation of H2O in subduction zones and its implications for global water circulation

Hikaru Iwamori[1]

[1] Dept. Earth Planet. Sci., Univ Tokyo

Recent experimental studies on the H2O content in the nominally anhydrous minerals (NAMs) in peridotitic and crustal rocks such as olivine, wadsleyite, ringwoodite, perovskite, pyroxenes, garnet and quartz (e.g., Skogby, 1994; Kawamoto et al., 1996; Kholstedt et al., 1996; Withers et al., 1998; Murakami et al., 2002; Forneris and Holloway, 2003), together with the stability fields and the maximum H2O contents in the hydrous minerals (e.g., Schmidt and Poli, 1998; Ono, 1998), allow us to estimate the water budget and flux of H2O associated subduction of the plates. In this study, we review and consolidate such studies, including the numerical modeling of flow-thermal structure in subduction zones, to estimate (1) dehydration processes of the hydrated lithosphere, and (2) the amount of H2O brought down into the deep mantle associated with subducting plates. Compilation of the experimental data (Iwamori, 2004) suggests that, along a representative geotherm, the maximum H2O content can be calculated as follows: 1.2 x 10ˆ21 kg (0.85 ocean mass) in the upper mantle, 5.6 x 10ˆ21 kg (4.0 ocean mass) in the transition zone, 6.2 x 10ˆ21 kg (4.4 ocean mass), and 13.0 x 10ˆ21 kg (9.3 ocean mass) in the whole mantle. This suggests that the mantle is a huge potential storage of H2O, and if there is a communication between the surface water and the mantle, the communication processes (such as regassing through subduction and degassing through magmatism) can greatly control the water circulation of the Earth.

In order to evaluate (1) and (2) described above, geological and seismological observations and the corresponding quantitative modeling have been compared, especially based on those for the Japan arcs. The results suggest that the major hydrous phases breakdown at relatively shallow depths (e.g., shallower than 200 km) except for those in a very cold subduction zones. The results also suggest that even after the completion of the major hydrous phases, NAMs can carry a significant amount of H2O into the deep mantle: 0.63 to 1.2 x 10ˆ11 kg/yr. This flux of H2O is roughly comparable to the outflow of H2O from the mantle at mid-oceanic ridges. Considering the short time scale of equilibration between regassing and degassing of the Earth's interior (e.g., McGovern and Schubert, 1989), the influx and outflow of H2O are likely to be roughly balanced in the present-day Earth. However, there is a evidence, which suggests that some flux of H2O (and/or CO2) has caused magmatism in a broad region: Cenozoic basaltic magmatism in the eastern Asia, ranging from SW Japan to Baikal Lake (e.g., Iwamori, 1992). This type of magmatism might have been caused by dehydration of H2O-bearing NAMs such as hydrous wadsleyite, which has been accumulated beneath the region by a long-term subduction at the eastern margin of the Eurasia plate.