G061-P002 Time: May 29 17:00-18:30

DEHYDRATION AND EARTHQUAKES: FROM INTERMEDIATE-DEPTH TO MANTLE TRANSITION ZONE

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The dehydration embrittlement of serpentine was experimentally observed [1,2], and previous studies suggested that the origin of the double seismic zone (DSZ) is decomposition of serpentine in a slab peridotite [3,4]. We started with four assumptions: 1) not only dehydration of serpentine, but any dehydration in a subducting slab induces earthquake; 2) subducting mantle is more or less hydrated; 3) dehydration proceeds in a near-equilibrium condition; and, 4) approximation of hydrated mantle by the MgO-Al2O3-SiO2-H2O (MASH) system. We show the close link between the topology of intraslab seismic zones and that of dehydration reactions in the hydrated slab peridotite; and then we explain that the depth-distribution of deep earthquakes also links to dehydration of DHMS in mantle transition zone (Fig.1).

Intermediate-depth earthquakes:

We constructed a petrogenetic grid in the model system MASH up to 9 GPa by thermodynamic calculation. Then, possible topologies of dehydration in subducting mantle are semi-quantitatively predicted along the model P-T path of the coldest thermal center of subducting slab. Predicted topology of the dehydration in the slab corresponds to the topology of seismic zone, on the basis of our assumptions. Earthquakes may occur on the univariant reaction curves, and in an area of continuous reactions. The predictions reproduced DSZ, in addition, multiple seismic zones and multiple convergences of the seismic zones were predicted.

These predictions were compared to seismic observations of NE-Japan at where the Pacific plate (120-130 Ma) is subducting. Hypocenter distribution in vertical section in NE-Japan at intermediate-depth (50-250 km) shows the typical feature of so-called DSZ, moreover, hypocenter clusters between upper and lower seismic planes are identified at 85-130 km, 145-170 km, and 170-195 km depth. These clusters may represent the predicted multiple convergences of dehydration induced seismic zones. Assuming the simple prograde P-T path for the coldest thermal center of the slab, the dehydration reactions representing interplane earthquakes are Atg+Br=phA+H2O (1) for 85-130 km, Atg+Tc=En+H2O (2) for 145-170 km, and Atg=phA+En+H2O (3) for 170-195 km. The reaction (3) also corresponds to lower plane and a part of upper plane at the end of DSZ. Shallower part of DSZ consists of the reactions: Atg=Fo+En+H2O (4) and continuous clinochlore (Chl)-decomposition by Chl+En in Opx=Mg-Ts in Opx+Fo+H2O (5) and Chl+Opx=Prp+Fo+H2O (6). The earthquakes at post-convergence depth (deeper than 200 km) corresponds to the reaction MgAl-pumpellyite+phA+En=Prp+H2O (7).

Deep earthquakes:

The link between intermediate-depth earthquakes and dehydration reactions allow us to evaluate the thermal structure of the subducting slab. The estimated temperature is high enough for equilibrium phase transition in mantle transition zone. Therefore, our dehydration-induced earthquake model is inconsistent with the metastable-transformation model for deep earthquakes. The depth-distribution of deep earthquakes is also explained by the link to dehydration reactions. The P-T conditions of dehydration reactions after the decomposition of antigorite were determined on the basis of high-P experiments in the MSH system [5-7]. The dehydrations, phE=shB+phD+H2O (8), and super hydrous phB+stishovite=akimotoite+H2O (9), are the candidate of triggers of earthquakes in the depth from 400 to 700 km.

References: [1] Raleigh, C. and Paterson, M, 1965, JGR, 70, 3965-3985. [2] Meade, C. and Jeanloz, R., 1991, Science, 252, 68-72. [3] Nishiyama, T., 1992, in Mathmatical Seismology VII, Report of The Institute of Statistical Mathematics, Tokyo, 34, 31-67. [4] Seno, T. and Yamanaka, Y., 1996, in Subduction Top to Bottom, AGU Geophysical Monograph, 96, 347-355. [5] Irifune, T. et al., 1998, GRL, 25, 203-206. [6] Ohtani, E. et al., 2001, PEPI. 124, 105-117. [7] Shieh et al., 1998, EPSL 159, 13-23.

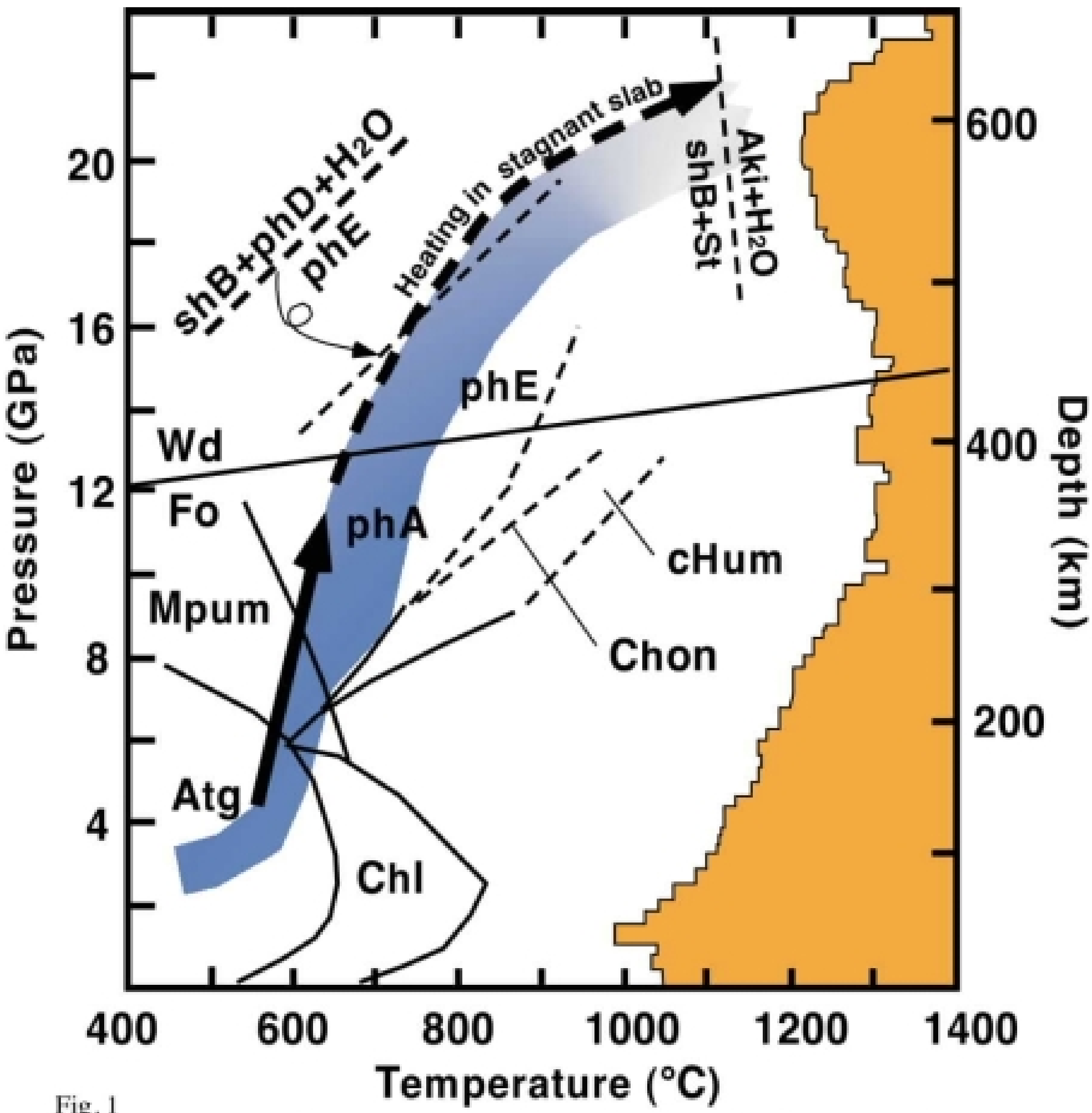

Fig. 1
P-T diagram showing depth-frequency relations of whole-subduction zone earthquakes (after Kirby, 1995) and dehydration reactions in hydrated mantle. Solid lines: dehydration curves calculatedby the present study. Dashed lines: approximate location of dehydration reactions estimated from high-P experiments [5, 6, 7]. Allows: P-T path of the coldest thermal center of the subducting slab.

P-T diagram showing depth-frequency relations of whole-subduction zone earthquakes (after Kirby, 1995) and dehydration reactions in hydrated mantle. Solid lines: dehydration curves calculatedby the present study. Dashed lines: approximate location of dehydration reactions estimated by Komabayashi et al. (2002) and Stalder and Ulmer (2001). Shaded areas are approximate P-T range of the hydrous portion of subducting lithosphere. Abbreviations: phD: phase D, phE: phase E, shB: super hydrous phase B.Allows: P-T path of the coldest thermal center of the subducting slab.