MIS31-P09 会場:コンベンションホール 時間:5 月 24 日 17:15-18:30

海洋玄武岩組成の熱力学相平衡図計算：沈み込む海洋地殻の脱水挙動への洞察
Calculated phase diagrams for oceanic basalt compositions: insight into dehydration behavior of subducting oceanic crust

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The uppermost part of the oceanic lithosphere is variably hydrated by various processes such as high-T hydrothermal circulation at the mid-ocean ridge, low-T alteration on the seafloor, and seawater infiltration along fractures associated with normal faulting at the outer rise. Moreover, hydration due to fluid influx from sediments during incipient subduction stages can also be important. Heterogeneously hydrated oceanic crust and lithospheric mantle transport H_2O to great depths in subduction zones and can be released during prograde metamorphism. The flux of H_2O fluid through the slab-wedge mantle interface depends primarily on the thermal structure of the subduction zone, initial water budget of the slab, reaction kinetics, and compositions and volumes of slab constituent rocks. The complex nature of the initial water distribution and the large chemical system required to adequately describe crustal rocks are two of the major difficulties when trying to model the water release process. Nevertheless, calculation of H_2O-saturated phase assemblage diagrams (pseudosections) for given rock compositions can be used to predict the change of mineral assemblage and the amount of structurally-bound H_2O along a specific P-T path. Recent significant advances in calibrating mixing properties of complex solid-solution minerals (e.g. amphibole and clinopyroxene) allow us to calculate pseudosections for mafic rocks with some precision and accuracy. In this study, we present calculated pseudosections in the chemical system K_2O-Na_2O-CaO-FeO-Fe_2O_3-MgO-Al_2O_3-SiO_2-H_2O for normal mid-ocean ridge basalt (N-MORB) compositions. To account for the variation in the input MORB compositions in modern subduction zones of SW- and NE-Japan, pseudosections were calculated for four representative MORB compositions taken from samples from the Shikoku Basin (DSDP Leg 58 Site 442; Wood et al. 1980), Nankai Trough basement (ODP Leg 131 Site 808; Siena et al. 1993), and the Cretaceous (133-130 Ma) northwestern Pacific Ocean floor (DSDP Leg 32 Sites 303 and 304; Janney and Castillo 1997). Among many hydrous minerals predicted in these rock compositions, important dehydration reactions at forearc mantle levels involve stilpnomelane, lawsonite and chlorite. Stilpnomelane and related hydrous sheet silicates may be important H_2O carriers in cold subduction zones but reliable thermodynamic models for these minerals are not yet available. High water content (~6 wt. %) is required to form H_2O-saturated equilibrium phase assemblages in MORB compositions at very low-T conditions (<450 deg.C at 2.0 GPa). Accordingly, cold subduction zones are not associated with the release of significant amounts of water in the forearc region. However, recent subduction-zone thermal models that incorporate a stress- and temperature-dependent mantle rheology predict a substantial temperature rise at the depth where the slab-mantle interface becomes mechanically strongly coupled. A review of worldwide subduction zones suggests this depth is ~80 km irrespective of the subduction zone (Wada and Wang, 2009). Modelling suggests that below this strong coupling depth there is a steep temperature gradient between the top and base of the slab crust at depth. Our modeling predicts that the presence of such a steep temperature gradient in cold subduction zones such as NE Japan results in the release of substantial amounts of H_2O fluid from the uppermost part of oceanic crust at the depth where strong coupling begins. In the case of warm and hot subduction zones such as SW Japan and Cascadia, substantial dehydration of the slab is expected even at the uppermost mantle levels mainly due to breakdown of lawsonite (~370 deg.C at 1.0 GPa) and chlorite (~470 deg.C at 1.0 GPa). The predicted P-T conditions and substantial fluid release are compatible with the high fluid pressure regions inferred from high Vp/Vs ratios observed in the plate interface of warm subduction zones such as SW Japan and Cascadia.

キーワード: 変成脱水反応, 中央海嶺玄武岩, シュードセクション, 沈み込み帯
Keywords: dehydration, MORB, pseudosection, subduction zone