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Special issue 'Geofluid processes in subduction zones and mantle dynamics'

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Introduction

Almost all physico-chemical characteristics of earth-forming materials are influenced by the presence of H_2O. As N. L. Bowen stated in 1928, H_2O plays the role of Maxwell's demon - it does just what a petrologist may wish it to do [p. 282, *The evolution of the igneous rocks* (Bowen 1928)]. In the following decades, this has been proven to be the case not only in petrology but in every field of solid Earth science.

H_2O is the most abundant fluid in the Earth, except for liquid iron alloys present in the outer core. Volcanoes emit magmas and volatiles, which include COH ± S ± N species, halogens (F, Cl, I, Br), rare gases (He, Ne, Ar, Kr, Xe), fluid-mobile elements such as alkali elements (Li, Na, K, Rb, Cs), B, possibly Pb and U, and less likely Th. In the Earth's interior, these volatile components exist as geofluids, affecting various phenomena and acting as effective tracers for the respective phenomena. Seawater and atmosphere are geofluids that have accumulated on the surface of the Earth, and they hydrate and carbonate lithosphere through chemical reactions and depositions. Geofluids are released from subducting lithospheres, migrate upward, and play vital roles in various subduction-zone phenomena, such as magma genesis (Kawamoto et al. 2012; Kimura and Nakajima 2014), seismic activity (Mitsui and Hirahara 2009; Shiina et al. 2013), rock deformation (Katayama et al. 2004; Hilairet et al. 2007), and electromagnetic response (Yoshino and Katsura 2013). Geofluids also affect mantle dynamics (Korenaga 2013; Reynard 2013), including global material circulation and chemical differentiation (Tatsumi 2005), and the transportation of mainly C-O-H fluids into the Earth's interior (Deschamps et al. 2013). This special issue is a collection of 30 studies on such geofluid processes.

Fluids in the mantle wedge and crust originating from the subducting slab

Kusuda et al. (2014) report on the chemical composition of non-volcanic hot springs in the forearc region of the Southwest Japan arc. The forearc hot springs have been studied by means of aqueous chemistry for over 40 years (Kazahaya et al. 2014). By comparing the analyzed chemical composition of hot water with modeled composition of dehydrated materials from downgoing oceanic crustal materials, the authors conclude that the water originates in the subducting oceanic plate (Matsumoto et al. 2003; Kawamoto et al. 2013; Kazahaya et al. 2014). Within the same forearc region in the Kii peninsula, Japan, Kato et al. (2014) report on an intensive non-volcanic seismic swarm and estimate a fine-scale seismic velocity structure of the region. The results indicate the presence of geofluids such as partial melt or water beneath the swarm. Such fluids may potentially be released from the subducting crust of the Philippine Sea plate.

In the near-trench area in the Northeast Japan arc, Togo et al. (2014) report on the isotopes of hydrogen/deuterium, oxygen, iodine, and chlorine, as well as tritium concentrations of deep groundwater. They propose that these are derived from subducting sediments. Okamoto et al. (2014) describe CH_4-CO_2-H_2O fluid inclusions in quartz veins from the Shimanto belt, a near-trench Tertiary accretionary prism in the Southwest Japan arc. Such fluids may represent fluids degassed from crystallizing near-trench magmas generated during subduction of hot oceanic lithosphere.

Mori et al. (2014) evaluate bleaching processes of pelite in serpentine mélanges by studying the chemical composition of a bleached and unaltered sedimentary rock at the reaction boundary between the surrounding chlorite schist and metapelite. Regarding reactions that take place inside subducting slabs, Zheng and Hermann (2014) summarize major and trace element features of slab-derived fluids based on an analysis of high-pressure and ultra-high-pressure metamorphic rocks. Koga et al. (2014) demonstrate that vibrational spectroscopy can be

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used to determine halogen content in Ti-clinohumite, a high-pressure hydrated phase formed from fluids produced by dehydration reactions in ultramafic rocks.

Within the deeper subducting slab, geofluids released from the slab trigger the melting of the mantle wedge. Ikemoto and Iwamori (2014) model trace element transport in volcanic rocks and show that disequilibrium transport through channels likely plays an important role in element cycling in subduction zones. Such fluid transport without further chemical changes is also seen in the hot springs in the forearc region that originated from subducting slabs (Kusuda et al. 2014).

Hydrous melting of the mantle produces hydrous magmas, leaving behind residual mantle minerals that have distinct compositions compared to those formed through anhydrous melting. Matsukage and Kawasaki (2014) compare the chemical composition of cratonic garnet peridotites and experimental peridotite residue under various H_2O contents from 100- to 200-km depth. The results suggest heterogeneity of H_2O content in the upper mantle during the early history of the Earth and raise the question of how much H_2O is present in current arc magmas. Hamada et al. (2014) describe differentiation processes of low-K tholeiite basaltic magma having H_2O content of 3 wt.% in a shallow magma chamber at approximately 4-km depth and propose possible differentiation processes of the magma at deeper crustal levels. Based on Ca/Na partitioning between plagioclase and melt, Ushioda et al. (2014) estimate the H_2O content in erupted basaltic magmas in the Northeast Japan and Izu arcs. According to their results, the frontal volcanoes appear to have higher H_2O content than the rear-arc volcanoes.

Rose-Koga et al. (2014) report on the abundance of H_2O, CO_2, F, Cl, and S and Pb isotopes in basaltic melt inclusions in a frontal-arc volcano in the Northeast Japan arc and discuss temperatures of slab surface and phase relationships of the dehydrating slab materials. Kawamoto et al. (2014) conducted synchrotron X-ray fluorescence (XRF) experiments to determine the effects of salinity and pressure on partitioning of large-ion lithophile elements such as Pb, Rb, and Sr between silicate melts and aqueous fluids. They propose a process of separation of Cl-bearing supercritical fluids from the slab and their subsequent incorporation into hydrous melts and saline fluids to explain the geochemical features of island arc basalts (Kawamoto et al. 2012).

The 2011 Tohoku-oki earthquake: friction, strength, and post-seismic deformation

Den Hartog et al. (2014) evaluate an experimental physical model of phyllosilicate-rich fault gouges in the megathrust. The results imply that water-assisted thermally activated quartz deformation is one of the major controlling factors of seismogenic properties in such megathrusts. Shimizu (2014) proposes a rheological profile across the source area of the 2011 Tohoku earthquake and argues that the large tsunamigenic slip during the Tohoku earthquake can be explained by a large gradient in fault strength on the up-dip side of the hypocenter. Based on a long-term multiscale earthquake cycle simulation on a three-dimensional (3D) plate boundary model, Ariyoshi et al. (2014) suggest that activation and quiescence of shallow, very low-frequency earthquakes following the 2011 Tohoku earthquake are closely associated with plate coupling perturbations resulting from the stress shadow effect of the Tohoku earthquake. By modeling the effect of poroelastic rebound on surface deformation following the 2011 Tohoku earthquake, Hu et al. (2014) show how the effect is restricted to the vicinity of the rupture area. They also show that the viscosity in the lower crust beneath the volcanic front is several orders of magnitude lower than the surrounding areas.

Geofluids detected with magnetotelluric and seismic observations

Kanda and Ogawa (2014) estimate a 3D distribution of fluids and melts under the Northeast Japan arc using geomagnetic transfer functions. Their results suggest the presence of a deep crustal conductor that may correspond either to partial melts and/or high-salinity fluids. Ichihara et al. (2014) present a 3D electrical resistivity model beneath the focal zone of the 2008 Iwate-Miyagi Nairiku earthquake that shows a shallow conductive zone beneath the Kitakami Lowland and several conductive patches beneath active volcanic areas. Yoshida et al. (2014) determined pore fluid pressure distribution in the focal region of the above earthquake and suggest that geofluids supplied from the mantle wedge have contributed to the generation of high pore pressures and to the lowering of frictional strengths of seismic faults in this region. Ogawa et al. (2014) conducted a densely distributed magnetotelluric survey around the Naruko Volcano in Northeast Japan and produced a shallow resistivity model of the Quaternary volcano. They found a southward-dipping, sub-vertical conductor that may imply the presence of geofluids just below the volcano. Okada et al. (2014) found seismic low-velocity zones beneath the same volcano and in the aftershock region of the 2008 Iwate-Miyagi Nairiku earthquake, both of which can be attributed to the presence of geofluids. The former, having a diameter of 10 to 20 km, resides in the lower crust. Kosuga (2014) observed the migration of seismicity for a seismic cluster near the Moriyoshi volcano in the Northeast Japan arc and identifies distinct seismic scatters above low-frequency earthquakes in the lower crust. He argues that the observed migration is associated with geofluids supplied from the uppermost mantle.

Shiina et al. (2014) show that hydrated mineralogy alone cannot sufficiently explain the low velocities observed in the subducting crust beneath Hokkaido, suggesting that fluids may coexist with hydrated rocks down to 80-km depth. Nakajima (2014) provides evidence of the presence of high-attenuation areas in a serpentinized mantle wedge using seismological tomography. These areas are associated with low seismic activity that may be explained by deformation of weak serpentine. Based on numerical simulation, Kirby et al. (2014) suggest that the serpentinized mantle was formed through plate subduction during the Mesozoic and Paleogene that has been sufficiently heated over time, releasing water into the crust over much of the history of the San Andreas Fault system. Kuwatani et al. (2014) apply the Markov random field model to the observed seismic velocity models in the mantle wedge of the Northeast Japan arc and estimate the porosity and pore shapes of rocks. There is a significant difference in the calculated porosity and aspect ratio of geofluids between the forearc side and the volcanic front.

A frontier letter by Pommier (2014) describes how electromagnetic and seismic methods can complement each other in providing information about the storage of fluids in subduction systems. She implies a possible correlation between electrical conductivity and seismic wave attenuation anomalies in the mantle wedge. Jung et al. (2014) studied seismic anisotropy of two fluid-induced peridotite samples collected from wall rock and mylonite fabrics and find that seismic anisotropy becomes significantly weaker as the percentage of mylonite increases. Ishikawa and Matsumoto (2014) measure Vp for quartz aggregate at PT conditions of the middle crust and quantify the effect of pore fluids on Vp. The results show that even a small amount of fluids (0.4 to 1.0 wt.%) reduces Vp by 3% to 4%. Shimojuku et al. (2014) report on the experimental results of conductivity measurement of saline-fluid-bearing rocks. Their set of data will be highly instrumental in distinguishing between magmas and saline fluids and also in determining their possible volumes and geometry based on comparison with the observed conductivity data in subduction zones.

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