Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SCG63-01 Room:104 Time:May 22 16:15-16:30

An interpretation of dehydration process in the subduction zone beneath Kyushu Island, Northwestern Japan

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The Japan Island Arc has different subduction settings; the young Philippine Sea plate (10-50 Ma) subducts beneath Kyushu Island in the southewestern Japan with dipping angles of about 60 degrees, while the Pacific plate older than 100 Ma subducts beneath Tohoku district in the northeastern Japan with dipping angles of about 45 degrees. It has been considered that these different subduction settings cause different volcanic activities and dehydration processes between Kyushu and Tohoku districts (e.g. Iwamori, 2007; Ichiki et al., 2009). In this study, we compiled the electrical conductivity (Handa et al., 1992; Handa et al., 1999; Ichiki et al., 2000; Hata et al., 2012) and seismic wave velocity (Nakajima et al., 2007; Zhao et al., 2012) models beneath Kyushu Island, and interpreted that dehydration process from subducting slabs and fluid transport process were consistent with each other between Kyushu Island and Tohoku district. The interpretation is 1) fluids dehydrated from subducting slab are absorbed in peridotites at the bottom of the mantle wedge. The hydrous minerals are dragged into the deeper part and dehydrated in the deeper mantle beneath the backarc region. 2) The fluids dehydrated from the hydrous peridotite indicate Rayleigh-Taylor instability in the upwelling process. This results in the volcanic and non-volcanic areas along the volcanic front of Kyushu Island.

An obvious negative free-air and/or Bouguer gravity anomaly is observed in the forearc region of Kyushu Island (Kono and Furuse, 1989; Shichi, 1997; cf. Nakada et al., 2002). The Vp/Vs and electrical conductivity values at ca. 40 km depth beneath the forearc region show higher than 2.0 (Saiga et al., 2010) and 0.02 S/m (Ichiki et al., 2000), respectively. These suggest that serpentine diapir underlies beneath the forearc region of Kyushu Island. However, these features have not yet been observed beneath the forearc region of Tohoku district. More observations focusing on the forearc region are required in the Tohoku district.

Keywords: Electrical conductivity, Seismic wave velocity, Subduction zone, Dehydration, Backarc, Serpentine

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SCG63-02 Room:104 Time:May 22 16:30-16:45

Slab-fluids: saline fluids in fore arc regions and supercritical fluids under volcanic arcs

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Chemical features of slab-fluids are essential to understand the geo processes in subduction zones. We studied the amphibole and phlogopite bearing harzburgite xenolith collected from the Pinatubo 1991 eruption. The harzburgite has coarse olivine having many fluid inclusions. The fluid inclusions are composed of H_2O-CO_2-Cl fluids with 5.1 +/- 1 wt% NaCl.. The Pinatubo volcano is located at the volcanic front of the Luzon arc subducted by South China Sea plate. We suggest that such CO_2 bearing saline fluids are infiltrated in the forearc mantle. We also studied plagioclase lherzolite xenoliths collected from the Ichinomegata volcano, Notheast Japan arc. The xenoliths have orthopyroxene grains having many CO_2-H_2O-Cl-S fluid inclusions with 3.7 +/- 0.8 wt% NaCl. We suggest that such fluids can be formed through degassing of arc magmas. We estimate that slab-fluids to produce the arc magmas have 1.1 ? 1.4 wt% NaCl with assumption of Cl partitioning between basaltic magmas and aqueous fluids.

The origin of such saline fluids remains unanswered at this moment. If the slab-fluids are saline fluids, their percolation processes may differ from pure H_2O fluids. Pressure-temperature conditions of critical endpoints between magmas and fluids may be different from those in the pure H_2O systems. There still remains to be investigated to answer for those questions. The chemical analyses of fluid inclusions in mantle rocks and melt inclusions in volcanic rocks should be conducted in more localities with more elements. And high-pressure and high-temperature experiments using saline solutions should be conducted to understand the role of saline fluids in subduction-zone processes.

Keywords: subduction zone, magma, fluid inclusion, mantle wedge, dehydration, chlorine

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SCG63-03 Room:104 Time:May 22 16:45-17:00

The maximum depth of the hydrothermal-convection zone in the crust controlled by the precipitation of silica minerals

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Precipitation of silica minerals ubiquitously occur in crustal environments. Quartz is the most stable phase of silica. Metastable silica polymorphs, such as amorphous silica, cristobalite, and chalcedony, also form in the surface and subsurface silica deposits. The dissolution-precipitation of silica minerals has a significant effect on both mechanical and hydrological properties of the Earth's crust. However, the structure of the crust has been studied mostly in geophysics, not in geochemistry.

Here we interpret the maximum depth of the hydrothermal-convection zone at Kakkonda geothermal field, Japan, on the dissolution-precipitation of silica minerals. The drilling of the well WD-1a at Kakkonda encountered the temperature exceeding the hydrostatic boiling-point curve, over 500 C at 3729 m depth (Doi et al., 1998). The boundary between the hydrothermal-convection zone and the heat-conduction zone was found at 3100 m depth because of the critical change of permeability.

First we calculated the quartz solubility along the P-T conditions of the WD-1a (Ikeuchi et al., 1998). The quartz solubility had the local minimum value at 3100 m depth which coincided with The boundary between the hydrothermal-convection zone and the heat-conduction zone, suggesting that quartz could precipitate from both upflow and downflow fluid at the boundary.

Next we conducted the hydrothermal flow-through experiments to investigate the temperature dependence of the precipitation of silica minerals. The P-T conditions for precipitation were from 170 to 430 C and 24 MPa. Any rock/mineral substrates were not used in the precipitation vessel. The initial solution was made by dissolution of granite at 350 C and 24 MPa. The Si concentration in the input solution, from 330 to 350 ppm, rapidly decreased to the quartz solubility at over 400 C. The experimental results indicated that quartz precipitation associated with nucleation occur dominantly at high temperature whereas it associated with quartz growth on quartz surfaces only occur at low temperature.

A large amount of quartz precipitate is expected to seal the fractures and to block the downflow fluid efficiently. The maximum depth of the hydrothermal-convection zone in the geothermal fields may reflect the significant precipitation of quartz at high temperature.

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Keywords: Silica minerals, Precipitation, Hydrothermal experiment, Geothermal field

SCG63-04 Room:104 Time:May 22 17:00-17:15

Clay mineral characteristics of the plate-boundary fault at the Japan Trench

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The 2011 Tohoku-oki earthquake (Mw9.0) rupture propagated along the plate-boundary megathrust and caused a huge tsunami. One anomalous aspect of this earthquake is that the seismic slip broke through the up-dip limit of the seismogenic zone, with slip propagating as far as the trench axis. In order to elucidate the physical mechanisms responsible for such unexpected behavior of the shallow fault, the IODP Ex 343 The Japan Trench Fast Drilling Project (JFAST) was carried out one year after the earthquake. It succeeded in recovery of material from within the plate boundary shear zone. Our data illustrate how mineralogical properties vary through a depth-section including the plate boundary fault rock, and we discuss the mechanical significance.

At the drilling site (C0019E) where the largest fault slip (>50m) occurred, a plate boundary shear zone was identified around 820 mbsf. X-ray diffraction (XRD) analysis of clay-fraction samples reveals that relative abundance of smectite is markedly higher at the fault (74-94 wt.%) than in the surrounding host rocks. Bulk-XRD results indicate the absolute smectite abundance in the fault rock reaches more than 70 wt.%, suggesting (by correlation with previous experimental studies of smectitic clays) the shear zone material had low intrinsic friction coefficient.

Because it has such a high smectite content, the shear zone is also expected to be influenced by physico-chemical interactions between smectite and interstitial water. In particular, the swelling behavior of smectite will affect the in-situ mechanical state of the fault. We estimated osmotic swelling forces the shear zone rock could cause by applying the Gouy-Chapman theory of diffuse double layer states under the restricted swelling strain condition. Based on measurements of exchangeable cation content, cation exchange capacity and BET surface area for some bulk rock samples (including 2 fault rocks), the theoretical estimate suggests osmotic repulsive forces of the order of ˜5MPa could act between the smectite particles within the fault. Thus, in addition to its contribution to a low friction coefficient, the swelling behavior of smectite might further reduce effective pressure (and therefore shear strength) of the plate-boundary fault, and help to promote localized slip on it.

Keywords: 2011 Tohoku-oki earthquake, JFAST, smectite

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SCG63-05 Room:104 Time:May 22 17:15-17:30

Relationship of intra-plate earthquake and dehydrated fluid -Example of the analysis of serpentinite body in Mt.Shiraga-

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SCG63-06 Room:104 Time:May 23 09:00-09:30

Influence of dehydration to Cl isotopic fractionations: implication for behavior of hydrophilic Cl during subduction

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Chlorine, which is known as a hydrophilic element, has been used for elucidating mechanisms of the oceanic materials recycling during subduction (Philippot et al., 1998). Since Cl-bearing minerals sush as NaCl are highly dissociative in solution, chloride can be a sensitive proxy for fluid mobility in crustal and subduction-related environments (Barnes et al., 2008).

Chlorine isotopic ratio (d^{37}Cl/permil vs. SMOC, standard mean ocean chloride) varies in a range of +-10permil. The highly positive d^{37}Cl values were found in the MORB while the negative d^{37}Cl values were seen in subduction-zone pore fluids. Serpentinized ultramafic rocks from ODP sites showed negative d^{37}Cl, indicating that a result of hydration of the ultramafic rock by infiltrating^{35}Cl-enriched pore fluids from the overlying sediments (Barnes and Sharp, 2006). The pore fluids having strongly negative d^{37}Cl values (Ransom et al., 1995) are also consistent with preferential retention or fixation of^{37}Cl in silicates.

However, the mechanism of Cl isotopic fractionation between two phases occurring phase separation along dehydration and recrystallization at subduction related environments has not been described well. To elucidate an influence of water to the Cl isotope fractionation, we have conducted anion exchange chromatographic experiments. The results showed the heavier isotope,^{37}Cl, enriched into liquid phase while the lighter,^{35}Cl, enriched into anion-exchange resin phase (Musashi et al., 2007).

The trend of the heavier isotopic enrichment into liquid phase by the chromatography was agreeable to the theoretical and experimental studies on Li isotope effect: dehydration of the Li hydrate influenced on^{7}Li enrichment into the liquid phase (Oi et al., 1991). Controversially, Schauble et al. (2003) theoretically estimated the lighter isotope, ^{35}Cl, enriched into liquid phase by the Cl isotope equilibrium of the anhydrates.

To understand the Cl isotopic fractionation factor (S) experimentally obtained, the reduced partition function ratios (named f value) of several Cl-hydrates were computed after geometrical structures of the Cl-hydrates were optimized by ab initio molecular orbital calculation. Remarkably, the Cl-hydrates were not optimized until hydration number being more than 100, although the number of the primary hydration sphere around a Cl- in aqueous solution was seven. This implied that the extremely dissociative Cl- was negatively hydrous and the hydration structure was unstable. The f value of the Cl-(H2O)n was calculated and 1000*ln f(100) =1.658 (n=100) (Oi, private comm.). The S value is expressed by the theory of two phases'separation as follows: ln S = ln F(m) - ln f(n) (Eq.1), where F(m) is a RPFR of Cl-(H2O)m adsorbing to resin with the hydration number of m, and f(n) is that of Cl-(H2O)n dissolved in solution with the number of n. Since the m becomes less than the n by dehydration, symmetry of the molecular structure of the former F(m) is less than that of the latter f(100). We speculate that F(m)$<$f(100), implying that^{37}Cl preferably can be enriched into solution phase by dehydration effect.

When we summarize from the above-mentioned things, the thermo-dynamical stability of the primary hydration sphere around Cl- ion is an important factor controlling the tendency of Cl isotope fractionation between liquid and solid phases of geochemical interests. Assuming an anion exchange resin as oceanic sediment, we may say that^{35}Cl preferentially enriches into the sediment phase while^{37}Cl enriches into the subduction-zone pore fluid phase. However, only if Cl- incorporated into the solid phase such as oceanic sediment is stable thermo-dynamically, as F(m)$>$f(n) (Schauble et al., 2003), the ^{37}Cl may enrich into the sediment phase rather than the pore fluid phase. Similarly, in case of the ultimate dehydration such as recrystallization of NaCl from the saturated solution, the^{37}Cl may enrich into crystal phase (Eggenkamp et al., 1995).

Keywords: chlorine isotope fractionation, hydrophilic, hydration structure, subduction-zone pore fluid, molecular orbital calculation, anion exchange equilibrium

SCG63-07 Room:104 Time:May 23 09:30-09:45

A numerical simulation of brine-rock interaction

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The thermodynamic database, SUPCRT92 (Johnson et al., 1992) has been widely used for analyses of water-rock interactions. However, since it gives thermodynamic data of solutes in pure water solvents, they cannot be applied to solutes in mixed solvents as common geological fluids.

According to Hoshino et al. (2009), the dielectric constant is a key parameter characterizing chemical properties of solvents. Within the framework of electrostatic approach to predict thermodynamic properties of aqueous fluids taken in SUPCRT92, a chemical potential of a certain solute can be divided to the structural non solvation and solvation terms (Akinfiev and Zotov, 1999). The latter is expressed by the Born equation with the Born parameter of the solute and the dielectric constant of the solvent. Hence, if we can estimate the dielectric constants of brines, we may calculate the chemical potentials of solutes in the brines from those in pure water solvents given by SUPCRT92. They also tried to estimate the constants of 1 molal NaCl solutions from quartz solubilities in brines measured in previous experiments. The estimated constants are higher than those of water below 400 C at 100 MPa and abruptly increase with decreasing temperatures at around 400 C. However, they estimated the constants from quite rough inter- and/or extrapolations of solubility data of experiments under various temperature and pressure conditions with different salinities.

Therefore, we carried out solubility measurements for the assemblage of quartz and wollastonite in 1 molal NaCl solutions at 400 and 300 C at 100 MPa by using Dr. HIP (internally heated pressure vessel) of the Institute for Study of the Earth's Interior, Okayama University. Small amounts of quartz and wollastonite crystals were sealed with 1 molal NaCl solutions in gold capsules. Each capsule was hung by Mo wire in the hot spot of a Mo furnace within the pressure vessel, and held for 91 and 64 hours at 300 and 400 C, respectively. At the end of the run, the hanging wire was broken with a surging current, thereby letting the capsule fall into the cold bottom of the vessel, resulting in quenching the capsule.

Since Si is dissolved in the brines mainly as SiO2(aq), while Ca is CaCl+ in the experimental conditions, the solubilities of the both minerals, i.e., concentrations of Si and Ca saturated with the minerals, are used for the consistency check of estimated dielectric constants and thermodynamic data for neutral and charged species.

The dielectric constants of the brines estimated from concentrations of Si, 15.83 for 400 C and 27.84 for 300 C, were, however, different from those estimated from Ca concentrations, 19.32 for 400 C and 34.38 for 300 C, probably due to analytical errors during concentration measurements. Another possibility is that the solutions continued to react with the minerals slightly after the ends of runs. Then, we estimated the quench temperatures where unique dielectric constants could be obtained for the both Si and Ca concentrations. The resultant temperatures are 385 C with the constant of 20.14 and 290 C with 34.51 for the 400 and 300 C runs, respectively. The constants are almost consistent with those estimated from Ca concentrations at 400 and 300 C. It should be emphasized that the born parameter of Ca2+ is about one order of magnitude larger than that of SiO2(aq), resulting in the larger effect of a difference in the dielectric constant on Ca concentrations than the effect on Si concentrations, and that a dilution rate of the solutions for concentration measurements of Si is 10 times larger than the rate for Ca measurements. Therefore, the dielectric constants estimated from Ca concentrations may be much reliable than those from Si concentrations.

Results of numerical simulations of brine-rock interactions using the above estimated dielectric constants will be shown in the presentation.

Keywords: dielectric constant, H2O-NaCl solution, solubility, SUPCRT92, geological fluid

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SCG63-08 Room:104 Time:May 23 09:45-10:00

Coupling of serpentinization reactions and silica diffusion

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Silica activity is considered to be one of the key factors in controlling reaction paths and rates of serpentinization (e.g., Frost and Beard, 2007; Klein et al., 2009). There are many experimental studies on serpentinization during mantle peridotites and water interaction, focusing on extent of serpentinization, evolution of fluid chemistry and generation of hydrogen and hydrocarbons. However, all of these studies focused on bulk solid materials and solutions within the reaction vessel, and local changes of products and silica concentration gradient have not been clarified; therefore, the role of silica transport on progress of serpentinization is still unclear. In this study, we conducted hydrothermal experiments in the olivine (Ol)?orthopyroxene (Opx)?H2O system at 250 degreeC and at a vapor-saturated pressure of 3.98 MPa to explore the role of silica diffusion in aqueous fluids during serpentinization. Olivine (Fo91), orthopyroxene (En92), or their composite powders (with Ol/Opx/Ol zones) were set in tube-in-tube vessels, and solution chemistry and the extent of serpentinization were analyzed in detail.

In the Ol?H2O experiments, the product changed from serpentine + magnetite to serpentine + brucite + magnetite, accompanied by a Si-drop in the solutions, that is similar to the results of our previous observations (Okamoto et al., 2011). Serpentinization proceeded uniformly throughout the reaction tube, indicating that the supply of water was not the rate-determining process. In the Opx?H2O experiments, orthopyroxenes were dissolved along the cleavages, and a small amount of serpentine + talc was formed. The silica activity of the solutions in the Opx?H2O experiments was at the level coexisting serpentine + talc, that is 1?3 orders higher than in the Ol?H2O experiments.

In the Ol?Opx?H2O experiments, serpentinization proceeded in both the Ol and Opx zones, and white-colored reaction zone (2 mm thick) was developed at the boundary of the Ol and Opx zones. In the Opx zone, the extent of serpentinization was nearly constant, and mixture of serpentine + talc was formed. In the Ol zone, the total amount of H2O revealed by thermogravimetry and SEM observations was most extensive along the boundary between the Ol and Opx zones, and it decreased gradually away from the boundary. Based on the Mg/Si values of the products, the ratio of talc in the products (Mtalc/Mtalc+Msrp) is highest in the Opx zone, and decreased steeply in the boundary zone, and talc was absent away from the boundary. The silica concentration in the bulk solution is lower than the stability field of talc, indicating the high Si gradient within the cm scale reaction tube.

Serpentinization in the Ol?Opx?H2O experiments was modeled simply by coupled processes involving silica diffusion and three reactions: (1) a silica?consuming reaction after olivine, (2) a silica-releasing reaction after orthopyroxene and (3) talc-forming reaction after serpentine. We will discuss the kinetic model explain the reaction progress and evolution of solution chemistry, and the role of silica on the rate of serpentinization. Our experimental results represent an analogue of serpentinization in natural hydrothermal systems with a high porosity, and we suggest that the spatial variation of serpentine as a function of the distance from a source of silica could be a useful indicator of the relative magnitudes of reaction, mass transport, fluid flow as well as temperature during hydrothermal alteration of oceanic lithosphere.

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Keywords: serpentinization, silica diffusion, rate-dermining process, olivine-orthopyroxene-H2O

SCG63-09 Room:104 Time:May 23 10:00-10:15

Influence of Si-metasomatism on slab-mantle interface rheology

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Aqueous fluids liberated during dehydration of the subducting slab cause hydration of the overlying forearc mantle wedge, changing the mechanical properties of the slab-mantle interface. Antigorite, a high-temperature serpentine mineral, is expected to be the main hydrous mineral present in the forearc wedge, while slab-derived fluids are likely to contain significant amounts of dissolved silica, leading to Si-metasomatism and replacement of antigorite by talc. However, it remains unclear how the strength and internal structure of antigorite-rich rocks evolve in the presence of reacting silica-rich fluids.

To determine the effect of Si-metasomatism on the rheological properties of antigorite, we performed a series of frictional sliding experiments on 100% antigorite, 100% talc and antigorite (70%) plus quartz (30%) gouges under hydrothermal conditions, using a ring shear machine. The pure antigorite and talc gouges showed steady-state shearing at a friction coefficient of 0.63 and 0.21, respectively. In contrast, the antigorite/quartz (atg/qtz) gouges exhibited a peak friction coefficient of 0.40-0.62 followed by strain weakening towards a quasi-steady-state strength with the friction coefficient of 0.25-0.47. The degree of weakening of atg/qtz relative to pure antigorite increased with increasing temperature and decreasing sliding velocity. The weakening was mainly due to the development of through-going, talc-bearing boundary shears, which widened until the steady-state sliding was attained.

Our experiments indicate that in the lowermost part of the forearc wedge, where silica-saturated fluids infiltrate from the dehydrating slab, metasomatically produced talc slip surfaces or shear bands will form in the intensely sheared plate interface, causing a much larger weakening effect than expected for antigorite, even if the total amount of talc formed is minor ($<$10 vol%).

Keywords: antigorite, fluids, mantle wedge, metasomatism, subduction zone, talc

SCG63-10 Room:104 Time:May 23 10:15-10:30

Geochemical variations in the Sangihe arc: Fluid and melt slab fluxes in response to slab temperature

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The Sangihe arc, northeastern Indonesia, is an oceanic arc situated in unique tectonic settings where the active arc-arc collision is ongoing in the northern arc sector. The compositional diversity of lavas from south to north in the arc should reflect influx from subducted slab in response to slab components and P-T conditions in the sub-arc mantle. To elucidate magma genesis and slab thermal structure in such a setting, we have obtained new geochemical data for lavas from the entire Sangihe arc. In the southern arc where is away from the collision zone, the across-arc geochemical variation demonstrates that slab component changes in character from low-temperature fluid, through high-temperature fluid, to partial melt from the volcanic front to the rear arc. The geochemical systematics, the estimated mass fraction of the slab component, and the inferred stability of accessory rutile, zircon, and phengite in the slab are all similar to other oceanic arcs, such as Izu arc, indicating that the thermal structure of the slab is not affected by impending collision. In contrast, volcanic front lavas from the dormant northern Sangihe arc are systematically more enriched in fluid-immobile elements than the southern volcanic front lavas. This may be related to advanced collision in the northern arc that could have slowed the subduction rate and heated the slab in the Pliocene followed by cessation of volcanic activity in the Quaternary.

Keywords: subduction zone, slab dehydration, slab melting, Sangihe arc, arc collision

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SCG63-11 Room:104 Time:May 23 10:30-10:45

Lateral variation of trace element of volcanic rocks from East Java, Sunda arc: estimation of slab fluid contributions

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We analyzed volcanic rocks from eastern part of Java island in order to estimate the influence of slab-derived fluid across the arc. Such lateral variation of slab-derived fluid contributions, from both sediment (SED) and altered oceanic crust (AOC), to arc magmas has been documented in central and western sections of Java island. The ratios of fluid-mobile elements to HFS (High Field Strength) elements (e.g. Ba/Nb, Ba/Zr, Ba/La) were examined as well to reveal the lateral variation of subduction components. We also evaluate the mantle source variability across this arc magmas by using Nb/HFSE (e.g. Nb/Ta, Nb/Zr) ratios.

Volcanic rocks from eastern part of Java island show general enrichment of LILE and LREE, and negative anomaly of Nb and Ti, in both the frontal-arc and back-arc regions. These arc magma's characteristics are also well observed in the volcanic rocks from central and western parts of Java island. The increasing ratios of Nb/HFSE in the back-arc region of eastern part of Java imply particular mantle source enrichment in this part. Subduction components, as represented by Ba/HFSE, are well observed all across the arc. These ratios decrease from volcanic front toward back arc, which suggests a recognizable influence of slab-derived fluid in this particular part of Java island. The back-arc alkaline volcanoes, such as Ringgit-Beser, are low in terms of Ba/HFSE ratios, suggesting the small input of subduction components. In terms of across-arc variation of slab-derived fluid, volcanic rocks from East Java show similar decreasing pattern, which is also shown by magmas from Central Java. However, the appearance of back-arc alkaline volcanism at 220 km depth of Wadati-Benioff zone, which is much shallower compared to 370 km in central part of Java, raises a question of different controls on back-arc volcano formation in Java island.

The decreasing patterns of slab-derived fluid across the eastern part of Java, which is recognized in Central Java as well, suggest the distinct contributions of slab-derived fluid into arc magmas in Sunda arc. In addition, this finding implies that subduction signature is observed not only in the frontal arc region, but also in the back-arc region of both East and Central parts of Java island.

Keywords: East Java, Sunda arc, slab fluid, lateral variation, trace elements

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SCG63-12 Room:104 Time:May 23 11:00-11:15

Electrical Conductivity of Highly Concentrated Salt Solution at Elevated Temperature and Pressure

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Introduction: Aqueous fluids in the Earth's crust would have large effect on the occurrence of earthquake and volcanic eruptions. To understand the effect of aqueous fluids, it is necessary to delineate their distribution in the Earth's crust. The distribution of the fluids has been expected to be revealed by electromagnetic observation, e.g. magnetotellurics. Electrical conductivity distribution in the crust is considered to roughly correspond to the fluids distribution because of the high electrical conductivity of fluids relative to solids. To develop a plausible model of the fluids distribution to explain the electromagnetic observations, we have to construct a database of the electrical conductivities of fluids over a range of pressure (p), temperature (T), and electrolyte concentrations (c). Classical molecular dynamics (MD) simulations are useful to obtain the physical properties of fluids at a range of p, T and c and to understand the underlying atomic-scale mechanism of the electrical conduction. Liquid and spuercritical phases of water and aqueous NaCl solutions are dominant at the p-T conditions of the Earth's crust. The aims of this study are (1) to develop a database of electrical conductivity of aqueous NaCl solution at a range of temperature, pressure, and salt concentrations and (2) to understand the physics and chemistry of the electrical conductivity of NaCl solution at extremely supercritical conditions.

Computational Methods: We used a flexible and induced point charge (FIPC) water model [1]. The point charges are fluctuated during the MD simulations. The MD simulations were performed using the code MXDORTO with some modifications. The database of electrical conductivity was developed for NaCl solution at $T < 2000$ K, $p < 2$ GPa, and $c < 9.5$ wt%

Results and Discussion: The electrical conductivity was almost constant at $T > 673$ K, $p > 0.5$ GPa, and low salt concentration $c = 0.6$ wt%. This is because the association of ions canceled out the mobility of ions at these conditions. At the salt concentration $c = 3.3$ wt%, which corresponds to the concentration of sea water, the electrical conductivity showed large temperature and pressure dependences at $T > 1000$ K and $p < 1.0$ GPa. The values were a function of temperature and density of the solution. The maximum conductivity was ˜25 S/m. The behavior of highly concentrated salt solution $c = 9.5$ wt%, which is a few times higher than the sea water, will be discussed in the presentation. In this study, we explain the underlying mechanism of the change of the electrical conductivity of aqueous NaCl solution in the supercritical phase from atomistic view and try to construct the useful equations for the electrical conductivity of aqueous NaCl solution in the supercritical phase.

[1] Sakuma, H., Ichiki, M., Kawamura, K., and Fuji-ta, K., under revision.

Keywords: NaCl, geofluid, MT, static dielectric constant, water, viscosity

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SCG63-13 Room:104 Time:May 23 11:15-11:30

3-D Channeling Flow through Rock Fracture Networks in Field-scale

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Rock fractures are recognized as the predominant pathways of fluid in the Earth's crust, because fractures usually have much greater permeability than the matrix permeability. Fluid flow through rock fractures is characterized by formation of preferential flow path (i.e. channeling flow) due to the heterogeneous aperture distribution created by the rough surfaces contacting, in part, each other.

In understanding the fluid migration within Earth's crust, discrete fracture network (DFN) model is one of the most powerful techniques to incorporate geometrical properties in fractures (fracture size, location, orientation, and density), and can account explicitly for the contribution of individual fractures on fluid flow. However, in the conventional DFN models, individual fractures were characterized by a single aperture value despite the fact that the real fractures had heterogeneous aperture distributions, and as a result the formation of 3-D preferential flow paths thorough fracture network were neglected. Therefore, the authors have developed GeoFlow, a novel DFN model simulator, where fractures are characterized by aperture distribution [Ishibashi et al., 2012]. In order to utilize GeoFlow for a field scale problems, the authors also developed a prediction method of fluid flow within multi-scaled fractures under confining stress [Ishibashi et al., 2012].

In the present study, we challenged to construct the precise fracture network with heterogeneous aperture distribution in field-scale. The Yufutsu oil/gas field in Hokkaido, Japan is well known as fractured type of reservoir, and selected as the subject for study. This is because reliable DFN models can be developed based on 3-D seismic data, acoustic emission data, in-situ stress measurement, and well logging for this field [Tamagawa et al., 2010]. The modeling domain is 1,050 (East-West) x 1,050 (North-South) x 1,050 (Depth) m3, and fractures are represented by squares of 50-390 m on a side. Aperture distributions are numerically determined by contacting a pair of fractal fracture surfaces to have the lab-scale non-scale-dependent contact area, and considered for the critically stressed fractures, which have high permeability due to shear dilation. Constructed DFN models are, then, converted into equivalent permeability continua that reflected contributions of both the matrix and fracture permeabilities. For the equivalent permeability continua, steady-state laminar flow of a viscous, incompressible fluid is simulated by GeoFlow under the unidirectional flow geometry.

The simulation results by GeoFlow show that the localization of flow paths in the fracture networks is much more remarkable than that simulated by conventional DFN models due to the 3-D channeling flow. Subsequently, percentage of total area of flow paths to total area of the fracture plane (flow area) is calculated for quantitative evaluation of flow path localization. As a result, the actual flow area is estimated to be around 20-50% of the flow area predicted by conventional DFN models. This finding implicates the followings: the reactive fields where water-rock interaction takes place are limited to narrower area than predicted by conventional DFN models, or 3-D channeling flow have a significant impact on well productivity of fractured type of reservoirs. In understanding the reality of the fluid migration within Earth's crust, 3-D channeling flow is one of the key phenomenon, and the suggested method in this presentation enables us to address this phenomenon.

Keywords: rock fracture, network model, channeling flow, heterogeneous aperture distribution, field-scale

SCG63-14 Room:104 Time:May 23 11:30-11:45

Fluid fraction dependence of elastic wave velocity and electrical conductivity of a water-saturated rock

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Fluid-filled cracks must be dominant conduction paths at the mid-crustal depth. Electrical conductivity must strongly depend on the connectivity of cracks. What amount of crack is required to form an interconnected network? How does its connectivity change with its amount? In order to solve these problems, we are experimentally studying electrical conductivity of water-saturated rocks with various amounts of crack. The amount of crack is changed by confining pressure, and evaluated via elastic wave velocity.

A cylindrical sample (D=25 mm, L=30 mm) of Aji granite (Kagawa pref., Japan) was saturated with KCl aqueous solution (0.01mol/L). The porosity is 0.68%, and the density 2.656 g/cm^3. Electrical conductivity was measured with the two-electrode method (Ag-AgCl electrodes, f=1 Hz-100 kHz), and elastic wave velocity the pulse transmission technique (PZT transducers, f=2 MHz). Measurements have been made using a 200 MPa hydrostatic pressure vessel, in which confining and pore-fluid pressures can be separately controlled. The confining pressure was increased up to 125 MPa, keeping the pore-fluid pressure 0.1 MPa. It took one day or longer for the electrical conductivity to become stationary after increasing the confining pressure.

The electrical conductivity decreased by an order of magnitude as the confining pressure increased from 0.1 MPa to 25 MPa. It decreased by only 1% with the increase of confining pressure from 25 MPa to 125 MPa. Elastic wave velocity increased by 5% as the confining pressure increased from 0.1 MPa to 25 MPa. It showed 2% increase with increasing confining pressure from 25 MPa to 125 MPa.

These changes in electrical conductivity and elastic wave velocities must be caused by the closure of cracks. Based on elastic stiffness of Aji granite at 180 MPa, we can estimate the aspect ratio of a crack which closes at a given confining pressure. The aspect ratio is 3.6x10^{-4} for the closure pressure of 25 MPa, and 1.8x10^{-3} for 125 MPa. The large decrease in conductivity, which was observed below 25 MPa, is caused by the closure of cracks with the aspect ratio less than 3.6x10^{-4}. Cracks with the aspect ratio from 3.6x10^{-4} to 1.8x10^{-3} closed as the confining pressure increased from 25 MPa to 125 MPa, leading to only a slight decrease in conductivity. The connectivity of fluid is still maintained by cracks with the aspect ratio lager than 1.8x10^{-3}. Two groups of crack dominate the change in electrical conductivity up to 125 MPa.

Keywords: water-saturated rock, elastic wave velocity, electrical conductivity, fluid fraction, aspect ratio of crack

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Sedimentary pore fluid-like halogens and noble gases in mantle peridotites from the Western-Pacific subduction zones

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Halogen and noble gas compositions can provide complementary information as tracers on origins and behaviors of H_2O in the mantle. This is because both groups of elements are strongly partitioned into fluids and have distinct elemental and/or isotopic compositions depending on their origins. Elementally fractionated atmospheric noble gases in the convecting mantle can be explained by subduction of seawater or sedimentary pore fluids [1]. A pioneer work suggests that halogens in a mantle wedge peridotite just above a subducting slab show a signature suggesting its origin involving sedimentary pore fluids [2]. Halogens and noble gases in pore fluids may be incorporated into serpentine minerals in oceanic plates, and then carried into the deeper mantle through the subduction [2,3]. Here, we present halogen and noble gas compositions of mantle peridotites from the Western-Pacific subduction zones to put a better constraint on how far the influence of subducted pore fluids extends in the mantle.

We apply the ”noble gas method” to samples, in which halogens (Cl, Br and I) and other elements (K, Ca, Se, Te, Ba and U) are converted to isotopes of Ar, Kr and Xe by neutron irradiation in a nuclear reactor [4]. This method has superior detection limits, two to five orders of magnitude lower than those by other methods, and can determine low halogen concentrations in mantle peridotites.

Samples studied in the present work are harzburgitic xenoliths from the Avacha volcano in Kamchatka, Russia and the Pinatubo volcano in the Philippines, and alpine-type peridotites from the Horoman massif in Hokkaido, Japan. H_2O-rich fluid inclusions have been described in minerals of those peridotites [5,6,7]. The Br/Cl and I/Cl values show heavy enrichments in I, suggesting a contribution of subducted fluids [2] to halogens in a mantle-like component [7] with various proportions, which have unique values in each locality. Slab-derived atmospheric noble gases are also dominated in these samples as previously reported [9,10].

The features of subducted halogens and noble gases in the mantle peridotites demonstrate that sedimentary pore fluids are carried beneath the island arcs through subduction and survive in the mantle wedge.

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Keywords: halogen, noble gas, peridotite, mantle, subduction zone, pore fluid

SCG63-16 Room:104 Time:May 23 12:00-12:15

Slab-mantle coupling condition beneath northeastern Japan estimated from distribution of serpentinite

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Seismic evidences (Kawakatsu & Watada, 2007; Tusji et al., 2008) shows a serpentinite layer in the mantle wedge just above the Pacific slab at depth 90-130 km beneath northeastern Japan. This is inconsistent with the hypothesis of common depths (about 80km) of slab-mantle decoupling among subduction zones (Wada & Wang, 2009). Numerical models show that at the transition depth from the decoupling to coupling, slab surface temperature increase abruptly so that serpentine become unstable at deeper depth. I examined several different coupling conditions in numerical models. The model assuming slab-mantle coupling at 130 km and gradual upward decoupling shows temperature distribution consistent with geophysical evidences. This result suggests that the decoupling depth is controlled by temperature distribution and varies among subduction zones.

Keywords: subduction zone, serpentinite, mantle wedge, thermal structure

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Intermediate-depth earthquakes: Role of geofluids and stresses

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Generation of intermediate-depth earthquakes is an ongoing enigma because high lithostatic pressures render ordinary dry frictional failure unlikely. Earthquakes in oceanic crust have been linked to the transformation of basalt to eclogite and concomitant dehydration (e.g., Kirby et al., 1996), and earthquakes in the oceanic mantle have been discussed in terms of dehydration of serpentine minerals (e.g., Yamasaki and Seno, 1996). Here we perform waveform analyses of two small seismic clusters in the crust and mantle of the downgoing oceanic lithosphere and show seismic evidence for fluid-related embrittlement for both crustal and mantle earthquakes. The observations presented in this study show the role of volume-change related stresses and fluid-related embrittlement as viable processes for nucleating earthquakes in downgoing oceanic lithosphere.

Eclogitization of the basaltic and gabbroic layer in the oceanic crust involves a volume reduction of 10%?15%. One consequence of the negative volume change is the formation of a paired stress field as a result of strain compatibility across the reaction front. Waveform analysis of an isolated seismic cluster reveals that tensional earthquakes lie 1 km above compressional earthquakes, and earthquakes with highly similar waveforms lie on well-defined planes with complementary rupture areas. The tensional stress is probably caused by the dimensional mismatch between crust transformed to eclogite and underlying untransformed crust, and the earthquakes are probably facilitated by reactivation of fossil faults extant in the subducting plate (Nakajima et al., Geology, 2013).

For mantle earthquakes, we focus on a seismic cluster that was activated in the Philippine Sea slab, 8 months after the megathrust Tohoku-oki earthquake (Mw9.0) on March 11, 2011. The seismic sequence started with an M 4.1 normal-fault event at the deepest part of the cluster, and subsequent earthquakes migrated upward along a conduit-like zone that dips northward. The tensional stress due to the co-seismic slip promoted the efficient upward migration of fluids from the underlying Pacific plate, producing overpressurized conditions at the tip of the fluid migration paths. The enhanced pore-fluid pressures and the resultant reduced effective normal stress weakened the strength of the faults sufficiently to bring the system into the brittle regime under the enhanced deviatoric stress. The gap of 8 months may represent the time needed for the increases in pore-fluid pressures to become sufficient to overcome the lithostatic pressure.

Keywords: Intraslab earthquakes, fluids, dehydration