Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SCG60-01 Room:201A Time:May 25 11:00-11:15

Thermal structure and melt fraction distribution of mantle from a 3-D electrical conductivity structure beneath Kyushu

HATA, Maki[1*] ; UYESHIMA, Makoto[1]

[1]Earthquake Research Institute, The University of Tokyo

The Kyushu Island in the Southwest Japan Arc has many Quaternary active volcanoes, which exist along the volcanic front of N30^{o}E-S30^{o}W, in relation to the subduction of the Philippine Sea Plate (PSP). The volcanoes are located in northern and southern regions of the island, and no volcano is located in the central region between the two volcanic regions of the island. We have performed three-dimensional (3-D) inversion analyses to obtain a lithospheric-scale electrical conductivity structure (model) beneath the entire Kyushu Island using the Network-Magnetotelluric (MT) data [*Hata et al.*, 2015]. One of two major findings from a distribution of conductive anomalies in the model is that the volcanoes in the northern and southern volcanic regions have two different origins bordering the non-volcanic region at deep depths. Secondly, the degrees of magmatism and the relative contributions of slab-derived fluids to the magmatism vary spatially in the one non-volcanic and two volcanic regions. Then, in this study, we try to verify whether the respective conductivity anomalies impart a different effect on temperature and melt fraction.

We use laboratory work results to determine thermal structure and melt fraction distributions derived from the electrical conductivity structure beneath the Kyushu Island. The laboratory work results are relation between electrical conductivity and temperature for four nominally anhydrous minerals (Olivine, Orthopyroxene, Clinopyroxene, and Garnet) in solid phase, relation between electrical conductivity and temperature for hydrous basaltic melt in liquid phase, and a parameterization result of isobaric hydrous mantle melting. In this presentation, we will show our approach to determine temperature and melt fraction as a function of the water contents among the four mantle minerals and the basaltic melt, which integrate laboratory-derived conductivity and field-derived conductivity. We will also show thermal structure profiles and melt fraction distribution profiles of the mantle wedge beneath the one non-volcanic region and the two volcanic regions of the Kyushu Island.

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SCG60-02 Room:201A Time:May 25 11:15-11:30

Subduction Initiation and spatial and temporal variation of magma generating condition in the Miocene SW Japan

MORISATO, Fumitoshi[1*] ; OZAWA, Kazuhito[1]

[1]Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo

Introduction

The relationships between arc magmatism and thermal and chemical structures of subduction zones have been investigated in two dimensions (e.g., Spiegelman & McKenzie, 1987; Tatsumi, 1989). However the necessity of a three-dimensional point of view is indicated in Northeast Japan (Tamura et al., 2002; Ueki & Iwamori, 2007) and 3-D numerical simulations (Honda, 2011). Processes involved in the initiation of 3-D structures in actual subduction have not been well studied because of the fragmental nature of geological records during subduction initiation (Umino & Ishizuka, 2010 etc.).

In the Miocene Southwest Japan, temporarily (12˜18Ma) and spatially (˜900km) wide spread magmatism occurred during the initiation of subduction (Sumii, 2000; Tatsumi et al., 2001, etc.). The migration of magmatism has been discussed with 2-D model (Kimura et al., 2005). Clustering of volcanic rocks spacing of ˜50km and elongating crossing the arc (west Shikoku, east Shikoku, and Kii Peninsula) and corresponding crustal structures strongly suggests 3-D mantle dynamics must be invoked. We tried to decipher 3-D heat and material transportation in the mantle by estimating spatial and temporal change of magma generating conditions of the Setouchi Volcanic Belt.

In the Setouchi Volcanic Belt, magma generating condition has been estimated from multiple-saturation experiments on andesitic lavas (Tatsumi & Ishizaka, 1982, etc.), geochemical characteristics (Shimoda et al., 1998, etc.), and modeling thermal structure (Furukawa & Tatsumi, 1999). The primitive andesitic magmas with more than 4 wt% H_2O was inferred to have been generated through reaction between wedge mantle and slab-derived melt (Tatsumi et al., 2006). We try to put proper constraints on melting conditions of mantle with least assumptions by exploiting useful information from volcanic rocks.

We focus on the eastern Shikoku cluster. We analyzed whole-rock compositions of andesites by using XRF and LA-ICP-MS in the central area (Kanayama, Kiyama, and Goshikidai area) and western margin (Shichiho-san area). We also used literature data from eastern margin (Shodo-shima area: Tatsumi et al., 2006).

Result and Discussion

In the central area, the variation of major element composition can be explained by fractional crystallization of a parental magma containing up to 2wt% H_2O (alphaMELTS) and magma mixing between the daughter magmas. Extensive degassing is not required if the water content (0.48˜1.7 wt%:Henmi et al., 1976) and a small amount of vesicles in the lavas are taken into consideration. We constrain a range of primary melt compositions from the most magnesian zone in oscillatory zoning of orthopyroxenes. The primitive magma was estimated to be SiO_2=56.8˜57.1 wt%, MgO=13.2˜11.7 wt%, and H_2O=0.9˜1.5 wt%. Such melt can be in equilibrium with harzburgitic mantle at ˜30km in depth (alphaMELS) and 1240˜1200 degrees Celsius (Sugawara, 2000; Medard & Grove, 2008).

The variations of HFSEs and HREEs against SiO_2 as a differentiation proxy, indicate later andesites in the central area were derived from more fertile material, although common sub-arc mantle was melted in three areas in the initial stage. The abundance of LILEs indicates the source materials of the central area and the eastern margin were significantly affected by slab-derived fluid in the later stage. The potential temperature and the initial depth of melting are estimated to be 1300˜1250 degrees Celsius and ˜75km respectively by assuming melting of a fertile lherzolite with 25% melting degree.

We proposed a model that the clustering of magmatism formed by upwelling of forced convection induced by subduction initiation. The temporal change of the source material is attributed to upwelling of deeper part of the mantle and involvement of slab components by deeper penetration of the slab. 3-D thermal structures in the steady-state subduction may be inherited from to dynamics of subduction initiation.

Keywords: Subduction initiation, Primary magma, Southwest Japan, Setouchi Volcanic Belt, Mantle dynamics

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SCG60-03 Room:201A Time:May 25 11:30-11:45

Development of a 3D thermal structure in the subduction zone due to a low viscosity layer at the plate interface

MORISHIGE, Manabu[1*]

[1]IGS, Kyoto University

It is essential to understand the detailed 3D thermal structure in the subduction zone to better constrain the transport of fluid and melt there. In this presentation, I will propose a simple and new mechanism to produce the along-arc variation in the thermal structure. In the northeast Japan, the earthquakes at the plate interface may occur down to 50 km depth. On the other hand, the slab and mantle may need to decouple down to 80 km depth in this region to explain the observed low surface heatflow in the forearc. These observations may show that the slab and mantle are decoupled by non-brittle deformation from 50 down to 80 km depth. Based on this idea, I set a thin low viscosity layer (LVL) just above the subducting slab within the depth range.

3D finite element models are used to investigate the effects of LVL on the thermal structure. The model domain is divided into four parts: the crust, a small portion of the mantle wedge tip which is rigid, the viscous mantle wedge, and the subducting slab. The model is exactly the same in the along-arc direction. The flow is computed only in the viscous mantle wedge, whereas temperature is computed for the whole model domain. When the viscosity in LVL is relatively high, the slab and mantle are effectively decoupled but there is no along-arc variation in the flow and thermal structure. I find, however, that when the viscosity in LVL is sufficiently low the corner flow starts to show 3D features and it leads to the along-arc temperature variation. It is well known that the distribution of Quaternary volcanoes in the northeast Japan forms clusters whose characteristic wavelength is around 80 km. The model proposed here successfully explains the observed wavelength based on an assumption which is simpler and better constrained by observations compared to previous models.

A previous study has proposed that slab and mantle are decoupled down to a common depth (70-80 km) for most subduction zones. It means that the LVL considered in this study could exist for other subduction zones as well. Therefore, the new model proposed here can be applied to a wide range of regions.

Keywords: subduction zone, plate interface, low viscosity layer, distribution of volcanoes, slab-mantle coupling

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SCG60-04 Room:201A Time:May 25 11:45-12:00

S-wave ray path analysis constrains the distribution and dynamics of the hydrated mantle wedge

NAGAYA, Takayoshi[1*] ; WALLIS, Simon[1] ; WALKER, Andrew[3] ; WOOKEY, James[2] ; KENDALL, Michael[2]

[1]Department of Earth and Planetary Sciences, Nagoya University, [2]School of Earth Sciences, University of Bristol, [3]School of Earth 9 and Environment, University of Leeds

Subduction fluids including H_2O are a key component of understanding the dynamics in convergent plate margins and recycling of materials from the Earth's surface into the deep interior. H_2O-rich fluids in the wedge mantle are dominantly derived from antigorite, dragged down by plate motion. Antigorite is generally thought to be distributed in the relatively warmer subduction zones where the dehydration of the subducting slab is predicted to occur. Seismic observations are commonly used to identify the location and proportion of antigorite-rich domains (low seismic velocities Vp = ~ 6.5 — 6.7 km/s, Vs = ~ 3.4 — 3.7 km/s and high Vp/Vs = ~ 1.8 — 1.9 for single antigorite crystals).

However, antigorite has a very strong seismic anisotropy (Δ Vp $\leq$ 46 % and Δ Vs $\leq$ 66 %), meaning that seismic velocities and the Vp/Vs ratio can show very large variations (Vp = 5.6 — 8.9 km/s, Vs = 2.5 — 5.1 km/s and Vp/Vs = 1.2 — 3.4) depending on the propagation path of the seismic wave. This means the analyses based on the observation of average seismic velocities cannot necessarily distinguish antigorite nearing rocks from dry olivine-rich mantle. The distribution and proportion of antigorite and hence water has thus far been impossible to determine.

In this study we calculated the shear wave splitting caused within the wedge mantle using the geometry of seismic ray paths observed in Ryukyu arc where trench-parallel S-wave anisotropy with large delay times (~ 1 s) has been observed. To match the shear wave splitting observations of both ray that arrived from forearc side and backarc side to the seismic stations, we find the alignment of antigorite must change from parallel to the subducting slab in the deepest part of the wedge to vertically aligned at intermediate depths in the wedge mantle and the proportion of these antigorite must be more than 65 %.

This type of analysis that takes into account ray paths geometry and the seismic anisotropy of deformed antigorite-bearing mantle can constrain the distribution, amount and orientation of antigorite.

The change in orientation of antigorite in Ryukyu arc suggests the presence of convective flow in the hydrated forearc mantle associated with a bulk long-term viscosity of less than 10^{19} Pa s.

The analysis of the shear wave splitting observations in other subduction zones shows that large delay times with trench parallel fast Vs within the wedge mantle, similar to the Ryukyu example, have been observed from even cold subduction zones (e.g Izu-Bonin and Tonga-Kermadec subduction zones) regardless of the age of the slab. This results implies the large-scale serpentinization and hydrous mantle flow associated with the dehydration of the slab are likely to be more widespread than generally recognized and the widespread view that the forearc mantle of cold subduction zones is dry, needs to be reassessed.

However, subduction zones with small delay times in the wedge mantle are also reported irrespective of the thermal structure in the wedge. The lack of a strong shear wave splitting in some subduction zones and the thermal structure in the subduction zones may be related to the tectonic erosion of hydrous material from the base of the mantle wedge. An additional factor may be subduction angle. Subduction zones with large splitting times show relatively steep slab dips (~ 40 — 60 ^{o}) (Ryukyu, Aleutians, Izu-Bonin and Tonga-Kermadec subduction zones) and no subduction zones with shallow slab dips are associated with large shear wave splitting. Steep subduction zone may be an important geometry requirement for convection cells to develop in the wedge mantle with both slab-parallel and sub-vertical foliation domains.

Keywords: Shear waves splitting, Antigorite, Hydrated mantle wedge, Seismic anisotropy, Seismic ray path, Mantle convection

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SCG60-05 Room:201A Time:May 25 12:00-12:15

The mantle anisotropy obtained from shear-wave splitting in the region of 1891 Nobi earthquake

IIDAKA, Takashi[1*] ; HIRAMATSU, Yoshihiro[2] ;
THE RESEARCH GROUP FOR THE JOINT SEISMIC, Observations at the nobi area[1]

[1]Earthquake. Res. Inst., University of Tokyo, [2]Kanazawa University

The Nobi earthquake which occurred in 1891 was one of the largest inland earthquakes in Japan. The magnitude of the 1891 Nobi earthquake was 8. The magnitude is much larger than those of other inland earthquakes in Japan. To know the cause of Nobi earthquake and crustal structure of the area, a temporary seismic observation was conducted. The seismic structure of the crust and uppermost mantle around the 1891 Nobi earthquake area is very important. We researched shear-wave splitting analysis to obtain seismic image around the 1891 Nobi earthquake area including uppermost mantle structure. The earthquakes which occurred from 2009 to 2014 are used. All of the earthquakes used here are deep earthquakes with depths are deeper than 200 km. The seismic stations of Hi-net and temporary seismic network were used for the shear-wave splitting analysis.

Shear-wave splitting is usually expressed by two parameters, the fast polarization azimuth ϕ (in degrees), and the time-lag τ (in seconds), which is the delay time between the fast and slow components of a shear wave. We use the following techniques to determine the shear-wave splitting. We pick S waves from individual seismograms. We calculated the cross-correlation of the two horizontal seismogram components over a grid -90^o to +90^o for ϕ and a window of 4 sec for τ with increments of 1^o and 0.01 sec., respectively. The time-lag τ (in seconds) and the fast polarization azimuth ϕ (in degree) are defined to be the values that yielded the maximum correlation.

The results suggested very interesting and remarkable pattern of the polarization directions. The northeastern part of the research area showed polarization direction of NE-SW. The eastern part of the research area suggested that the polarization directions are almost E-W. However, the polarization direction at the 1891 Nobi earthquake area was NW-SE. Most of the averaged time lag values are larger than 0.5 sec. The value is much larger than that of the maximum time-lag value cause by crustal anisotropy in this area (Hiramatsu et al. submitted to EPS). The maximum crustal anisotropy was considered to be less than 0.1 sec. We consider that the observed shear-wave splitting was caused by the mantle anisotropy. The shear-wave splitting of the mantle anisotropy was studied by previous studies. The polarization direction with E-W at the eastern part of the research and the polarization direction with NE-SW are consistent with the results of previous studies (e.g., Ando et al. 1983, Iidaka et al., 2009). The polarization direction can be explained by the preferred orientation cause by the mantle flow relating to the subducting Pacific and Philippine Sea plates. However, the polarization direction with NW-SE is not consistent with both of the subduction directions of oceanic plates. The cause of anisotropy is considered based on the two models. One is the model that the shear-wave splitting is caused by the heterogeneous structure which is related to the fluid or magma in the mantle wedge. The other model is that the shear-wave splitting is cause by some irregular mantle flow. The cause of the polarization direction will be discussed based on other observations.

Keywords: mantle, Splitting, Nobi earthquake

SCG60-06 Room:201A Time:May 25 12:15-12:30

Reconsideration of serpentinite in the shallow wedge mantle -Importance of brucite-

KAWAHARA, Hirokazu[1*] ; ENDO, Shunsuke[2] ; WALLIS, Simon[1] ; NAGAYA, Takayoshi[1] ; MORI, Hiroshi[2] ; YAMAMOTO, Koshi[1] ; ASAHARA, Yoshihiro[1]

[1]Earth & Planetary Sciences, Nagoya University, [2]National Institution of Advanced Industrial Science and Technology (AIST)

The flux of H_2O rich fluid is an important aspect of geological processes operating in the shallow wedge mantle. In the dunite-H_2O system, two of the most important hydration-dehydration reactions are as follows:

antigorite (Atg) = olivine (Ol) + orthopyroxene (Opx) + H_2O (1)

Atg + brucite (Brc) = Ol + H_2O (2)

Natural examples of the breakdown dehydration of Atg (reaction 1) have been closely studied (e.g. Padron-Navarta et al., 2011). However, there are relatively few well-documented studies describing the dehydration associated with reaction between Atg and Brc (reaction 2). Formation and breakdown of Brc (reaction 2) is potentially important when considering the H_2O flux in the shallow wedge mantle. It is also important to note that the product of Ol reacting with an SiO_2-bearing H_2O fluid is Atg and Brc is not formed. This can be expressed by the following reaction:

Ol + SiO_2 aq + H_2O = Atg (3)

This means that presence of Brc has the potential to be used as an indicator of the former action of an SiO_2-rich fluid. Brc is much weaker than Ol or Atg and its presence in sufficient quantities may have an important influence on the physical properties of the wedge mantle, for example development of shear zones. It is important therefore to obtain more information about the abundance and microstructure of Brc in serpentinite when considering a wide range of physical processes occurring in the shallow wedge mantle. However, Brc is not generally considered an important component of the shallow wedge mantle in previous studies.

Numerous ultramafic bodies that originated in the wedge mantle are distributed throughout the high-pressure/temperature subduction-type Sanbagawa metamorphic belt (Aoya et al., 2013). Here, we focus on the Shiraga (SG) body, which is a kilometer-scale ultramafic body located in the low-grade metamorphic region (corresponding to depths of about 30km). The SG body is a metaserpentinite, which originated as dunite. The body underwent metamorphism after serpentinization and metamorphic Ol (m-Ol) formed by reaction 2 is widely present (Kunugiza, 1980). This study shows that Brc was once widely distributed in the SG body. The major exception is the eastern margin of the body where a 100m thick serpentinite zone containing only Atg is found. Microstructural observations and compositional mapping show that Brc can be divided into two distinct types. Brc Ⅰ existed before peak metamorphism (within the Ol + Atg or Ol + Brc stability field), and Brc Ⅱ formed during the retrograde metamorphism. Brc Ⅰ occurs as inclusion in m-Ol and veins composed of coarse grains. Brc Ⅰ is separated from Atg by m-Ol. Brc Ⅱ occurs as veins and is in direct contact with Atg. Brc Ⅰ locally shows a clear zonal structure with a brown core containing significant amounts of magnetite (Mgt) exsolution lamellae surrounded by a colorless rim. Estimations of the initial composition of Brc before exsolution yield Mg# (= Mg / (Mg + Fe)) of Brc Ⅰ that increase from core to rim. In contrast, Mg# of Brc Ⅱ decreases from core to rim. m-Ol also shows a zonal structure with increasing Mg# from the core to the rim. In an Fe-bearing system, reaction 2 is a continuous reaction, which shows that the observed compositional changes of Brc Ⅰ and m-Ol are formed during the rising temperature period and those of Brc Ⅱ are formed in descending temperature period. Representative pseudosections of metaserpentinite in an Fe-bearing system were constructed to estimate the amount of Brc before peak metamorphic condition. The results suggest that the original rock contained about 20 vol% assuming weak Si metasomatism. If such large amounts of Brc are present in the shallow wedge mantle, they would significantly influence the physical property of the wedge mantle.

References: Aoya, M. et al. (2013) Geology, 41, 451-454; Kunugiza, K. (1980) J. Jpn. Assoc. Min. Petrol. Econ. Geol, 75, 14-20; Padron-Navarta, J. A. et al. (2011) J. Petrol, 52, 2047-2078.

Keywords: brucite, antigorite, wedge mantle, serpentinite, subduction zone

SCG60-07 Room:201A Time:May 25 12:30-12:45

Brittle-ductile transition of serpentinites in subduction zones: Roles of pore fluid pressure

SHIMIZU, Ichiko[1*]

[1]Faculty of Earth and Planetary Science, University of Tokyo

Geophysical observations suggest that the mantle wedge and subducting slabs and partly serpentinized. Low-velocity and high-Vp/Vs anomaly zones were identified along the subducting plate boundary in SW Japan, where slow earthquakes and deep tremors occur, whereas no such velocity anomaly zones have been observed in the source region of the 2011 Tohoku-oki earthquake (M9) in the NE Japan subduction zone (Shimizu, 2014). These facts indicate that seismogenic processes on the plate interfaces are greatly influenced by the presence or absence of serpentinites and overpressurized fluids. Relationships between intermediate-depth earthquakes and dehydration of serpentinites have been discussed based on high-PT deformation experiments and the studies of thermal structures in subduction zones. Several different mechanisms have been proposed for mechanical instability in double seismic zones in subducting slabs triggered by dehydration reaction. In this talk, I briefly review the rheological and frictional properties of serpentinites at high-PT conditions and show some experimental results of ourselves, and then discuss the influence of pore fluid pressure on brittle-ductile transition of serpentinites and seismogenic processes in subduction zones.

Reference

Shimizu, I., 2014, Rheological profile across the NE Japan interplate megathrust in the source region of the 2011 Mw9.0 Tohoku-oki earthquake, Earth, Planets and Space, 66:73, doi:10.1186/1880-5981-66-73
(http://www.earth-planets-space.com/content/66/1/73)

Acknowledgement: I would like to thank K. Michibayashi, Y. Watanabe, M. Takahashi, S. Uehara, M. Nakanani, N. Katsuta, and T. Murakami for their collaboration in experimental works of antigorite-serpentinites.

Keywords: serpentine, pore pressure, rheology, brittle-ductile transition, seismogenic zone, high-PT deformation experiment

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SCG60-08 Room:201A Time:May 25 14:15-14:30

Streak process due to irregular slab topography and the classification of subduction zones

EGUCHI, Takao[1*]

[1]Dept. Earth and Ocean Sci., N.D.A.

We demonstrate some physical features of streak (or abrasion) process associated with the surface convex topography of downgoing oceanic slab at subduction zones.

Then, we reconsider more realistic classification model of subduction zones, based on not only the streak process due to the irregular slab topography and/or with the degree of accreting process at the leading edge of the overriding lithosphere, but also the other tectonics parameters such as slab age etc.

Keywords: streak, subduction zone, oceanic slab, convex topography

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SCG60-09 Room:201A Time:May 25 14:30-14:45

Split of the Philippine Sea plate and non-volcanic seismic swarm in Wakayama district, SW Japan

KATO, Aitaro[1*] ; IWASAKI, Takaya[2]

[1]Graduate School of Environmental Studies, Nagoya University, [2]Eathquake Research Institute, the University of Tokyo

To understand the driving force of an intensive non-volcanic seismic swarm in Wakayama district of the Kii Peninsula, Japan, we used a series of dense seismic linear arrays to measure fine-scale variations of seismic structures beneath the seismic swarm area. Kato et al. (2014, EPS) revealed that a low-velocity anomaly confined to just beneath the seismic swarm area is clearly imaged, which correlates spatially with an uplifted surface area and a highly conductive and strong attenuative body, implying the presence of fluids therein. In addition, they suggested that dehydration conversion from oceanic basalt to eclogite within the subducting Philippine Sea Plate takes place at depths greater than 50 km. Fluids released from the subducting oceanic crust could cause serpentinization of the mantle wedge.

In 2013, we conducted a new seismic experiment (deployment of 40 portable seismic stations) to investigate the structure between Wakayama district and Awaji Island at the western extension of the seismic swarm area, where the Philippine Sea Plate has been proposed to split (Ide et al., 2010). From a new receiver function image with high spatial resolution, we found that the dehydrated oceanic crust (high-velocity without intra-slab seismicity) steeply gets to be shallow toward offshore from Wakayama district and close to the bottom of the overlying crust beneath Awaji Island. Interestingly, we found out a split or gap of the oceanic crust beneath the center of Awaji Island. However, the gap width appears to be significantly smaller than one proposed by Ide et al. (2010). Due to this split of the oceanic crust, hot mantle is easily leaking into the mantle wedge beneath Wakayama district, resulting to warm thermal condition. These anomalous structures of the oceanic crust and mantle wedge may locally promotes dehydration reactions of the subducting oceanic crust, leading to local increase in fluid flux to the shallow seismic swarm area.

SCG60-10 Room:201A Time:May 25 14:45-15:00

Insight into earthquake generation from evolution of pore fluid pressures in a stimulated geothermal reservoir

TERAKAWA, Toshiko[1*] ; DEICHMANN, Nicholas[2]

[1]Graduate School of Environmental Studies, Nagoya University, [2]ETH Zurich

We developed an inversion method to estimate the evolution of pore fluid pressure fields from earthquake focal mechanism solutions. The basic assumption in this approach is that seismic slip occurs in the direction of the resolved shear traction acting on pre-existing faults, controlled by the Coulomb failure criterion with a constant friction coefficient. Application of the method to induced seismicity in the Basel enhanced geothermal system (EGS) in Switzerland shows the evolution of pore fluid pressure in response to fluid injection experiments. For a few days following the initiation of the fluid injection, overpressurized fluids were concentrated around the injection well and then anisotropically propagated within the reservoir until the well was shut in and bled off. At four representative locations the pore fluid pressure increased together with the wellhead pressure for the first 3?5 days, and reached a ceiling by the time of shutting in. The peak pressure in the reservoir was less than the minimum principal stress at each depth, indicating that hydraulic fracturing did not occur during the stimulation. This suggests that seismic events may play an important role in promoting the development of permeable channels, particularly southeast of the borehole where the largest seismic event (Mw 2.95) occurred. The induced events were primarily controlled by a decrease in fault strength due to an increase in pore fluid pressures. However, the largest event (the mainshock) was not directly related to a drastic decrease in fault strength at the hypocenter. The precise relative location of the hypocenters indicated that substantial stress loading by the preshocks on the same fault plane promoted the dynamic rupture of the mainshock.

Keywords: pore fluid pressure, stress, earthquake, focal mechanism, inversion theory, fluid injection

SCG60-11 Room:201A Time:May 25 15:00-15:15

Characteristics of slab-derived fluids beneath Kii Peninsula inferred from seismic travel-time tomography

SHIBUTANI, Takuo[1*] ; HIRAHARA, Kazuro[2]

[1]DPRI, Kyoto Univ, [2]Science, Kyoto Univ

1. Introduction

Deep low frequency events (DLFEs) are distributed at the depths of 30 - 40 km near the subducting Philippine Sea plate widely from western Shikoku to central Tokai (Obara, 2002). Hot springs with high ^{3}He/^{4}He ratios are found in an area between central Kinki and Kii Peninsula despite in the forearc region (Sano and Wakita, 1985). Arima-type deep thermal water with CO_2 and high salt contents is found at hot springs in the area. These phenomena suggest the process that H_2O subducting with the oceanic crust dehydrates at the depths of 30 - 40 km, causes the DLFEs, and uprises to shallower depths.

2. Receiver function analyses

We carried out seismic observations in Kii Peninsula since 2004 in order to estimate the structure of the Philippine Sea plate and the surrounding area. We deployed seismometers along profile lines with an average spacing of ~5 km. We applied receiver function analyses and obtained images of S wave velocity discontinuities. We estimated 3D configurations of the continental Moho, the slab top and the oceanic Moho from receiver function images for four profile lines in the NNW-SSE direction which is the dip direction of the Philippine Sea plate and for two profile lines in the NNW-SSE direction that is almost perpendicular to the dip direction.

3. Seismic travel time tomography

We carried out the tomography with FMTOMO (Rawlinson et al., 2006) in which a robust wavefront tracking (de Kool et al., 2006) is implemented for the theoretical travel time calculation and the ray tracing. We used a velocity model with 3D geometries of the three discontinuities derived from the receiver function analysis. We also used observed travel times at temporary stations in the dense linear arrays in addition to permanent stations. A dense distribution of the temporary stations contributed to higher resolutions of tomographic images.

A result of the seismic tomography is shown in Figure 1. The generating area of the DLFEs (red circles) shows low velocity anomaly of ~5 %. As mentioned above, H_2O is discharged from hydrous minerals in the oceanic crust at the depths of 30 - 40 km. This can cause the low velocity anomaly.

Another strong low velocity anomaly more than 10 % is widely distributed in the lower crust beneath northern Wakayama Prefecture (N34.0 - 34.5^o). It is known that seismic activity is very high in the upper crust above this low velocity anomaly. This can be explained by a mechanism that fluids upwelling from the low velocity anomaly in the lower crust increase the pore pressure in existing cracks in the brittle upper crust.

The Vp/Vs ratio of the low velocity anomaly in the lower crust beneath northern Wakayama Prefecture has small values near 1.6. Contrastingly the Vp/Vs ratio of the low velocity anomaly in and around DLFEs shows larger values 1.75 - 1.8. This difference in the Vp/Vs ratios of the two low velocity anomalies can be explained by the difference in the aspect ratios of the pores filled with the fluids. And/or the small Vp/Vs ratio in the lower crust beneath northern Wakayama Prefecture might be due to silica-saturated fluids (Manning, 1996).

We used waveform data from permanent stations of NIED; JMA; ERI, Univ. of Tokyo; Nagoya Univ. and DPRI, Kyoto Univ.

Keywords: tomography, receiver function, Philippine Sea slab, Kii Peninsula, slab-derived fluids, Nankai Trough megaquake

SCG60-11 Room:201A Time:May 25 15:00-15:15

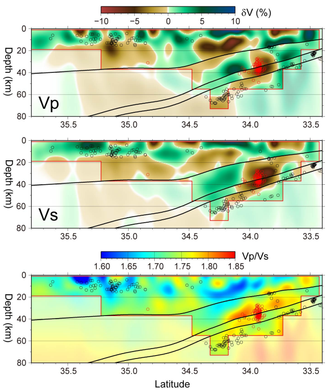

Figure 1 Resulting heterogeneous velocity field in the north-south cross-section along E135.7° for P wave velocity (Vp, uppermost), S wave velocity (Vs, middle) and Vp/Vs ratio (lowermost). The red and black circles are deep low frequency events and ordinary earthquakes, respectively. The three thick black lines are the continental Moho, the slab top and the oceanic Moho from shallow to deep.

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SCG60-12 Room:201A Time:May 25 15:15-15:30

Coseismic fluid-rock interactions in subduction-zone faults: Constraints from geochemical analyses of fault rocks

ISHIKAWA, Tsuyoshi[1*]

[1]JAMSTEC Kochi

In this paper, we report recent progress on geochemical method for evaluating coseismic fluid-rock interactions in subduction-zone fault zones on the basis of trace element and isotope analyses. Compositions of slip-zone rocks from the Taiwan Chelungpu fault and the Boso accretionary complex showed distinct decreases of Li, Rb and Cs and an increase of Sr, indicating coseismic fluid-rock interaction at high temperatures of >350 deg. C (Ishikawa et al., 2008; Hamada et al., 2011). In the Shimanto accretionary complex at the Kure area, the slip-zone rocks exhibited trace element characteristics consistent with coseismic high-temperature fluid-rock interactions followed by frictional melting to form pseudotachylite (Honda et al., 2011). Such geochemical anomaly induced by coseismic hydrothermal processes can be reproduced by high-velocity friction experiments at wet condition (Tanikawa et al., submitted).

Geochemical evaluation of coseismic fluid-rock interactions in fault zones is useful means not only to understand the slip mechanism (e.g. thermal pressurization) but also to constrain compositions of the fluids in the fault zones. Trace element and isotope characteristics of slip-zone rocks from the Midian Tectonic Line in Japan (Ishikawa et al., 2014) and from the Kodiak accretionary complex (Yamaguchi et al., 2014) both requires interactions with high-Li fluids, which implies that coseismic hydrothermal processes took place in the presence of fluids that had migrated from the depth.

Keywords: fluid-rock interactions, fault rocks, earthquake, geochemistry, subduction zones

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SCG60-13 Room:201A Time:May 25 15:30-15:45

Effect of swelling cray minerals on permeability and occurrence condition of abnormal pore pressure

KAKU, Nahomi[1*] ; KATAYAMA, Ikuo[1]

[1]Department of Earth and Planetary Systems Science, Hiroshima University

The March 11, 2011, devastating Tohoku-Pacific Ocean Earthquake had its epicenter at the Sanriku coast as the Hokuriku plate tip had slipped significantly. However, it raises question on the traditional theory that plate tip never slips on a large scale. Geological survey in this area brings out the fact that, smectite, one of the swelling clay minerals, is present in 78% of the fault samples. Hence, smectite seems to be controlling the generation of the earthquake. In this study, it is hypothesized that swollen clay minerals reduced the permeability and caused the abnormal pore pressure. By measuring permeability of clay minerals, this hypothesis is validated and discussed about the earthquakes that occur in the plate boundary.

Permeability is measured using water and nitorogen gas as pore fluid by the constant differential pressure flow method. The method helps to determine the permeability based on the flow rate through the downstream in a state of constant pore pressure difference applied across the sample. The vessel deformation permeability testing machine is used in case of gas, whereas the syringe pump is used in case of water as pore fluid. During the experiment the confining pressure is controlled up to 10MPa, while pore pressure up to 5MPa. Two types of clay minerals i.e. illite, and montmorillonite are used as sample. At the beginning gas is used as the pore fluid, and then measured using water and compared for results.

Measurement results indicate that permeability of water is lower than the value measured using gas as pore fluid. Moreover, the decrease is 1.5 orders of magnitude in illite, while about 4.4 orders of magnitude in montmorillonite.

The reduction in permeability from gas to the water is due to water absorption and swelling of clay minerals. It decreases the gap between the clay particles reducing the flow paths. Montmorillonite has large decrease in permeability, leading to larger control of water effect. It is considered that a local presence of smectite will reduce the permeability in the underground. In addition, this result is applied to the abnormal pore pressure producing conditions. In case of illite, abnormal pore pressure does not occur to meet the condition. On the other hand, in case of montmorillonite the results satisfied the required condition, and there is a high possibility that abnormal pore pressure occurs when present locally in the subduction zone.

SCG60-14 Room:201A Time:May 25 15:45-16:00

Fracture sealing and permeability change induced by silica dissolution and precipitation

OKAMOTO, Atsushi[1*] ; YAMADA, Ryo[1] ; TANAKA, Hiroto[1] ; SAISHU, Hanae[2] ; TSUCHIYA, Noriyoshi[1]

[1]Tohoku University, [2]National Institute of Advanced Industrial Science and Technology

Solubility of silica significantly varies with depth within the crust; therefore, dissolution and precipitation of silica minerals control the hydrological properties of the crust (Saishu et al., 2014), and may affect earthquake cycles (Audet and Burgmann, 2014). However, permeability is usually measured as a static property of a rock, and it is unclear how porosity structure of a fracture and permeability changes during dissolution or precipitation of minerals (i.e., silica); especially the effects of saturation index and effective confining pressure. In this study we conducted two-types of the hydrothermal experiments; (1) silica precipitation in porous media and (2) dissolution of granite with a fracture. For both experiments, we used novel flow-through reactors with tube-in-tube vessel, which make possible, after the experiments, to analyze porosity structure by micro X-ray CT (revolution is 10 micron/boxel).

The silica precipitation experiments were conducted under the supercritical (420 degreeC, 30 MPa) and vapor conditions (380 degreeC, 20 MPa). The inner tube of the precipitation vessel (4 mm diameter, ~200 mm long) was filled with alumina balls (1 mm diameter). The input solution was made by dissolution of granite + quartz sands under liquid conditions, and thus, high supersaturated solutions were brought into the precipitation vessel. In both conditions, nucleation of silica minerals occurred but showed the contrasting porosity patterns. In the supercritical condition, amorphous silica was surrounded the surfaces of alumina balls and walls, and discrete quartz grains and cristobalite formed within the amorphous silica. In contrast, in the vapor condition, fine-grained quartz crystals were nucleated, and settled on the bottom. As the results, the developed porosity in the supercritical fluids was more tortuous that in the vapor. At the end of the experiments under the supercritical condition, the oscillation of upstream fluid pressure (and thus permeability) was observed; such an oscillation was probably caused by repeated sealing and break of the bottleneck of the pore network.

In the granite dissolution experiments, the granite core (Aji granite, 8 mm diameter, 45 mm long) with a tensile fracture was input into the inner SUS jacket with 0.1 mm thick. The P-T condition for the dissolution was 350 degreeC and 25 MPa, under the effective confining pressure of 0 ? 15 MPa. The X-ray CT images revealed that (1) quartz was preferentially dissolved to form the convex surfaces, whereas that (2) mean fracture aperture decreased with time. The decrease in the mean aperture was consistent with the decrease in permeability from 10^{-13} to 10-15 m^2 during experiments. According to the solution chemistries, feldspars (Pl + Kfs) dissolution also occurred, which volume was about one-third of that of quartz. The dissolution of feldspars at the contact regions (pressure solution) is critical for the permeability decrease in the granite fracture under confining pressure.

References
Saishu, H., Okamoto, A., Tsuchiya, N., 2014. Terra Nova, 26, 253-259.
Audet, P., Burgmann, R., 2014. Nature, 510, 389.

Keywords: silica, granite, dissolution/precipitation, porosity structure, X-ray CT, permeability

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SCG60-15 Room:201A Time:May 25 16:15-16:30

Experimental study on the hydration rate of peridotites at forearc mantle wedge conditions

NAKATANI, Takayuki[1*] ; NAKAMURA, Michihiko[1]

[1]Graduate School of Science, TOHOKU Univ.

Recent ground water studies in southwestern Japan suggest that slab-derived fluid upwells through the forearc mantle wedge without significant reaction with the country rocks (e.g., Kazahaya et al. 2014; Kusuda et al., 2014), which may provide a clue to understanding the hydrological budget in forearc regions. The rate of serpentinization is one of the primary parameter for constraining the flow regime of slab-derived fluid in the stagnant forearc mantle wedge. Hydration experiments for kinetic studies have been vigorously conducted previously at relatively low P-T conditions (up to ca. 350 ℃ and 0.3 GPa), in which olivine reacts with water to form the low T serpentine variety lizardite (or chrysotile) and brucite. However, antigorite is expected to be the dominant serpentine variety under the higher P-T condition corresponding to the forearc mantle wedge (350 to 650 ℃ and 1.0 to 2.0 GPa). Moreover, serpentine formation needs a silica source in addition to olivine (e.g., orthopyroxne) at the temperature above 450 to 500 ℃ due to the instability of phase assemblage serpentine + brucite.

In order to constrain the serpentinization rates of peridotite under the mantle wedge conditions, we conducted piston-cylinder experiments at temperature of 400 ℃ (brucite-present condition) and 500 to 580 ℃ (brucite-absent condition), and pressure of 1.3 and 1.8 GPa. Three types of starting materials were prepared from the crushed powder of a San Carlos lherzolite xenolith: 1) olivine (Ol), 2) orthopyroxene (Opx) + clinopyroxene (Cpx) and 3) Ol + Opx. Hereafter these systems are abbreviated as OL, OPX+CPX and OL+OPX respectively. The starting materials were reacted with 15 wt% distilled water for 4 to 19 days. The hydration reaction proceeded in all the experiments, except for the OL system under the brucite-absent conditions. Based on Raman spectroscopy results and crystal shapes, the synthesized serpentine minerals were identified as lizardite in most of the runs except for antigorite in the OL+OPX system at 1.8 GPa. The Al_2O_3 in the system possibly stabilized the aluminous lizardite (Caruso and Chernosky, 1979). In the OL+OPX system, the reaction progress followed a diffusion-controlled rate law in the brucite-present condition and an interface-controlled rate law in the brucite-absent conditions. The rate constants were estimated to be 1.5×10^{-16} m^2/s and 8.7×10^{-12} to 1.5×10^{-11} m/s in the brucite-present and the brucite-absent condition, respectively.

We applied the experimentally-obtained hydration rates of peridotites to a reactive-transport model for the stagnant mantle wedge hydration. In the case of grain-scale pervasive flow, slab-derived fluid is completely fixed in the mantle wedge peridotite. Otherwise, aqueous fluid possibly penetrate all the way through the mantle wedge via crack-like pathways (we assumed the vertical distance of 10 km) with a spacing $>$0.025 to 0.80 m in the brucite-present conditions and $>$2.6 to 4600 m in the brucite-absent condition. This indicates that slab-derived fluid may upwell easily through a cold forearc mantle wedge like in Western Shikoku rather than a warm forearc mantle wedge like in Cascadia.

Keywords: forearc, mantle, fluid, serpentinite, antigorite, kinetics

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SCG60-16 Room:201A Time:May 25 16:30-16:45

Hydrothermal experiments on the metasomatic reactions at crust-mantle boundary.

OYANAGI, Ryosuke[1*] ; OKAMOTO, Atsushi[1] ; TSUCHIYA, Noriyoshi[1]

[1]Graduate School Of Environmental Studies, Tohuku University

Hydration and dehydration reactions play crucial roles on global circulation of H2O in the earth's interior and serpentinization (hydration of ultramafic rocks) is representative hydration process at slow-spreading ridge, bending faults and subduction zone. It is known that silica activity has a large impact on controlling the reaction path during serpentinization [e.g., 1 and 2]. At the crust?mantle boundary, a steeper silica activity gradient is expected, and a large mass transfer including silica would cause metasomatic zoning. However, detailed mechanism to produce metasomatic reactions and its relation to the mass transfer are still poorly understood.

In present study, hydrothermal experiments (250C, Psat) were carried out in two systems: the olivine (Ol)?quartz (Qtz)?H2O and Ol?plagioclase (Pl)?H2O system, as analogues of crust-mantle boundary. Especially, by using unique tube-in-tube type hydrothermal experiments vessel, spatio-temporal evolution for metasomatic reactions as a function of distance from Ol?Qtz or Ol?Pl boudaries were evaluated.

In the Ol?Qtz?H2O experiments, the mineralogy of the reaction products in the Ol-hosted region changed with increasing distance from the Ol?Qtz boundary, from smectite + serpentine (Smc zone) to serpentine + brucite + magnetite (Brc zone). Mass balance calculations revealed that olivine hydration occurred without any supply of silica in the Brc zone. In contrast, the Smc zone was formed by silica metasomatism via competitive hydration and dehydration reactions. In the Smc zone, smectite formed via the simultaneous progress of olivine hydration and serpentine dehydration, and around the boundary of the Smc and Brc zones, serpentine formation occurred by olivine hydration and brucite dehydration.

In the Ol?Pl?H2O experiments, the mineralogy of the reaction products in the Ol-hosted region changed with increasing distance from the Ol?Pl boundary, from chlorite + serpentine (Chl zone) to serpentine + brucite + magnetite (Brc zone). Olivine hydration proceeded in both zones, but the total H2O content in the products was greatest at the boundary than other part of the inner tube in the Ol?Pl?H2O experiments.

Our result indicates that in Ol?Qtz?H2O experiments, the competitive progress of serpentinization and silica metasomatic reactions would cause fluctuations in pore fluid pressure. However, in Ol?Pl?H2O experiments, fluid pressure was not raised. This metasomatic reaction possibly affects the mechanical strengths of the crust?mantle boundary.

References
[1] Frost, B. R., & Beard, J. S. (2007). Journal of Petrology, 48(7), 1351?1368.
[2] Ogasawara, Y., Okamoto, A., Hirano, N., & Tsuchiya, N. (2013). Geochimica et Cosmochimica Acta, 119, 212?230.

Keywords: Ultramafic rocks, Metasomatism, Serpentinization, Pore fluid pressure

SCG60-17 Room:201A Time:May 25 16:45-17:00

Hydrogen and oxygen isotope of glaucophane in lawsonite eclogites preserving pillow structure

MASUYAMA, Yuya[1] ; HAMABATA, Daichi[1] ; TOMIYASU, Fumiya[2] ; UENO, Yuichiro[2] ; OKAMOTO, Kazuaki[1*]

[1]Saitama University, [2]Tokyo Institute of Technology

In order to understand evolution of life, change of seawater chemistry from Hadean, Archean to present is significant. Pillow structure is well-preserved in the Archean greenstone belt (e.g. Komiya et al., 1999). Oxygen and hydrogen isotope of rims in the pillow is useful conventional tool to decipher chemistry of Paleao-seawater from Archean to Present. However, Archean greenstone belt suffered regional metamorphism from greenschist to Amphibolite facies condition. Therefore, it is necessary to testify the validity of pillow chemistry from recent (Phanerozoic) metamorphosed greenstone. We have systematically collected pillowed greenstone from blueschist and eclogites. Two eclogite exhibiting pillow structures were chosen for oxygen and hydrogen isotope analysis. One is from Corsica (lawsonite eclogite collected with Dr. Alberto Vidale Barbarone) and another is from Cazadero, Franciscan belt (collected by Dr. Tatsuki Tsujimori). The both are ascribed as MORB from major and trace bulk chemistry and Ca is rich in the core and Na is poor in the rims. The former exhibits garnet, omphacite, lawsonite, and glaucophane. Phengite is in core of the pillow and chlorite is in the rims. In the latter, besides garnet, omphacite, epdiote and glaucophane, chlorite is recognized with phengite in the core. Glaucophane is richer in the rims from the both samples, therefore istope analysis of glaucophane was done. Mineral separation was carefully done using micro-mill, heavy liquid and isodynamic separator. 20 mg specimens were used for oxygen isotope analysis and 2mg were for hydrogen analysis. $\delta^{18}O$ of the all analysis (7.7 to 8.3) is within the range of unaltered igneous oceanic crust and high temperature hydrothermal alteration although rims (8.3 for Franciscan and 8.0 for Corsica) are higher than cores (7.7 for Franciscan and Corsica). δD data is also consistent with hydrothermal alteration. It is relative higher in core from the Corsica and Franciscan (-45 and -56) than of the rims (-49 and -57, respectively), suggesting dehydration in deep subduction zone.

Keywords: lawsonite eclogite, pillow structure, glaucophane, oxygen isotope, hydrogen isotope, seawater chemistry

SCG60-18 Room:201A Time:May 25 17:00-17:15

Structure and physico-chemical properties of interfacial water on a quartz revealed by molecular dynamics simulation

ISHIKAWA, Satoru[1*] ; SAKUMA, Hiroshi[2] ; TSUCHIYA, Noriyoshi[1]

[1]Graduate School of Environmental Studies, Tohoku, [2]National Institute for Materials Science

Structure of water in thin film may have different characteristics compared with that of bulk water. Thin film water can be present at mineral grain boundaries or fractures, and its structure might be influenced by mineral surface. In this study, classical molecular dynamics (MD) simulations were performed to investigate the structure and physico-chemical characteristics of thin film water on a quartz surface.

The model of the quartz surface was characterized by the termination of silanol (Si-OH) group. Water molecules were confined between these surfaces, and we simulated several thicknesses of water in the slab geometry.

Density of water oscillates to be about 1 nm from the quartz surface at 298 K. This structure became less clear with heating, and almost disappeared above 473 K. The self-diffusion coefficients of the confined water were calculated from mean square displacements. These values were lower than that of bulk water indicating that the mobility of confined water is low between quartz surfaces.

These changes in the physical properties of interfacial water on quartz might affect such as slips in the fracture surface of the Earth's crust.

Keywords: interfacial water, quartz, molecular dynamics, self-diffusion coefficient

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SCG60-P01 Room:Convention Hall Time:May 25 18:15-19:30

Seismic attenuation in the Pacific slab beneath northeast Japan

SHIINA, Takahiro[1*] ; NAKAJIMA, Junichi[1]

[1]RCPEV, Grad. Sch. of Sci., Tohoku Univ.

Seismic activity and arc-magmatism in subduction zones are considered to relate to water carried with a subducting oceanic plate (e.g., Kirby et al., 1996; Nakajima et al., 2013). It is known that the existence of hydrous minerals, aqueous fluid, and melt contribute to reducing seismic velocity and increasing seismic attenuation. Therefore, investigations of seismic velocity and attenuation structures are important to constrain fluid distribution in subduction zones.

Seismic velocity structure in the Pacific slab beneath northeast (NE) has been investigated by a lot of studies, and characteristic structures, such as the low-velocity subducting crust down to a depth of ~100 km (e.g., Shiina et al., 2013) and a low-velocity zone along the lower plane of the double-seismic zone (e.g., Zhan et al., 2004), have been revealed. However, seismic attenuation structure in the Pacific slab is not estimated precisely, because conventional tomographic methods are difficult to resolve detailed seismic attenuation in the slab.

To investigate seismic attenuation in the Pacific slab, we calculated the spectral ratio of the direct P waves for a pair of intraslab earthquakes with similar ray paths from shallower earthquake to a common station. Then, we estimated attenuation between the two earthquakes by fitting the Brune's source model (Brune, 1970) and t^* value to the spectral ratio, assuming constant stress drops for all earthquakes. The t^* value estimated here represents a path-averaged attenuation between the two earthquakes.

The results obtained in this study are summarized as follows.

1) In the slab mantle, observed attenuation is higher in the fore arc than in the back arc.

2) Attenuation in the subducting crust is higher than that in the slab mantle.

3) Highly attenuated ray paths are obtained in the Pacific slab near the hypocenter of the 2003 off-shore Miyagi earthquake (M7.1).

These results imply spatial changes in compositions or fluid distributions in the Pacific slab, providing a crucial constraint for the understanding of the seismic properties of rocks in the Pacific slab.

Keywords: Seismic attenuation, spectral ratio, the Pacific slab, intra-slab earthquake

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SCG60-P02 Room:Convention Hall Time:May 25 18:15-19:30

3-D P-wave anisotropy tomography of the crust and upper mantle beneath Hokkaido

TORIMOTO, Tatsuya[1*] ; ZHAO, Dapeng[1] ; TOYOKUNI, Genti[1] ; KITAGAWA, Hiroki[1] ; FUJISAWA, Moeto[1]

[1]Department of Geophysics, Tohoku University

The velocity of seismic wave depends on the direction of wave propagation, which is called seismic anisotropy. Seismic anisotropy is induced mainly by the lattice-preferred orientation of anisotropic minerals in the mantle, especially olivine which exhibits strong anisotropy. Olivine can changes its type depending on temperature, pressure, and water content. Isotropic seismic tomography determines velocity anomalies in the crust and mantle, but it cannot directly provide us with information on mantle dynamics. Considering seismic anisotropy in tomography can provide such useful information. P-wave anisotropy tomography has been proposed, which can determine azimuthal and radial anisotropy (e.g., Wang and Zhao, 2013). In this work we focus on 3-D P-wave radial anisotropy.

We estimated 3-D P-wave velocity structure and P-wave anisotropy of the crust and upper mantle under Hokkaido using a large number of arrival-time data from local earthquakes recoded by the dense Kiban seismic network. We used P-wave arrival-time data selected from the JMA Unified Catalog and the data reprocessed by staffs of Research Center for Prediction of Earthquakes and Volcanic Eruptions of Tohoku University. Our study region is between 40N˜46N and 138E˜147E. To determine the velocity structure under the entire Hokkaido, our study region also includes northern Tohoku. We set up a 3-D grid and invert for isotropic velocity and radial anisotropy parameter at each grid node. We also compared our results with those of previous studies. One previous study is Wang and Zhao (2013) on P-wave tomography for 3-D azimuthal and radial anisotropy of Tohoku and Kyusyu subduction zones. The other study is Liu et al. (2013) on P-wave azimuthal-anisotropy tomography under Hokkaido.

In this study, we used 333 seismic stations. The followings are our criteria for the selection of local earthquakes. (1) Earthquake epicenters are located between 40N˜46N and 138E˜147E ; (2) The focal depths are $<$350 km; and (3) the event epicenters are located beneath the land of Hokkaido or the Pacific Ocean within 20 km from the coastline. As a result, our data set contains about 170,000 P-wave arrival times from 2030 local earthquakes.

The grid interval is 0.2 degree in the latitude and longitude directions, and the grid nodes are set up at depths of 8, 25, 40, 65, 90, 120, 150, 180, 200, 250, 300 and 350 km. The starting velocity model for the 3-D tomographic inversion is the 1-D J-B model, whereas we have added +4% high-velocity anomaly to the subducting Pacific slab. The results of this work are summarized as follows.

(1) Prominent low-velocity anomalies are revealed under Mt. Tarumae, Tokachi, and Usu active volcanoes, which may contain high-temperature melts associated with slab dehydration.

(2) Low-velocity anomalies exist in the mantle wedge beneath the volcanic front and back-arc area. The vertical-velocity is greater in the low-V zones, which is similar to that beneath Tohoku and Kyusyu.

(3) The horizontal-velocity is greater in the subducting slab, similar to the radial anisotropy results in Tohoku and Kyusyu.

(4) There is little azimuthal anisotropy in the low-velocity body under Mt. Usu (Liu et al., 2013), but our study shows very strong radial anisotropy. This result suggests the existence of upwelling flow in the mantle wedge beneath Mt. Usu.

References

Liu, X., D. Zhao, S. Li (2013) Seismic heterogeneity and anisotropy of the southern Kuril arc: Insight into megathrust earthquakes. Geophys. J. Int. 194, 1069-1090.

Wang, J., D. Zhao (2013) P-wave tomography for 3-D radial and azimuthal anisotropy of Tohoku and Kyushu subduction zones. Geophys. J. Int. 193, 1166-1181.

Keywords: Tomography, Anisotropy, Hokkaido, Subduction zones, Mantle wedge

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SCG60-P03 Room:Convention Hall Time:May 25 18:15-19:30

P and S wave attenuation tomography of the Southwest Japan arc

LIU, Xin[1] ; ZHAO, Dapeng[1*] ; NISHIZONO, Yukihisa[2] ; INAKURA, Hirohito[2]

[1]Tohoku University, Department of Geophysics, [2]West Japan Engineering Consultants, Inc.

We determined the first high-resolution P- and S-wave attenuation (Qp and Qs) tomography of the crust and upper mantle under the entire Nankai subduction zone from the Nankai Trough to the Japan Sea using a large number of high-quality $t*$data measured from P- and S-wave spectra of local earthquakes. The suboceanic earthquakes used in this study were relocated precisely using sP depth phases and ocean-bottom-seismometer data. The overall pattern of the obtained Q models is similar to that of velocity models of the study region. Our present results show that high-Q (i.e. weak attenuation) anomalies in the upper crust generally correspond to plutonic rocks widely exposed in the Nankai arc. Some of the low-Q (i.e. strong attenuation) anomalies in the upper crust along the Pacific coast are associated with the Cretaceous-Cenozoic accretionary wedge. Obvious low-Q anomalies exist in the crust under the active arc volcanoes. Most of the large inland crustal earthquakes are located in or around the low-Q zones in the crust. The subducting Philippine Sea slab is imaged clearly as a landward dipping high-Q zone. Prominent low-Q anomalies are revealed in the mantle wedge under the volcanic front and back-arc area, which reflect the source zone of arc magmatism caused by slab dehydration and corner flow in the mantle wedge. Significant low-Q anomalies exist in the fore-arc mantle wedge, which reflects a highly hydrated and serpentinized fore-arc mantle wedge due to abundant fluids released from dehydration of the young and warm Philippine Sea slab.

Keywords: Southwest Japan, subduction zone, Seismic attenuation, slab, fluids

SCG60-P04 Room:Convention Hall Time:May 25 18:15-19:30

Geofluid migration process inferred from a 3-D electrical conductivity model beneath Tohoku district.

ICHIKI, Masahiro[1*] ; OGAWA, Yasuo[2] ; KAIDA, Toshiki[1] ; DEMACHI, Tomotsugu[1] ; HIRAHARA, Satoshi[1] ; HONKURA, Yoshimori[2] ; KANDA, Wataru[2] ; KONO, Toshio[1] ; KOYAMA, Takao[3] ; MATSUSHIMA, Masaki[2] ; NAKAYAMA, Takashi[1] ; SUZUKI, Syuichi[1] ; TOH, Hiroaki[4] ; UYESHIMA, Makoto[3]

[1]Graduate School of Science, Tohoku University, [2]Volcanic Fluid Research Center, Tokyo Institute of Technology, [3]Earthquake Research Institute, The University of Tokyo, [4]Graduate School of Science, Kyoto University

We carried out long-period MT observation using the state-of-the-art equipments. The MT impeadance responses were inverted into 3-D electrical conductivity model using WSINV3D (Siripunvaraporn et al, 2005). The 3-D model delineates vertical continuous conductive zone from subducting Pacifc plate surface to lower crust below Ou backbone range. The conductive body indicates saline fluids and/or melt pathway from the subducting slab surface to lower crust. The resistivity of the lower crust conductor is 1 Ωm or more conductive and saline fluids and/or melt volume fraction is estimated to be 7 vol. % at minimum. Other resistivity profile in the across-arc direction indicates that conductive body separated from Pacific plate surface at 80-100 km depth and assumes an overturned form towards backarc direction. The head of the conducting body attains to the lower crust just below Mt. Gassan. This suggests the backarc volcanisms are caused by saline fluids and/or melt overturn rising towards backarc direction.

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SCG60-P05 Room:Convention Hall Time:May 25 18:15-19:30

Fluid-rock interaction in deep portions of subduction plate boundaries

SAITO, Tsubasa[1*] ; UJIIE, Kohtaro[1]

[1]University of Tsukuba

Fluid-rock interaction at deep portions of subduction plate boundaries is a key to understand roles of fluid on deformation and mass transfer during subduction and accretion. In the Upper Cretaceous Shimanto accretionary complex of eastern Kyushu, the melange composed of basaltic slices in the argillaceous matrix and the coherent clastic rock occur three times, representing the repetition of ocean plate stratigraphy associated with the duplex underplating at a depth of ~ 13 km and temperatures of 340-400 ℃. One well-exposed basaltic slice consists mainly of massive basalt, pillow basalt, and dolerite in which argillaceous rocks are intercalated with the dolerite in the uppermost part of the slice. The argillaceous matrix commonly shows pressure solution cleavage in which muscovite and carbonaceous material occur as insoluble residue. The argillaceous rock less than 20 cm from the upper boundary of the basaltic slice is highly bleached in association with the modal increase in albite and consumption of muscovite and carbonaceous material, while that intercalated with the dolerite shows various degree of bleaching. Plagioclase phenocrysts in the dolerite near the upper boundary are replaced to muscovite. Mass-balance estimated from isocon method indicates that the bleached argillaceous rock and the uppermost dolerite are depleted in fluid-mobile elements such as Sr and Ba relative to surrounding rocks. Deformation is concentrated into the uppermost dolerite, which is marked by elongated phenocrysts. These results suggest that the albitization of argillaceous rock by infiltration of Na-rich fluid and the deformation accompanying with fluid-dolerite interaction occurred during the melange-forming process. Infiltration metamorphism during incorporation of basaltic slices in the argillaceous melange matrix may play an important role on mass transfer in subduction plate boundary.

Keywords: fluid-rock interaction, subduction plate boundary, argillaceous rock, dolerite, albitization

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SCG60-P06 Room:Convention Hall Time:May 25 18:15-19:30

Mechanism of overpressure development in the Kazusa Group

MARUMO, Haruna[1] ; KANEKO, Sachiyo[2] ; TAMURA, Yukie[3] ; MITSUHASHI, Shunsuke[4] ; UEHARA, Shin-ichi[2*]

[1]Graduate School of Science, Toho University, [2]Faculty of Science, Toho University, [3]Skylark CO., LTD., [4]Graduate School of Life and Environmental Sciences, Tsukuba University

Abnormally high pore pressure zone may affect many properties and processes in underground, and thus it is important to study the mechanism of developing the high pore pressure zone. In mudstone formations of the Kazusa Group at the Boso peninsula, high porosity anomaly of approximately 5 to 20 % is observed, and this anomaly is suggested to have been generated by an abnormally excess pore pressure. However, the development process of the high pore pressure is still unknown. In general, pore pressure anomalies can develop through normal sedimentation-compaction process under some conditions of permeability and storage capacity, and/or sedimentation rate. In this study, we investigated how much pore pressure and porosity anomalies can develop just only by normal sedimentation-compaction process in the case of the Kazusa Group mudstone formation. Firstly we obtained effective pressure dependencies of permeability and porosity for siltstone specimens from the Kazusa Group by using laboratory experiments, and then carried out 1-D numerical simulation of pore pressure development during sedimentation-compaction processes using the parameters from the experiments.

The rock samples used in the experiments were collected from outcrops at Umegase Formation (Fm.), Otadai Fm., Kiwada Fm., Ohara Fm. and Katsuura Fm. of the Kazusa group. The collected samples were shaped into a cylindrical shape about 40 mm in diameter and about 30 mm in height. The measurements were performed using an intra-vessel deformation fluid-flow apparatus at Toho University. Distilled water was used for pore fluid and confining pressure was applied by using oil. Permeability and porosity of siltstones were measured at room temperature and under effective pressures from 2 to 35 MPa. To obtain porosity under effective pressure, we measured a volume of water discharged from the specimen when confining pressure was applied. We measured permeability by monitoring flow rate through the specimen under the condition of constant pore pressure differences at the both side of the specimen. Measured porosity ranged from approximately 34 to 42 %, except for the specimens of Ohara Fm., porosity of which was up to 55 %, higher than others. Permeability ranged from 10^{-20} to 10^{-16} m^2. We obtained the effective pressure dependencies of porosity and permeability for each specimen by fitting normal consolidation domains of the experimental results with some functions. We then simulated developments of pore pressure and porosity anomalies during sedimentation of silt(stone) layer up to the thickness of 3000 m. By using finite difference method, we discretized a differential equation modeling pore pressure developments by sedimentation-and-compaction, and diffusion in the vertical direction of pore pressure. The conditions for the simulation are as follows: the lower boundary of the calculation domain is impermeable, and pore pressure is constant at the upper boundary of the sediments. The sediment layer is initially 54 m in the thickness, and the initial pore pressure is hydrostatic (no pore pressure anomaly). Skempton's constant is 0.9. The sedimentation rate is constant, and we used three values, 4.0, 9.49, 40.0×10^{-4} m/year, estimated from the previous studies at the Kazusa Group. The results of the numerical simulations suggested that, pore pressure anomaly was increased as the depth was increased, and when the sedimentation rate was 9.49×10^{-4} m/year, developed maximum pore pressure and porosity anomaly ranged from 3 to 12 MPa and 0.5 to 6 %, respectively. As the sedimentation rate was increased, the anomalies were increased, and pore pressure and porosity anomalies were increased up to 18 MPa and 8 % when the sedimentation rate was 40.0×10^{-4} m/year. These results indicate that, when considering conditions for the Kazusa Group, pore pressure anomaly of more than 10 MPa and porosity anomaly of several percentages can develop.

Keywords: the Kazusa Group, overpressurization, permeability, laboratory permeability measurement, numerical simulation

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SCG60-P07 Room:Convention Hall Time:May 25 18:15-19:30

Dehydration effect on frictional instability: Experimental study using gypsum hemihydrate

SASAKI, Yuto[1*] ; MUTO, Jun[2] ; NAGAHAMA, Hiroyuki[2]

[1]Div. GeoEnviron. Sci., Tohoku Univ., [2]Dept. Earth Sci., Tohoku Univ., [3]Now at: Dept. E. P. Sci., Univ. Tokyo

Subduction zone seismicity can be controlled by water. For example, dehydration embrittlement of subducting slab is thought to generate intermediate depth earthquakes and their epicenters concentrate in ”the upper plane earthquakes belt.” The lower boundary of ”the upper plane earthquakes belt” is possibly related to the stability of anhydrous phase after dehydration [1, 2]. Besides, the presence of serpentinized mantle wedge or excess pore pressure derived from hydrous slab may explain the distribution of asperities possibly inducing plate boundary earthquakes [2, 3]. In this way, hydrous minerals in subducting slab physicochemically transport water into deeper part of the Earth at subduction zone; the water probably has relationship with seismicity. Nevertheless, it has not concretely resolved yet how water has elementary microscopic effects on the macroscopic seismicity.

Many hydrated minerals such as serpentinites [4] exhibit mechanical instability such as dehydration weakening. Especially for gypsum, previous researches clarified that the condition of brittle-ductile transition and dehydration reaction can be achieved easily in laboratory [5, 6], so that gypsum is thought to be a good rheological analogue for hydrous slab. Thus, in this research, we investigate a following problem on the hypothesis that hydrous mineral dehydration microprocess affects frictional characteristics and rheology. The problem is how dehydration of hydrous minerals controls frictional properties and rheology of seismogenic zone by friction experiments of simulated gypsum gouges.

In this study, simulated gouge sample of gypsum hemihydrate, bassanite, between precut gabbro pistons was deformed in gas-medium apparatus at confining pressures of 10 − 200 MPa and temperatures up to 180 ℃. From the results at room temperature, the magnitude of stress drops proportion to confining pressure explains the depth distribution of seismicity in subduction zones. At 200 MPa, 70 ℃ corresponding to non-dehydration condition, samples exhibited stick-slip behavior and the strength of the samples became larger. On the other hand, at 200 MPa, 110 ℃ and higher, likely corresponding to condition for stable anhydrite phase, stick-slip behavior was found to be diminished with the reduction in mechanical strengths with strain. Microstructural observations clarified opening shear planes (R_1) oblique to shear direction in non-dehydrated samples, while the number of shear planes decreased and another sets of shear planes parallel (Y) or orthogonal (X) to the direction against shearing were formed in dehydrated samples. Cleavages were turned parallel to shearing by shape preferred orientation of the gouge particles and most of deformation was covered along them as mechanically weaker planes. The generation of excess pore pressure generated by dehydration of hydrous minerals, low permeability of the surroundings and connection of internal shear planes or cleavages may have significantly reduced the strength of rock. Because the phase after dehydration, anhydrite, is known to show higher frictional strength than the hemihydrate, bassanite [7], existence of excess pore pressure rather than the change in frictional properties may induce weakening during or after the dehydration. Hence, this implies that the dehydration weakening process is possibly related to formation of aseismic or stable sliding zones.

References: [1] Kita *et al.* (2006) *GRL*, **33**, L24310. [2] Hasegawa *et al.* (2012) *Jour. Tokyo Geogr. Soc.*, **121**, 128. [3] Fagereng and Ellis (2009) *EPSL*, **278**, 120. [4] Raleigh and Paterson (1965) *JGR*, **70**, 3965. [5] Brantut *et al.* (2011) *JGR*, **116**, B01404. [6] Heard and Rubey (1966) *GSAB*, **77**, 741. [7] Shimamoto and Logan (1981) *JGR*, **86**, 2902.

Keywords: dehydration weakening, phase transition, hydrous mineral, gypsum

SCG60-P08 Room:Convention Hall Time:May 25 18:15-19:30

Spatial variation of magmatic temperatures and water contents in western Java Island, Indonesia: estimation from mineral

TAKAYAMA, Kohei[1*] ; OHBA, Tsukasa[1] ; ABDURRACHMAN, Mirzam[2] ; IWAN, Setiawan[1] ; FIRMANSYAH, Reza[2]

[1]Akita University, [2]Institut Teknologi Bandung

Across-arc variations of magmatic temperatures and water contents in West Java were investigated from whole-rock chemistry, petrography, and phenocryst mineral compositions. Volcanic rocks were collected from eight volcanoes in the region. To determine these properties, the pyroxene thermometer by Brey and Kohler (1990) and the plagioclase-melt hygrometer by Putirka (2008) were applied. Rocks in this region range from basalt to andesite with some exceptions: dacite from Guntur and latite from Dago. Silica contents range from 53-58 wt% in Papandayan, 51-63 wt% in Guntur, 50-57 wt% in Galunggung, 57-61 wt% in Cikuray, c. 57 wt% in Tangkuban Parahu, 56-57 wt% in Dago, 49-57 wt% in Tampomas, and 55-61 wt% in Ciremai, respectively. Although a majority of rocks belong to medium-K series, potassium content varies by location, increasing with the distance from the trench. Basalt and basaltic andesite from Galunggung, one of the frontal volcanoes, are classified as low-K series, and part of rocks from rear-arc volcanoes, Tampomas, Tangkuban Parahu, and Dago, are assigned to high-K series. To equalize effects of differentiation, samples with similar silica contents (c. 57 wt%) are selected to apply the geothermometer and the hydrometer. Pyroxene rims indicate a temperature range from 900-1050 ℃ (970-1000 ℃ in Papandayan; 900-1020 ℃ in Guntur, 970-1020 ℃ in Galunggung, 970-1020 ℃ in Cikuray, 940-1050 ℃ in Tangkuban Parahu, 970-980 ℃ in Tampomas, and 950-1020 ℃ in Ciremai). The temperature estimates of cores range from 900-1030 ℃ (970-1000 ℃ in Papandayan, 930-950 ℃ in Guntur, 950-1030 ℃ in Galunggung, 960-1010 ℃ in Cikuray, 990-1030 ℃ in Tangkuban Parahu, 950-1030 ℃ in Tampomas, and 900-940 ℃ in Ciremai). Water content of plagioclase rims ranges from 0.5-1.6 wt % and each volcano exhibit narrow range (1.0-1.2 wt% in Papandayan, 1.6 wt% in Guntur, 0.9-1.2 wt% in Galunggung, 1.6-1.8 wt% in Cikuray, 0.5-0.7 wt% in Tangkuban Parahu, 0.7 wt% in Dago, 1.1-1.3 wt% in Tampomas, and 1.2 wt% in Ciremai). The water contents estimated from core composition show no distinct difference from those of rims, ranging from 0.6-1.4 wt% (1.3-1.5 wt% in Papandayan, 1.1-1.4 wt% in Guntur, 0.6-1.0 wt% in Galunggung, 1.1-1.4 wt% in Cikuray, 0.8-1.1 wt% in Tangkuban Parahu, 0.6-0.8 wt% in Dago, 0.9-1.2 wt% in Tampomas, and 1.0 wt% in Ciremai). Neither temperature nor water content is correlated with the distance from the trench; lateral variations are not distinct in terms of these properties. In many samples, pyroxene crystals exhibit reverse-zoning with increasing Mg-number, and the estimated temperatures at rims are higher than those of cores, implying recharge of hot magmas into colder magma reservoirs.

Keywords: across-arc variation