MIS35-01 Room:201A Time:May 24 09:00-09:15

Impact history revealed by the cratering records of the Moon and planets

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It is thought that the supply process of water to the Earth is closely related to the dynamics of the early solar system. Unraveling the impact history in the early Earth-Moon system is essential to understand the origin of water in the Earth. The cratering records of the Moon and planets preserve the impact history in the solar system during the past 4.5 Gyr, which is a key information to understand the source and the dynamical and collisional evolutions of small bodies.

In this talk, I would like to review the statistical studies of the cratering records of the Moon and planets and its findings. Also, I will present findings on the impact history in the early Earth-Moon system revealed by the Japanese lunar explorer SELENE (Kaguya).

Keywords: impact, crater, cratering chronology, Moon, late heavy bombardment

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

MIS35-02 Room:201A Time:May 24 09:15-09:30

Solar system science by the Subaru Hyper Suprime-Cam survey

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Hyper Suprime-Cam (HSC) survey has been started as a Subaru Strategic Program from March 2014, which has planned to survey about 1500 square degree on the sky. This is the first large field survey using Subaru telescope. Owing to a large aperture of Subaru telescope, it is expected to detect the small solar system bodies with the magnitude range of r'= 22-27 mag. It is definitely deepest survey for the small solar system bodies and absolutely an excellent opportunity to determine the feint end of the size distribution of each small solar system bodies group.

This kind of observations that determine the feint end size distribution of small solar system bodies has been done by the Suprime-Cam, which is also mounted on the Subaru Telescope. However, the survey area was narrow (about $<$10 square degrees), it has been required to increase the determination accuracy of the size distribution with more samples.

Since the HSC survey can detect one order large samples than all of the survey done by Suprime-Cam so far, the size distribution of each main belt region (inner (mostly S-type asteroids) / center (S / C types) / outer (mostly C-types)) can be determined. From that information, we are able to reveal a relationship between the collisional evolution and asteroid's composition, therefore, aims to reveal the composition and internal structure of a whole asteroid belt. Another important expectation is the finding of main belt comet candidates by using the point spread function of object image, which is important bodies in order to clarify the water distribution in the main belt.

Some of the main belt objects are known to evolve into near Earth objects (NEOs), they might supply a significant amount of water to the Earth. Therefore, the observational results collected by the HSC survey, which is the material composition/distribution of the entire main belt, together with the theoretical studies on planetary migration and the orbital evolution of small bodies, will supply an important clue to reveal aspects of substance transportation into the Earth.

In the HSC survey, we can also detect enough samples of Jupiter trojans and TNOs. Therefore we have a plan to investigate physical and chemical differences between the L4 and L5 swarms of Trojans and the size distribution difference between the cold / hot population of TNOs.

In my presentation, I also introduce results that has done by the Suprime-Cam so far and describe what we can do more science in the HSC survey.

Keywords: Small Solar System Bodies, Wide field survey, Photometry, Asteroids, Trojans, TNOs

MIS35-03 Room:201A Time:May 24 09:30-09:45

Exploring the origin of Earth's water by the Hayabusa-2 near-infrared spectrometer

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NIRS3, the near-infrared spectrometer onboard the Hayabusa-2 spacecraft, is a remote-sensing instrument to obtain the reflectance spectra including 3-μm absorption features due to structural OH ions and H2O molecules. In 2018-2019, we are planning to perform proximity observations of a near-Earth C-type asteroid 1999JU3 using NIRS3 and to reveal the distribution of hydrated minerals on the asteroid surface. Recently, the results indicating the presence of internal water ice for C-type asteroids were reported from ground-based observations. Hence, there is a possibility that the contribution of C-type asteroids to formation of Earth's ocean becomes larger than that predicted so far. It is required to understand the behavior of water in the aqueous alteration to verify the internal water ice. Thus, NIRS3 aims at obtaining information about the aqueous alteration discerning the secondary alteration effects such as thermal dehydration and space weathering from observations of the crater formed by the artificial impact experiment. In this presentation, we introduce the expected outcome of NIRS3 based on the current knowledge of C-type asteroids.

Keywords: Hayabusa-2, asteroids, water, near-infrared spectroscopy

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

MIS35-04 Room:201A Time:May 24 09:45-10:00

Dehydration and rehydration of hydrous carbonaceous chondrites

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Asteroidal water in hydrous C-complex asteroids is one of the possible source of Earth's ocean. The hydrous C-complex asteroids consist of hydrous carbonaceous chondrites and therefore the water came to the earth as such hydrated meteorites. CM chondrites are the most abundant group of carbonaceous chondrites, composed mainly of hydrous minerals such as serpentine (cronstedtite) and tochilinite. They show 0.7-μm and 3-μm absorption bands in the reflectance spectra. The 0.7-μm band is a spectral feature characteristic of CM chondrites, because it is common in CM chondrites and rare in other hydrated carbonaceous chondrites (Cloutis et al. 2011). Recent investigation on spectral data of asteroids indicated that 30$\pm$5% of C-complex asteroids shows 0.7-μm band (Rivkin, 2012), suggesting that CM materials are also common at main belt asteroids.

Some CM chondrites have been heated to temperature sufficient for dehydration of hydrous minerals (e.g., Akai, 1990: Nakato et al. 2008) and are classified to heating stage I to IV based on the degree of heating (Nakamura, 2005). On the other hand, not a few C-complex asteroids show reflectance spectra similar to dehydrated CM chondrites (Hiroi et al. 1993). In the present study, we performed analyses of reflectance spectra, X-ray diffraction, and water contents of hydrated and dehydrated CM chondrite samples. In addition, heating experiments were conducted in order to observe changes of reflectance spectra, X-ray diffraction, and water content with increasing temperature. Murchison CM chondrite was heated for 50 hours at temperatures of 400, 600, and 900 ℃ at IW oxygen buffer.

Heating experiments showed that tochilinite decomposes and serpentine partly becomes amorphous at 400 ℃, serpentine completely decomposes and secondary olivine nucleates at 600 ℃, and olivine becomes well crystalline and metallic FeNi generates at 900 ℃. The samples heated at 400, 600, and 900 ℃ reproduced the mineralogy of CM chondrites with heating stage II, III, and IV, respectively. The 0.7-μm band disappears by heating at 400 ℃. The 3-μm band strength decreases with increasing temperature, but does not disappear even at 900 ℃. Water contents of unheated and experimentally heated Murchison samples were determined by the Karl Fischer titration method with stepped heating: 10.0, 6.6, 1.2, and 0.6 wt% of water recovered from unheated, 400, 600, and 900 ℃ samples, respectively. The result clearly indicates that the dehydration proceeds with increasing temperature. On the other hand, in the stepped heating analysis, most of the water was released below 600 and 900 ℃ from 600 and 900 ℃ heated samples, respectively. This indicates that water in the 600 and 900 ℃ samples (1.2, and 0.6wt%, respectively) was acquired into samples by rehydration in the atmosphere after heating experiments. The rehydration water is tightly bounded to samples, because the largest release of water was detected at 400 ℃ from both 600 and 900 ℃ heated samples. If we omit rehydration water from the total water contents, then dehydration is completed in Murchison by heating at 600 ℃ for 50 hours (heating stage III).

On the other hand, the results of reflectance spectra measurement of naturally heated CM chondrites reveals that even samples of heating stage IV such as Dho735, B7904 and Y86720 show 3-μm absorption band, which suggests rehydration. Water-content analysis of Dho735 confirms the rehydration: most of water was released at 300~600 ℃. The water analysis concludes that dehydrated CM chondrites are a strong water absorber. This suggests that dehydrated-CM materials on the surface of C-complex asteroids would resorb the water released upon impacts of hydrous micrometeorites from other asteroids and comets.

Keywords: aqueous alteration, C-complex asteroids, reflectance spectra, water analysis

MIS35-05 Room:201A Time:May 24 10:00-10:15

Significance of incompleteness as an aqua planet: Earth's climate with land-sea coexistence

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Our planet Earth is in a habitable zone in the Solar System, but is not entirely covered by liquid water, because its crust has separated into higher (continental) and lower (oceanic) parts. Such a planet of land-sea coexistence has a climate different from so-called aqua-planets or land planets.

Firstly, because oceans cannot flow beyond lands, the zonal vortical motion dominant generally in rotating planetary fluids must turn poleward near coasts in the oceans and contribute to meridional heat transport. Secondly, because of heat capacity contrast between ocean and land, the periodical variability of solar irradiance on a planet with rotation and revolution induces striking horizontal temperature gradient and wind in the bottom of atmosphere. Thirdly, the atmospheric mechanical forcing may be balanced (interacted) with the oceanic thermal forcing, whereas the rapid maritime water vapor transport must be balanced with the slow river flow on land. The coastline is just like a triple point among three geophysical phases of atmosphere, ocean and crust, maintained by an erosion-orogeny balance.

The land-sea coexistence is essentially important in equatorial climate, where the dominant motion is convective and governed by the temperature contrast and water budget between land and sea. Thus the longest coastlines in the Indonesian maritime continent (IMC) generate the largest rainfall on Earth. A super cloud cluster coupled with warm ocean water may circulate eastward with an intraseasonal period along the equator on an aqua-planet, but must be modified by reflection of ocean water (waves) at the coasts of IMC and American/African continents with an interannual time scale. Therefore, IMC is an important region in which we can study the climate of a land-sea planet based on observations.

The coastlines and rivers important climatologically as mentioned above are also zones in which human population, infrastructure and hence observations are concentrated. This is partly why we could start climatology even in an early history of the human beings. The leadership of climate observations in IMC is being transferred to the new G20 country, and we are entering into a new era for truly global observation of our planet Earth.

Keywords: land-sea coexistence, coastline, climate, rotation and revolution, human beings, Indonesian maritime continent

MIS35-06 Room:201A Time:May 24 10:15-10:30

Water transport to the deep mantle and its effects on the mantle dynamics

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Numerical study for water transport under a volcanic arc revealed dynamics of the water processes inducing melt generation (Iwamori, 1998). Back-arc and intra-plate volcanisms also indicate water migration from a deeper section of the subduction zone. Aiming to understand geodynamical processes of water derived and transported from the subducted slab in the deep subduction zone, we developed a numerical model of water transport coupled dynamically with plate-mantle convection system with a whole mantle scale. We here focus on the mechanism of dehydration from stagnating or penetrating slab and water transport from the mantle transition zone (MTZ). We also consider water transport to deeper mantle and the effects on the global distribution of water-compatible elements that is indicated by the independent component analysis (ICA) of isotope anomaly space (Iwamori and Nakamura, 2012).

We assume that a viscous fluid in a 2-D rectangular box with an extended Boussinesq approximation represents the mantle convection system with integrated lithospheric plates (Tagawa et al, 2007). We incorporate water transport and hydrous mineral phase diagram (Iwamori, 1998; 2007) into the numerical plate-mantle model. We assume that the water dehydrated from water-saturated minerals migrates upward instantaneously with porous flow that is much faster than mantle flow. We introduce reduction of the density and the viscosity due to the hydration into the density and rheology model according to experimental study (Karato and Jung, 2003). We also consider viscous weakening of serpentine or chlorite that is important for water transport in shallow subduction zone.

A serpentine layer generated by dehydration of the oceanic crust plays a key role to control water transport by the subducted slab shallower than about 150 km (Iwamori, 1998; 2007; Horiuchi, 2013). To continuously generate this layer, coupling between the serpentine layer and the plate boundary fault is essential. After dehydration of serpentine, nominally anhydrous minerals (NAMs) (Iwamori, 2007) are a main veneer of the water. In this stage, water capacity of NAMs, which depends on the grain boundary storage as well as that of the hydrous minerals, is the primary factor to control the amount of transported water. This is not so large as about 0.4 wt. % to maintain water-filled region under the arc. The water is carried without dehydration above the 660 km boundary. When the water capacity of the NAMs is about 0.2 wt. %, the amount of the water transported to the mantle transition zone is about 1 % of the basaltic crust mass. When the lower mantle water capacity is lower than the water capacity of the NAMs, the water is expelled at the 660 km phase transition. While the water ascends with the porous flow, the medium rocks descend with asthenospheric flow dragged by the downwelling slab. The repetition of these processes broadens the hydrous layer at the 660 km boundary. A thin water-saturated layer is formed at the 660 km boundary around the penetrating slab. Because of the buoyancy, this becomes unstable so that hydrous plumes are generated. The hydrated layer above the lower mantle slab is thickened by 4 to 5 time more than that in the upper mantle. This result in the increase of the water amount transported into the lower mantle by 4 to 5 times larger than that estimated from the ratio of the water capacity between the upper and lower mantles.

The water reaches the core-mantle boundary region with the subducted slab. The subducted slab sweep out the dense chemical layer above the CMB, so that the dense materials forms a pile-like structure. The distributions of the hydrated materials become exclusive to that of the chemical piles. Iwamori and Nakamura (2012) showed that water-compatible elements (IC2) and OIB components (IC1) have divided distribution. This suggests that the dense chemical pile is not a source for the IC1.

Keywords: water transport, subduction, mantle convection, large-scale heterogeneity

MIS35-07 Room:201A Time:May 24 10:30-10:45

On the degassing of water vapor inferred from mantle convection simulations

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The degassing process of volcanic activity would be influenced to the formation of surface environment of Earth, which has been argued from simplified and theoretical model of co-evolution of planetary interior and surface [e.g. McGovern and Schubert, 1989; Tajika and Matsui, 1992]. Those models, however, used the parameterized convection model for heat transfer and volatile circulation as well as degassing process. Recent progress of numerical modeling of mantle dynamics can trace the magmatic activity and water circulation over the geologic time-scale [e.g. Nakagawa et al., submitted]. However, such an investigation was not included for effects of melt-phase system such as expressed by the density structure of silicate melt. This effect would be essential for reconciling the thermo-chemical state of early Earth' interior [Labrosse et al., 2007; Lee et al., 2010]. In this study, we attempt to construct global-scale water circulation model in thermo-chemical mantle convection simulations including melt-phase system and degassing-regassing processes over the geologic time-scale. The melt-phase system is based on the density structure of molten silicate found from Stixrude et al. [2009]. Preliminary results found from this study are suggested that huge volcanic activity would be expected in early Earth when the density crossover between solid silicate and molten silicate is assumed in the deep mantle, which the molten silicate is much denser than solid silicate. This also suggests that the degassing rate of water vapor in the early Earth would be more efficient with the denser molten silicate in the deep mantle compared to the less dense case. More detailed results and discussion will be shown in the presentation.

Keywords: Melt-phase system, Water circulation, Mantle convection, Magmatism, Degassing

MIS35-08 Room:201A Time:May 24 11:00-11:15

Origin and evolution of water in the Earth inferred from geological evidences

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The persistent liquid ocean is a result of balance between input and output of water through the Earths mantle; however, the mass of ocean could be markedly reduced since Archean and might be disappeared in future. In this project, we plane to investigate the origin and evolution of water in the Earth, based mainly on D/H ratio of fluid inclusion, water content of primary magma and it time evolution, and water transportation into the mantle at subduction zone. Integrating these evidences, quantitative estimate of mass of liquid ocean through Earth history will be discussed.

Keywords: water differentiation in the Earth, water evolution in the Earth, water transportation into the Earth

MIS35-09 Room:201A Time:May 24 11:15-11:30

Water transportation into the earth's interior - Oceanic plate and its evolution -

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Plenty of liquid water exists at the Earth's surface. If water is transported from the surface into the Earth's interior, the water affect various processes in the solid Earth, such as mantle convection, generation of earthquakes, and magmatism. The evolution of the Earth cannot be explained without the transportation of water into the Earth's interior from the surface. How is the water transported into the interior? High pressure and high temperature in the deep interior prevent the penetration of water from the surface. Instead, water is transported as hydrous minerals by the subduction of the oceanic plate as part of the global mantle convection. Therefore, the amount of hydrous minerals within the oceanic plate just prior to subduction determine the amount of water transported into the Earth's interior and have an impact on the evolution of the Earth.

Crustal hydration by the hydrothermal circulation at the mid-ocean ridge was formerly considered to be a first-order control on the degree of oceanic plate hydration. However, recent several observations suggest that plate bending-related faults just prior subduction may enhance the hydration of oceanic crust and mantle. If this hypothesis is correct, the amount of water transported by the oceanic plate is much larger than foremerly expected because mantle have a potential to contain much larger amount of water than the crust.

In the last decade, to test this hypothesis, a number of structure studies have been conducted in the trench-outer rise region around the world. We JAMSTEC also have conducted extensive active source seismic structure studies in the northwestern Pacific. We have shown that seismic velocities gradually reduce toward the trench axis accompanied by the development of bend faults. In addition, we have shown that the Poisson's ratio (Vp/Vs ratio) increase toward the trench axis. These observation indicates that water content within the oceanic plate increases toward the trench and suggests that the bend faults just prior to subduction is one of keys to understand the evolutionary history of the Earth.

In this paper, we are going to show the results of our seismic structure studies as well as the other structure studies in the trench-outer rise region. Then we will discuss the remaining issues such as quantitization and spatial inhomogenity in the water amount.

Keywords: oceanic plate, outer rise, hydration, seismic survey, water transportation, Vp/Vs

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

MIS35-10 Room:201A Time:May 24 11:30-11:45

Origin of the oceanic lithosphere inferred from Po/So waves

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It has long been recognized that the oceanic P and S waves (Po and So waves) have signal with high frequency, large amplitude, and long duration and propagate for large distance up to 3000 km across the ocean. The Po/So waves are developed by multiple forward scattering of P and S waves due to small-scale heterogeneities in the oceanic lithosphere and scattering and capturing of P wave in seawater layer [e.g., Shito et al., 2013; Kennett and Furumura, 2013]. In order to study the origin of the small-scale heterogeneities, the Po/So waves travelling in the Philippine Sea are analyzed.

The Philippine Sea is one of the marginal seas of the Pacific Ocean. It is fundamentally divided into two regions bounded by the Kyushu-Palau Ridge, each is considered to be formed in different episodes of back-arc spreading and that western part (45-60 Ma) is older than eastern part (15-30 Ma) [e.g., Seno and Maruyama, 1984]. The comparison of the Po/So waves propagation in the different ages of the oceanic lithosphere is expected to reveal the origin of the small-scale heterogeneities.

Seismological observations using BBOBSs was conducted in the Philippine Sea from 2005 to 2008 as a part of the Stagnant Slab Project [Fukao et al., 2009], and high-quality Po/So waves from earthquakes in subducting Philippine Sea plate were recorded very clearly. The findings from the observed Po/So waves in the Philippine Sea plate are summarized as follows [Shito et al., 2014]. (1) The Po/So waves propagate even in youngest oceanic lithosphere (15 Ma) near the past spreading center of the Shikoku Basin. (2) The Po/So waves propagate much more effectively in older western part than younger eastern part of the Philippine Sea.

We investigate the mechanism of this propagation efficiency using numerical a Finite Difference Method simulations of 2-D seismic wave propagation. The comparison of the observed and calculated Po/So waves indicates that the age-dependence can be explained by the thickness of the heterogeneous lithosphere. The estimated thicknesses of the oceanic lithosphere are consistent with those obtained by a previous study based on receiver function analysis [Kawakatsu et al., 2009]. The expected depth of the lithosphere asthenosphere boundary corresponds to the top of partial melting region calculated on the basis of the model defined by the water solubility of 1000 parts per million H2O [Mierdel et al. 2007].

The results suggest that the oceanic lithosphere including the small-scale heterogeneities thicken with age. These small-scale heterogeneities may form continuously in oceanic lithosphere from the time of its formation at a spreading ridge, via the solidification of melts distributed in the asthenosphere.

Keywords: Po/So waves, Philippine Sea Plate, oceanic lithosphere

MIS35-11 Room:201A Time:May 24 11:45-12:00

Abyssal peridotites from the Central Indian Ridge: Implications for mantle heterogeneity and oceanic plate formation

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It is generally accepted that abyssal peridotites are formed as residue after partial melting and melt extraction in the adiabatically upwelling mantle beneath the present mid-ocean ridge system. However, Os and some other isotopic characteristics of some abyssal peridotites suggest their ancient residual origin, which might be formed by ancient melting event(s) (Brandon et al., 2000; Standish et al., 2002; Harvey et al., 2006; Liu et al., 2008).

Indian MORBs are well known their distinctive isotopic compositions as compared to other oceans (e.g., Iwamori & Albarede, 2008; Iwamori et al., 2010). Because abyssal peridotites are recovered from the Central Indian Ridge (CIR hereafter) (Hellebrand et al., 2002; Seyler et al., 2003; Morishita et al., 2009, 2014; Zhou and Dick, 2013; Yi et al., 2014) where the spreading rate increases from north to south (DeMets et al., 2010), CIR peridotites would provide spatial information on mid-ocean ridge mantle. Several JAMSTEC cruises succeeded to recover abyssal peridotites from the southern end of the CIR. Abyssal peridotites in the southern end of the CIR are characterized by residues after medium-degree of partial melting followed by chemical modifications from evolved melts, which form gabbroic veins (Morishita et al., 2015). These results combined with previous data from northern part of the CIR suggest that relatively depleted residual peridotites are frequently outcropped in the CIR. Addition to this, orthopyroxene-rich peridotites which have high in Os isotopic compositions are recovered from an oceanic hill on the ocean ridge. These characteristics of the peridotites are expected for those from the mantle wedge. In conclusion, diverse peridotites, which might be formed during or before the formation of the Pangea-Gondwanaland, are now incorporated into asthenospheric mantle beneath the CIR. If this is a case, some peridotites can upwell near the ocean floor without creating thick basaltic crust, followed by faulting and hydration resulting in serpentinized peridotites as a part of oceanic plate. We need to reconsider the formation processes of the oceanic plate based on the heterogeneity of oceanic mantle.

Keywords: Central Indian Ridge, Abyssal peridotite, Mantle heterogeneity, Formation of Oceanic Plate

MIS35-12 Room:201A Time:May 24 12:00-12:15

Heterogeneous structure of the incoming Philippine Sea plate along the southwestern Nankai Trough

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The next large-thrust earthquake along the Nankai Trough, southwest Japan is concerned to occur within this century. First break of historical large-thrust earthquakes along the Nankai Trough are known to be always located off the Cape Shiono. Nonvolcanic deep low-frequency tremors and earthquakes considered as one of indicators of the future large-thrust earthquakes are observed around the down-dip limit of the coseismic rupture zone of the last Tonankai and Nankai earthquakes [Obara, 2002]. However the absence of Nonvolcanic deep low-frequency tremors and earthquakes is recognized between Shikoku Island and Kii Peninsula. One of the causes of these low-frequency seismic phenomena is considered to be fluid generated by dehydration processes from the subducting slab. It is important to investigate structural variation in the incoming Philippine Sea plate, including its fluid content to understand the generation of the low-frequency seismic phenomena as well as large-thrust earthquakes.

In 2014, we conducted the seismic refraction and reflection survey in the northern margin of the Shikoku Basin, where the Philippine Sea plate is subducting beneath the Eurasia plate at the Nankai Trough. We conducted a 360km long seismic profile about 50-60km seaward of the deformation front along the Nankai Trough. 35 OBSs were deployed along the profile with the interval of 10km. A tuned airgun array shot with a total volume of 7800 cu. in. every 200m for OBSs, and 380 cu. in. every 37.5m for a 192-channel, 1.2km-long hydrophone streamer.

In the time-migrated reflection section, variation in the sedimentary layer and basement reflection can be recognized off Shikoku, which may correspond with the boundary of the plate age proposed by magnetic lineation [Okino et al., 1999]. In the southwestern part of the profile, the basement reflection is not always clear, and shows smooth structure. Comparatively in the northeastern part, basement changes in depth drastically with prominent reflection signals. Moreover result of first-arrival tomography based on the wide-angle OBS data shows dramatic change in P-wave velocity just beneath the basement corresponding with the structural boundary observed along the reflection section as mentioned above.

We will show the structural variation of the oceanic crust and the uppermost mantle of the incoming plate, which may be related to the formation of the Shikoku Basin as well as the generation of large-thrust earthquakes and low-frequency events, by using OBS data.

This study is part of ‘Research project for compound disaster mitigation on the great earthquakes and tsunamis around the Nankai Trough region’ funded by MEXT, Japan.

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

MIS35-13 Room:201A Time:May 24 12:15-12:30

Mantle wedge structure of the Japan Sea derived from Ocean Bottom Seismometer observation

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Subducting hydrous oceanic plate carries water by hydrous minerals into the earth and contributes to a melt generation. Aqueous fluid dehydrated from the subducting oceanic plate plays an important role in magma generation. The Japanese Island are located at subduction zones where the Philippine Sea plate subducts from the southeast beneath the Eurasian plate and the Pacific plate descends from the east beneath the PHS and the Eurasian plates. To understand the water circulation and magmatism, a huge number of seismic tomography studies have been conducted in the Japan Island. However, a regional tomography using the land seismic station data could not reveal the deep seismic structure beneath the Japan Sea. The information of the deep mantle wedge structure is important to understand transportation and circulation of water and melt generation in subduction zones. Therefore, we conducted the repeating long-term seismic observations using Long-term ocean bottom seismometer(LT-OBS)s in the central Japan Sea from 2001 to 2004 and from 2013 to 2014. We apply travel-time tomography method to the regional earthquake and teleseismic arrival-data recorded by LT-OBSs and land stations. We obtained the P and S wave tomographic images down to a depth of 300 km beneath the Japan Sea. The tomographic P-wave image has a high velocity anomaly in the mantle wedge extending down to a depth of approximately 150 km beneath the Yamato Basin. In addition, the resulting tomographic image has three low-velocity anomalies in the mantle wedge. First, an inclined low velocity anomaly approximately parallel to the Pacific slab within the mantle wedge is observed in the around 100 km upper part of the Pacific slab. Second, low velocity anomalies are imaged at a depth of 150 km beneath northeastern Japan and 250 km beneath central Japan. Third, a low velocity zone is imaged from just above the subducting Pacific slab at a depth of 300 km. These low velocity anomalies are interpreted to be represented melt production affected by the fluid dehydrated from Pacific slab. The depth of dehydration from subducting slab is consistent with the results of numerical modeling studies. Our observations suggest that deep dehydration from the Pacific slab occurs at a depth of approximately 300 km and the Pacific plate subduction drives a large-scale upwelling flow beneath the Japan Sea.

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

MIS35-14 Room:201A Time:May 24 12:30-12:45

Slab dehydration and melt generation in subduction zones

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Volcanic and seismic activities in subduction zones are the result of complex interaction of geophysical and geochemical processes. I have investigated the hydration and dehydration and the generation and transportation of melt in subducting slab and adjacent mantle wedge using a numerical model. The model includes hydration and dehydration of the slab and mantle wedge, melting and solidification of mantle peridotites, permeable flow of melt and aqueous fluids, and temperature-dependent solid flow of mantle peridotites with water- and melt-induced weakening. In addition to these processes, I will discuss in particular the effect of fractional melting on melt distribution and composition. The model shows the following features. 1) Lherzolite flows into mantle wedge from back-arc side and harzburgite subducts with slab after segregation of melt under the arc. 2) Melt composition and melt fraction vary spatially and are controlled by the degree of mantle depletion and the amount of water supplied by slab dehydration. I will also discuss the effects of water content of the subducting oceanic crust and mantle on the melt distribution.

Keywords: subduction zones, slab dehydration, fractional melting

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

MIS35-15 Room:201A Time:May 24 14:15-14:30

Carbon-bearing saline fluids in the subduction channel and mantle wedge

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We find C-bearing saline fluids in the subduction channel and mantle wedge. Saline fluids are found with or without methane in jadeitites of serpentinite melanges located in Southwest Japan [Mori, Shigeno, Kawamoto, Nishiyama, in progress]. Carbon dioxide-bearing saline fluid inclusions are also reported from sub-arc mantle peridotite xenoliths: 3.7 wt% NaCl in Ichinomegata lherzolites, Northeast Japan arc [Kumagai et al., 2014] and 5.1 wt% NaCl in Pinatubo harzburgites, Luzon arc [Kawamoto et al., 2013]. These findings indicate that aqueous fluids in the subduction channel and mantle wedge can contain certain amounts of C and Cl.

We suggested that separation of slab-derived supercritical fluids into aqueous fluids and melts plays an important role in elemental transfer from subducting slab to the mantle wedge [Kawamoto et al., 2012]. It is, therefore, important to determine the effect of Cl on the trace element partitioning between aqueous fluids and melts. Synchrotron radiation X-ray fluorescence (XRF) analysis is conducted to know Rb, Sr, and Pb partitioning between aqueous fluids and melts simultaneously at high-temperature and high-pressure conditions. There is a positive correlation between partition coefficients and pressure, as well as salinity [Kawamoto et al., 2014]. Two slab-derived components, melt and fluid components, are suggested to explain trace element characteristics of arc-basalts in the Mariana arc [Pearce et al., 2005]. The fluid component is characterized by enrichment of alkali, alkali earth elements, and Pb. Such features can be explained if the fluid component is a saline fluid, because alkali earth elements and Pb are much less mobile with Cl-free fluids than Cl-rich fluids [Kawamoto et al., 2014].

We suggest that slab-derived components have compositional features consistent with a saline fluid and a melt, which can be formed through a separation of a slab-derived supercritical fluid [Kawamoto et al., 2012, 2014]. Slab-derived supercritical fluids contain Cl, and separated aqueous fluids inherit much of the Cl and some of the large-ion lithophile elements. Dissolution of carbon materials into aqueous fluids is enhanced by the salinity [Newton and Manning 2002] and their species can be controlled by oxygen fugacity.

Reference

Kawamoto T., Kanzaki M., Mibe K., Matsukage K. N., Ono S., 2012, Separation of supercritical slab-fluids to form aqueous fluid and melt components in subduction zone magmatism. Proceedings of the National Academy of Sciences, U. S. A., 109, 18695-18700.

Kawamoto T., Yoshikawa M., Kumagai Y., Mirabueno M. H. T., Okuno M., Kobayashi T., 2013, Mantle wedge infiltrated with saline fluids from dehydration and decarbonation of subducting slab. Proceedings of the National Academy of Sciences, U. S. A., 110, 9663-9668.

Kawamoto T., Mibe K., Bureau H., Reguer S., Mocuta C., Kubsky S., Thiaudiere D., Ono S., Kogiso T., 2014, Large ion lithophile elements delivered by saline fluids to the sub-arc mantle, Earth, Planets and Space, 66, 61.

Kumagai Y., Kawamoto T., Yamamoto J., 2014, Evolution of carbon dioxide bearing saline fluids in the mantle wedge beneath the Northeast Japan arc, Contributions to Mineralogy and Petrology, 168, 1056.

Newton, R.C. and Manning, C.E., 2002, Experimental determination of calcite solubility in H_2O-NaCl solutions at deep crust/upper mantle pressures and temperatures: implications for metasomatic processes in shear zones. American Mineralogist, 87, 1401-1409.

Pearce J. A., Stern R. J., Bloomer S. H., Fryer P., 2005, Geochemical mapping of the Mariana arc-basin system: Implications for the nature and distribution of subduction components. Geochemistry, Geophysics, Geosystems, 6, Q07006.

Keywords: aqueous fluid, fluid inclusion, arc magma

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

MIS35-16 Room:201A Time:May 24 14:30-14:45

Behaviour of subducted water and its role in magma genesis

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Water at subduction zones is carried to mantle depths by the subducting oceanic plate and then released by dehydration. It then migrates upwards and contributes to melting of the mantle wedge to form primary arc magma. The magma thus captures and transfers water to the crust, or outgasses water to the atmosphere. Water, either in fluids or melts in both the slab and the mantle, promotes the dissolution and mobilization of elements and affects the physical properties of the sub-arc slab, mantle, and seismicity. In this paper, we present a coherent model to explain the geophysical and geochemical role of water beneath NE Japan. We first investigate the seismic structures of the downgoing slab and sub-arc mantle and examine the role of subducted water in forming these structures. We then use the Arc Basalt Simulator version 4, a petrological-geochemical model developed to describe the geochemical behaviours of water and elements in the slab, mantle, and arc basalt. Parameters governing these petrogenetic processes are also estimated by the model and compared to geophysical observations. The combined approach shows that (1) subducted sediment and igneous oceanic crust are almost fully hydrated, whereas only partial hydration occurs in the oceanic mantle; (2) this high slab water content leads to melting of the slab sediment and the uppermost basalt layer beneath the arc; (3) the released water via slab liquid promotes 3?25% melting of the mantle wedge at a depth of 50?30 km at a mantle temperature of 1250?1350(C); (4) virtually 89% of slab water is released, 22% of the water returns to the forearc, and 38% enters the arc crust with the magma; and (5) 11% of the subducted water retained beyond a depth of 180 km is held in the slab, and 29% in nominally anhydrous minerals in the wedge mantle.

Keywords: Subduction zone, Water, Magma

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

MIS35-17 Room:201A Time:May 24 14:45-15:00

Water carrier in the Earth's deep upper mantle and residues under hydrous condition

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The chemical differentiations and homogenizations of the Earth's mantle are largely controlled by melts and fluids (e.g., silicate melts, H2O fluid). To understand the influence of H2O to the chemical evolution of the Earth's mantle, hydrous melting experiments at temperatures up to 1900 K at pressure of 3-8 GPa were performed using the multi-anvil apparatus. In hydrous conditions, the stability field of residual orthopyroxene expands relative to olivine above solidus, and the harzburgitic residue contains large amounts of Mg-rich (Mg# $>$0.92) orthopyroxene at 4.5 to 6 GPa. The residual chemistry obtained from our experiments agrees well with the chemical variation of the continental cratonic garnet peridotites xenoliths, which was transported by kimberlite magmas. The observation indicates that the cratonic harzburgite with high orthopyroxene contents possibly reflects formation by melt depletion under various water contents from almost anhydrous to 2 wt% in the upper mantle at depths of about 100 to 200 km. The orthopyroxene-rich harzburgite similar to the continental cratonic harzburgite may be formed at deep mantle wedges in the present Earth because water is dragged into the deep mantle wedge by subducting slabs. In present, it is difficult to obtain a petrological evidences for the formation of Si-rich and Mg-rich residues at the deep wedge mantle because a magma upwelling from the deep mantle ($>$200 km) does not exist. However, the orthopyroxene-rich harzburgite may be detected by seismological observations because a jump of elastic wave velocities possibly occurs at 9-10 GPa (270-300 km in depth) in the orthopyroxene-rich harzburgite due to the orthorhombic to high-pressure monoclinic phase transition in (Mg, Fe)SiO3 pyroxene. A small jump in seismic velocities at about 250-300 km in depth, the X discontinuity, has occasionally been observed in seismic profiles from some subduction zone, southern Africa and southern Pacific. I consider that the phase transition of (Mg, Fe)SiO3 pyroxene in orthopyroxene-rich harzburgite may correspond to the X discontinuity.

Keywords: Hydrous melting experiments, high-pressure and high-temperature, wedge mantle, orthopyroxene, craton, X discontinuity

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

MIS35-18 Room:201A Time:May 24 15:00-15:15

Water release from subducting slab inferred by upper mantle electrical resistivity structures beneath back-arc basins

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We present and compare four 2-D electrical resistivity structures of the upper mantle beneath three back-arc basins; the Lau Basin, the southern Mariana Trough, and the central Mariana Trough. The magnetotelluric (MT) method is a base to estimate upper mantle resistivity structures. The electromagnetic variation data on the ocean bottom were obtained from observations using OBEM (Ocean Bottom Electro-Magnetometer) and OBM (Ocean Bottom Magnetometer). We carried out the time-series data analysis is to estimate the MT responses and corrected topographic distortions in the MT responses. We have basically performed a smooth model inversion analysis using the processed MT responses to estimate a resistivity structure with minimum model smoothness, and also have considered a prior constraint in the inversion analysis for the subducting slab inferred from a seismic research. In the Lau back-arc basin, we obtained 12 months length data by 2 OBEMs and 7-9 months length data by 11 OBMs on the 2 observation lines across eastern Lau spreading center at 19.7 S and 21.3 S; the length of both observation lines are 150 km. It is worth noting that it is the first experiment to use OBSMs (ocean bottom seismograph with magnetometer); that is OBM attached to ocean bottom seismograph. Matsukura (2014) analyzed these data to derive 2-D upper mantle resistivity structures beneath the two observation lines. In the southern Mariana Trough back-arc basin, we carried out an electromagnetic observation along a 120 km length observation line across the spreading axis, and we obtained about 85 days length data by two OBEMs and for about 60 days by six OBEMs. Shindo (2013) reported preliminary results from these data, and we reanalyzed the data to derive a 2-D upper mantle resistivity structure beneath the observation line. We also compared these structures with a 2-D upper mantle resistivity structure beneath the central Mariana subduction system including the central Mariana Trough back-arc basin (Matsuno et al., 2010). All the 2-D upper mantle resistivity structures beneath three back-arc basins indicate that the mantle resistivity directly above the resistive subducting slab start decreasing at a characteristic depth; conductive region of less than 50 ohm-m exists at the deeper region. The depth is 140 km except 60 km for the central Mariana Trough back-arc basin where the subducting slab is so steep that the conductive region has ascended nearly vertically to the shallower depth or that the vertical resolution could not be good enough. This result suggests that the conductive region of less than 50 ohm-m is probably due to water release from the subducting slab and that the water release becomes dominating in the mantle above the slab when the slab reaches 140 km depth.

Keywords: water, subducting slab, upper mantle electrical resistivity structure, back-arc basin

MIS35-19 Room:201A Time:May 24 15:15-15:30

3-D electrical conductivity image of the upper mantle beneath the Society hotspot

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The mantle upwellings are one of the most important features for understanding the mantle dynamics. A large-scale mantle upwelling beneath the French Polynesia region in the South Pacific has been suggested from seismic studies, which is called the South Pacific superplume. Nolasco et al. (1998) carried out magnetotelluric (MT) survey around the Society hotspot, which is one of the hotspots in the French Polynesia region, in order to estimate electrical conductivity structure beneath and the vicinity of the Society hotspot in two-dimension. This previous study is not enough to understand the geometry of the hotspot, because the hotspot is tubed like form according to the results from the seismic study. Moreover, Suetsugu et al. (2009) suggested that the slow velocity anomaly continues from the lower mantle to the uppermost upper mantle just beneath the Society hotspot. The geometry, temperature, and composition of the Society hotspot remain controversial, however, due to still insufficient accumulation of the geophysical data.

Then, we carried out the TIARES project that composed of multi-sensor stations that include broadband ocean bottom seismometers, ocean bottom electromagnetometers (OBEMs), and differential pressure gauges from 2009 to 2010. To obtain three-dimensional (3-D) image of the upwelling of the Society hotspot in terms of electrical conductivity, we newly settled eleven OBEMs and obtained MT responses at 20 sites totally. A 3-D marine MT inversion program, which can treat topographic change distorting EM data, was applied to these MT responses to estimate 3-D electrical conductivity image. The result detected a conductive anomaly elongating from the mantle transition zone to the uppermost upper mantle just below the Society hotspot. This feature is consistent with the slow velocity anomaly obtained from the surface wave tomography (Suetsugu et al., 2009). We calculated differences in temperature between the conductive anomaly and the surrounding mantle using conductivity-temperature relationship for dry olivine based on laboratory measurements. The resultant temperature difference is about 400 K at the depth of around 100 km, which is much larger than that estimated from a past seismic study. These results might imply that the effects of partial melt and/or volatiles are necessary in order to explain the high electrical conductivity anomaly beneath the hotspot.

Keywords: hotspot, marine magnetotellurics, electrical conductivity, three-dimensional inversion, the French Polynesia

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

MIS35-20 Room:201A Time:May 24 15:30-15:45

Quantitative interpretation of electrical conductivity structure of the mantle

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Studies on electrical conductivity of the mantle based on magnetotelluric (MT) survey frequently discuss the water distribution in the mantle because the conductivity of the mantle minerals is thought to be highly sensitive to only small amount of water dissolved in minerals. The electrical conductivity is also strongly dependent on the temperature and the fraction and connectivity of the melt if the mantle is partially molten. Thus, it is impossible to distinguish the impacts of these parameters from the electrical conductivity alone and use of other independent information is indispensable to distinguish the impacts of each parameter.

In this presentation, I introduce my recent work on quantitative interpretation of electrical conductivity of oceanic upper mantle estimated from seafloor MT data. The keys are 1) selection of possible scenarios to reduce the model space to be searched, 2) self-consistency between temperature and existence of melt. For oceanic upper mantle, it is reasonable to test a thermal model like plate cooling or half-space cooling because these models explain the bathymetry subsidence and heat flow variation with the lithospheric age well. I here chose the model space of one-dimensional electrical conductivity associated with a thermal structure which is described as the function of lithospheric age, thickness of thermally conductive plate, and potential temperature. The effect of partial melting is taken into account by a self-consistent manner. I use the information about solidus temperature of the mantle rock and incipient melting process with the solidus reduction due to dissolved water and carbon to check if the melt is stable and how much melt is stable if so for given temperature and contents of water and carbon. The electrical conductivity can be calculated applying laboratory experiment models for hydrous olivine and hydrous carbonated melt. The MT response is produced from the conductivity structure by forward modeling and compared with the observed MT response in statistical sense. This procedure enables me to detect possible range of the parameters to explain the data and the trade-off relation of each parameter quantitatively. I show an example of application to real data obtained in the northwestern Pacific Ocean.

The future work must be a joint analysis with other observation, for example, seismic data to constrain each parameter more strictly reducing the trade-off relation.

Keywords: oceanic upper mantle, magnetotellurics, electrical conductivity structure, H2O, CO2, partial melt