Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SIT040-01 Room:104 Time:May 23 14:15-14:30

Accumulation of anti-continent at the base of the mantle and formation of the D” layer

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The continental crust is a unique reservoir of light elements in the solid Earth; it possesses an intermediate composition and is believed to have been created principally along volcanic arcs, which are major sites of terrestrial andesitic magmatism. Mantle-derived arc magmas are, however, generally mafic or basaltic. A simple mechanism to overcome this apparent dilemma and generate andesitic melts in such a setting is through the partial remelting of an initial mafic arc crust by heat supplied from underplating basaltic magmas. An antithesis to the formation of continental crust in this way should be the production of refractory melting residue, here referred to as ’anti-continent’. This anti-continent is likely to detach from arc crust as a result of a density inversion and descend into the upper mantle. High-pressure experiments of two end-member anti-continent compositions with and without olivine cumulates demonstrate that sinking anti-continent is, in contrast to the subducting oceanic crust, always denser than the surrounding mantle, suggesting that it penetrates through the upper-lower mantle boundary, without stagnation, and accumulates at the base of the mantle to form a 200-400 km thick mass known as the D” layer. Geochemical modeling provides further evidence that this accumulating anti-continent contributes to a deep-seated hotspot source. Therefore, through complementary processes, Earth creates buoyant continents and dense anti-continents at the top and the base of the mantle, respectively, and has recycled portions of anti-continent in mantle plumes.

Keywords: anti-continent, D” layer, recycle

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SIT040-02 Room:104 Time:May 23 14:30-14:45

Changes in physical properties of iron on high spin-low spin transition

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The properties of the major constituents of the Earth's inner core, i.e., iron and its alloys, have long been of great interest to geophysicists. Therefore, pure Fe under high pressure has been investigated by numerous theoretical and experimental studies. Under high pressure, the body-centered cubic (bcc) structure transforms into the hexagonal close-packed (hcp) structure, and this structure seems to be stable over a wide range of pressures and temperatures approaching those existing in the inner core. The magnetic state of iron has a major influence on the physical properties of iron and its alloys, including the relative stability of iron polymorphs. Although the magnetic structure of hcp-Fe has been investigated for over three decades, contradictory results from experimental and theoretical studies have been reported. We made use of a high-pressure diamond anvil cell apparatus and first-principles calculations using density functional theory, to investigate the physical properties of hcp-Fe at high pressures and high temperatures.

First-principles simulations were performed using the projector augmented wave implementation of the density functional theory using the Vienna ab initio simulation software package. For the Brillouin zone sampling at 0 K calculations, we used a large number of k-point grids, which provided the convergence of the total energy to within 1 meV/atom. We also used super-cells, gamma-point for the Brillouin zone sampling, a time step of 1 fs for the first-principles morecular dynamics simulations at high temperatures. High-pressure X-ray diffraction experiments were performed using a laser-heated diamond anvil cell. The samples were heated with a laser to overcome any potential kinetic effects on the possible phase transitions. The heated samples were probed using an angle-dispersive X-ray diffraction technique at the synchrotron beam lines. The angle-dispersive X-ray diffraction patterns were obtained on an imaging plate. The pressure was estimated from the observed unit cell volume of NaCl that was used as the pressure-transmitting medium, using the equation of state for B2-NaCl [1].

In high-pressure experiments, no structural phase transition in hcp-Fe was observed up to a maximum pressure of 110 GPa. An interesting variation in the ratio of the cell parameters (c/a) of hcp-Fe as a function of pressure was observed. As the pressure increased up to approximately 50 GPa, the c/a ratio decreased from 1.61 to 1.60. At pressures greater than 50 GPa, the ratio was approximately constant. According to our first-principles calculations, the magnetic moment of iron and the c/a ratio decrease up to approximately 55 GPa, and then the calculated c/a ratio increases slightly with increasing pressure. These calculated results were in good agreement with experimental observations. This indicated that the transition pressure of high spin-low spin state is approximately 50 GPa. As the spin state of iron could be estimated accurately using our calculations, we also calculated elastic properties of different spin states. For example, our calculations predict that the bulk modulus of the high spin state is 10% less than that of the low spin state [2]. Such change in elastic property should be considered to investigate the dynamic of the inner core.

[1] Ono et al. (2006) Structural property of CsCl-type sodium chloride under pressure. Solid State Communications, 137, 517-521.

[2] Ono et al. (2010) High-pressure magnetic transition in hcp-Fe. American Mineralogist, 95, 880-883.

Keywords: Iron, Spin transition, Inner core, High pressure experiments, First-principles calculations

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SIT040-03 Room:104 Time:May 23 14:45-15:00

Phase relation of C-Mg-Fe-Si-O system under various oxygen fugacity conditions: Implication for planetary interior

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Many exoplanets have been found recently based on the spectroscopic observation. A carbon-rich circumstellar gas was reported to exist around "beta-Pictoris", which has an exoplanet (Roberge et al., 2006). In such gas, carbon-enriched planet, "carbon-planet" may be formed. Carbon-bearing phase, such as carbide, carbonate, graphite and diamond are likely to compose the carbon-planet interior. Therefore, it is important to investigate phase relations of carbon-rich systems under high pressure conditions. In this study, C-enriched Mg-Si-Fe-O-C system was investigated at high pressure and temperature in order to understand the internal structure of the carbon-planet.

Phase relations were studied based on 2 series of experiments; (I)textural observation and chemical analysis of the recovered sample from 4 GPa and 1873K and (II)in situ X-ray diffraction experiments under high pressure and temperature. For the starting materials, we used several different oxide/metal components, as shown below: (i) MgCO3 + Fe + Si + C, (ii) (Mg1.8,Fe0.2)SiO4 + Fe + SiO2 + C, (iii) (Mg1.8,Fe0.2)SiO4 + Fe + Si + C, (iv) MgO + Fe + SiO2 + C, (v) MgO + Fe + Si + C. Oxygen fugacity (fO2) of the sample vaies depending on these assembleges due to different O amount in the starting materials. The sample was enclosed in graphite or MgO capsule. MgO capsule enables us to estimate fO2 in the sample based on the FeO content of the capsule contacting with the samples. Chemical analyses of the recovered samples were performed using an electron microprobe. In situ X-ray diffraction experiments were conducted at 4 and 15 GPa, and up to 1873 K at BL04B1 beamline, SPring-8 synchrotron facility.

Observed mineral/metal assemblages and their compositions vary depending on the redox condition of the sample. The compositions of metallic melt phases changes from Fe-C composition (C = 6.9~8.2 wt.%) in oxidizing conditions (deltaIW = -2.4 ~ -1.7) to Fe-Si composition (Si = 18 wt.%) in the more reducing condition (deltaIW $<$ -4.8). SiC grains were also found in the most reducing condition. The solubility of C into the Fe-melt phase increases with fO2, whereas the solubility of Si decreases with increasing fO2. Based on in situ X-ray diffraction experiments at 4 GPa, Fe3C was formed at 1073 K in the all samples. Fe3C peak disappeared and FeSi and SiC peaks appeared at 1373 K in the most reducing sample (v), whereas Fe3C remained in the other samples. Metallic phases in all samples were melted at 1673 K. In the experiment at 15 GPa, FeSi was formed at 1573 K and SiC was also observed at 1673 K in the sample (v). This is indicated that FeSi is stable at high pressure and reducing condition despite carbon-saturated condition. No carbonates was observed under the present experimental conditions. Therefore, carbon-bearing phases correspond to graphite/diamond, SiC and Fe-C alloy or Fe-Si-C alloy in the present redox conditions at 4~15 GPa. The present results may suggest that these carbon?bearing phases consist of carbon-planets interiors.

Keywords: Carbon-planet, Carbide, Silicon carbide, Oxygen fugacity

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SIT040-04 Room:104 Time:May 23 15:00-15:15

Waveform inversion of broadband body wave data for the S-velocity structure in the lowermost mantle beneath India

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We conduct waveform inversion for the radial shear velocity structure of the lowermost mantle beneath India using transverse component body wave waveform data obtained from the ORPHEUS and IRIS arrays in the passband 8?200 s for earthquakes that occurred in 1995-2006 beneath Southeast Asia with epicentral distances of 60?95 degrees. As we use higher frequency data than most previous waveform inversion studies, we make several improvements in the techniques. We introduce a new method for data correction. We also conducted tests to confirm the robustness of the results for several different starting models, and varying other conditions as well. The average S velocity of this region is almost the same as PREM, but we find that the velocity is faster than PREM between 2500?2750 km and slower than PREM between 2750 km? CMB. This suggests that the pv to ppv phase transition occurs in this region. Following Kawai & Tsuchiya (2009), if we assume the composition of D” is pyrolitic, the thickness of the thermal boundary layer in this region is about 250?300 km.

Keywords: waveform inversion, lowermost mantle, D”, beneath India

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SIT040-05 Room:104 Time:May 23 15:15-15:30

Lateral heterogeneity of the electrical conductivity in the lowermost mantle inferred from geomagnetic jerks

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Geomagnetic jerks are abrupt changes in the linear trend of the geomagnetic secular variation, and are the surface observable shortest-period components of the geomagnetic field variation of core origin. Hence, the jerks have been studied by many authors to infer dynamics of the core and the electrical conductivity of the lower mantle in the last few decades. Geomagnetic jerks are traditionally studied using time series of the magnetic field recorded in geomagnetic observatories. The uneven distribution of the observatory network precludes the investigation of global distribution of the geomagnetic jerks, and internal origin of the jerks have been questioned by a number of authors. Recently, as a result of continuous satellite measurements since 1999, the magnetic fields and their variations can now be described with high resolution in space and time, and the internal origin of most of the known jerks and their global nature are now firmly established. Since jerks are generated in the core, they will pass through the electrically conducting mantle, before arriving at the surface. Consequently, the geomagnetic field observed at the surface will correspond to a filtered version of the original field generated in the core. Even an 1D electrical conductivity distribution in the mantle exerts screening effects such as delaying and smoothing of signals on the surface observed geomagnetic field. Moreover, a laterally heterogeneous electrical conductivity structure causes more dramatic changes in time and space on the magnetic fields come through the heterogeneous layer. Recent discovery of the postperovskite phase change at the lowermost mantle, and the measurements of the electrical conductivity in the high P and high T condition expected at the bottom of the mantle, predict very high and heterogeneous electrical conductivity structure in the lowermost mantle adjacent to the core surface. Observation of the geomagnetic jerks at the Earths surface may reveal this possible electrical conductivity heterogeneity in the lowermost mantle. For that purpose, however, we need to estimate the source field in the core.

In the present study, filtering effects of an electrically heterogeneous layer in the lowermost mantle on the short-period variations of the geomagnetic field of core origin are examined by using a newly formulated induction equations in a 3D heterogeneous mantle (Hamano, 2002). As the source field at the core surface, we use the temporal variations of toroidal and poloidal magnetic fields obtained by the high-resolution MHD dynamo models (Sakuraba and Roberts, 2009), in which high frequency variations of magnetic fields such as torsional oscillations are clearly reproduced. Results of the numerical calculation indicate that the heterogeneous layer in the lowermost mantle cause very complicated spatial variations of the surface geomagnetic field reflecting the pattern of the electrical conductivity heterogeneity in the lowermost mantle.

Keywords: geomagnetic jerks, geomagnetic field, geodynamo, electrical conductivity structure, lowermost mantle

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SIT040-06 Room:104 Time:May 23 15:30-15:45

A sharp lateral gradient of shear-wave velocity at the western edge of the Pacific LLSVP

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The western margin of the Pacific LLSVP (Large Low Shear Velocity Province) in the D” region is investigated. The differential travel times of ScS-S are measured for the rays propagating along nearly the north-south direction, which is considered to be parallel to the strike direction of the western boundary of the Pacific LLSVP. Over 190 high-quality ScS-S differential travel times from 52 events occurred in the North Pacific and Southeast Asia recorded at the broadband stations in Japan and Australia are used. The differential travel times were corrected for the contribution above D” (250 km above the CMB) using eight global tomography models. The abrupt change in the differential travel times is very clearly observed beneath the region East of Philippine Islands, indicating a sharp lateral boundary in shear-wave velocity across this region. The Vs contrast of up to 4 percent is observed beneath the region from -4 to 4 degrees in latitude and 130 to 140 degrees in longitude, within 400-600 km. We will discuss the possible origin of the structure in terms of the thermal and chemical anomalies.

Keywords: Pacific LLSVP, ScS, D”, lowermost mantle, plume

SIT040-07 Room:104 Time:May 23 15:45-16:00

Study of melting phenomena under the deep mantle conditions

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It is known that the subducting plate carry the Earths surface materials (such as the basaltic crust) to the Earths deep interior. As a result of this process, the mantle is highly heterogeneous in chemical composition. At the core-mantle boundary, there is a possibility that Mid Ocean Ridge Basalt (MORB) exists and it causes the seismic anomalies. Seismological studies indicate the presence of Ultra-Low Velocity Zone (ULVZ) above the core-mantle boundary (Williams and Garnero, 1996). This region exhibits reduction of seismic velocities at least 10% and the thickness of this region is about 5 - 40 km. The most probable cause of the seismic velocity reduction is partial melting of the lowermost mantle.

In this study, We carried out melting experiments of MORB using a laser heated diamond anvil cell to investigate the melting phase relations of MORB. The phase relations in MORB were investigated from 31 to 156 GPa and 1500 to 4400 K by in situ X-ray diffraction experiments and chemical analysis of the quenched samples using field emission-scanning electron microscope (FE-SEM) and transmission electron microscopy (TEM). In-situ X-ray diffraction experiments were performed at SPring-8 to determine the subsolidus phase assemblage. The MORB composition consists of MgSiO3-perovskite, CaSiO3-perovskite, stishovite, and Al-rich phase (likely CaFe2O4-type Al-phase) in the upper part of the lower mantle. Stishovite transforms to CaCl2-type SiO2 phase above 60 GPa and 2000 K and further to alpha-PbO2-type phase above 110 GPa. Phase transition of CaSiO3-perovskite from tetragonal to cubic was also observed with increasing temperature. At 37 GPa, the first consuming phase is likely to be stishovite and the melting temperature is 2700 K. At 118 GPa, the first consuming phase is also alpha-PbO2-type SiO2 phase and the temperature is 3700 K.

Keywords: MORB, lower mantle, melting

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SIT040-08 Room:104 Time:May 23 16:00-16:15

Constraints on the 3D shape of the ultra low shear velocity zone at the base of the mantle beneath the central Pacific

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Prominent postcursors to S/Sdiff waves with delays as large as 26 s are observed in Northern America for Papua New Guinea events (To et al., 2011). The emergence of the postcursor is explained by placing a laterally localized ultra low shear velocity zone (ULVZ, dVs/Vs < -25%) on the CMB, which is fully or partially covered by a broad and weak anomaly region (dVs/Vs -5%). The ULVZ is located beneath the central Pacific.

In the previous study, we limited our focus to an azimuthal range around 60 degrees from the source in Papua New Guinea, where the records show a relatively small azimuthal variation, suggesting a relatively small 3D effect there. We attempted 2D structural modelling along the great circle plane towards stations in southern US. The modelling was limited in 2D, partly due to the sparse station distribution in Midwestern US at the time.

In this study, I investigated USArray station data and further constrained the 3D shape of the ULVZ. The postcursors to S/Sdiff waves are observed at 240 USArray stations for an event, which occurred at Papua New Guinea in 2010. The records from the large number of stations enable me to conduct array analysis. First, I mapped the variation of the incident azimuth of the secondary arrival to the stations. In southern stations, which are located along the azimuth of approximately 60 degrees from the source, the postcursors arrive approximately from the direction of the great circle plane between the source and stations. On the other hand, in northern stations, which are located along the azimuth of 52 degrees from the source, the postcursors arrive from the azimuth of 5 to 10 degrees to the south with respect to the direction of the great circle plane. Second, I compared the observed amplitude of the main S/Sdiff phase with synthetic waveforms created by Direct solution method (Kawai et al., 2006). The comparison shows that the amplitude of the main phase become very small at stations which are located at the distance around 100 degrees and the azimuth of 50 degrees from the source. These observations indicate that the ULVZ, located beneath the central Pacific, is elongated in the east-west direction.

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SIT040-09 Room:104 Time:May 23 16:30-16:45

Viscosity of the D” layer inferred from the decay time of Chandler wobble and tidal deformation

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Viscosity of the D” layer of the Earth’s mantle, the lowermost layer in the Earth’s mantle, plays an important role in the dynamics and evolution of the Earth. That is, its rheological properties control a number of important geodynamic and geochemical processes such as chemical interactions between the mantle and core and the nature of the observed ultralow-velocity regions in D” layer. However, inferring the viscosity of this region is difficult because of the lack of relevant geodynamic observations. A commonly used analysis of geophysical signals in terms of heterogeneity in seismic wave velocities suffers from major uncertainties in the velocity-to-density conversion factor, and the glacial rebound observations have little sensitivity to the viscosity of the D” layer. In this paper, we show that the decay time of Chandler wobble and semi-diurnal to 18.6 years tidal deformation combined with the constraints from the postglacial isostatic adjustment observations provide a strong constraint on the viscosity of this layer. The decay time of Chandler wobble (30-300 years) indicates the effective viscosity of the D” layer (~300 km thickness) to be 10^19-10^20 Pa s, and the tidal deformation with periods less than 20 years suggests the bottom of the D” layer (~100 km thickness) to be less than 10^18 Pa s. The viscosity structure may be consistent with the temperature distribution inferred from the double-crossing of seismic rays of the phase boundary between perovskite and post-perovskite. The results have a number of implications including the core-mantle interaction through small-scale convection and the interpretation of the ultralow velocity region in terms of partial melting.

Keywords: D” layer, viscosity, Chandler wobble, tidal deformation

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SIT040-10 Room:104 Time:May 23 16:45-17:00

Numerical simulations on fall of stagnant slabs into the lower mantle

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Global seismic tomography has recently revealed horizontally lying slabs near the upper and lower mantle boundary beneath the Northwestern Pacific region. Although physical mechanisms that could produce such slab stagnation have been proposed based on numerical simulations, there has been little research into what occurs after slab stagnation. We proposed trench advance and trench jumps as effective mechanisms related to the fall of stagnant slabs into the lower mantle, and our numerical simulations of temperature and fluid flow associated with slab subduction in a 2-D box model confirmed these mechanisms. Our results indicate that a supply of slab material associated with further slab subduction after slab stagnation plays an important role in differentiating further slab stagnation from the falling of slabs into the lower mantle. A shortage of material supply would produce extended slab stagnation near the 660-km boundary for ringwoodite to perovskite + magnesiowustite phase transformation, whereas downward force due to further slab subduction on a stagnant slab would enhance its fall into the lower mantle. The behaviors of falling stagnant slabs were not affected by Clapeyron slope values associated with phase equilibrium transformation within the range from -3.0 to 0.0 MPa/K. Compared with models of normal mantle viscosity, a high-viscosity lower mantle played a role in hindering the fall of slabs into the lower mantle, resulting in complicated shapes and slow falling velocities. Lower mantle viscosity structure also affected slab behavior. Slabs tended to stagnate when a low-viscosity zone (LVZ) existed just below a depth of 660km because friction between the slab and the LVZ was weak there. Slab stagnation around a depth of 660km also occurred when a high-viscosity zone existed below a depth of 1200km and acted as a resistive force against a slab, even if the slab existed in the lower part of the upper mantle.

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SIT040-11 Room:104 Time:May 23 17:00-17:15

Post-spinel transitions in pyrolite and Mg2SiO4:Effect of solid-solution components on the post-spinel transition

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It is widely accepted that the 660-km discontinuity of the interior of the earth is due to post-spinel transition of spinel which is the major mantle mineral. This transition pressure in Mg_2SiO_4 and pyrolite which has a representative composition of the upper mantle have been examined with a quench method and in situ XRD observation by many investigations. But it is still discussed whether this transition really corresponds to the 660-km discontinuity or not, because there are problems of uncertainty of pressure in pressure scales, and so on. In high-pressure experiments on Mg_2SiO_4 and pyrolite, our results indicated that the post-soinel transition in pyrolite occurs at lower pressure by 0.1-0.5 GPa than that in Mg_2SiO_4, and the Clapeyron slope in pyrolite is more gentle than that in Mg_2SiO_4. Therefore, we have expected that the cause of decline of transition pressure and the Clapeyron slope is due to effect of solid-solution components (Fe^{2+}, Fe^{3+}, Al^{3+}) other than Mg^{2+}, and have compared the influence on post-spinel transition of these components using a multicell technique.

As starting materials, we prepared a mixture of Mg_2SiO_4 : Fe_2SiO_4 = 9 : 1 with mole ratio ($Fo_{90}Fa_{10}$), Mg_2SiO_4 and $MgSiO_3$: Fe_2O_3 : Al_2O_3 = 85 : 15 (mole ratio) with 6 : 4 (weight ratio) (Fo+En+$FeAlO_3$), Mg_2SiO_4 and $MgSiO_3$: Al_2O_3 = 85 : 15 (mole ratio) with 6 : 4 (weight ratio) (Fo+En+Al_2O_3). High-pressure experiments were made at 22.3-24.5 GPa and 1200-1600C with a Kawai-type 6-8 multianvil apparatus. Three sample combinations in one run were (Mg_2SiO_4, $Fo_{90}Fa_{10}$ and Fo+En+$FeAlO_3$) and (Mg_2SiO_4, Fo+En+$FeAlO_3$ and Fo+En+Al_2O_3). Three samples were packed in a Re capsule with three holes, kept simultaneously at desired pressure-temperature conditions for 3 hours, quenched and recovered after the run. Phase identification of each sample was made with a microfocus X-ray diffraction apparatus, and compositional analyses of them were made with a SEM-EDS.

The post-spinel transition pressure in $Fo_{90}Fa_{10}$ is slightly higher than that of Mg_2SiO_4, and those of Fo+En+$FeAlO_3$ and Fo+En+Al_2O_3 are lower than. Two transitions in Fo+En+$FeAlO_3$ and Fo+En+Al_2O_3 were a reaction from ringwoodite + garnet to perovskite + magnesiowustite (or periclase) + garnet. The results suggest that Fe^{2+} makes the transition pressure higher, and Fe^{3+} and Al^{3+} make it lower. $Fo_{90}Fa_{10}$ has a similar Clapeyron slope to Mg_2SiO_4. On the other hand, the Clapeyron slope of Fo+En+$FeAlO_3$ is more gentle than that of Mg_2SiO_4. This trend is consistent with the results of phase relations in pyrolite. Therefore, we conclude that the effect of Al^{3+} on the post-spinel transition pressure is more than Fe^{2+} and Fe^{3+}.

Keywords: postspinel transition, ringwoodite, perovskite, 660km discontinuity, high pressure experiment

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SIT040-12 Room:104 Time:May 23 17:15-17:30

An in situ measurement of creep strength of wadsleyite in a D-DIA apparatus at P-T conditions of mantle transition zone

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In order to study creep strength of wadsleyite at P-T conditions of the mantle transition zone, technical developments have been made by optimization of a multi-anvil 6-6 (MA6-6) assembly for extending P-T conditions of in situ stress-strain measurements in a deformation-DIA (D-DIA) apparatus over 10 GPa and 600 K. Deformation experiments of wadsleyite were conducted using a cubic-anvil apparatus SPEED-Mk.II with a D-DIA system, which was newly installed in 2010, at BL04B1 beamline of SPring-8. We used second-stage anvils made of cubic BN and tungsten carbide with a truncated edge length of 2.5 mm. The stress and the strain of wadsleyite were quantitatively determined at experimental processes including deformation at high P-T conditions using in situ X-ray radial diffraction and radiography, respectively. In the optimization, efficiency of pressure generation was improved to adjust dimensions of a preformed gasket, and materials with low X-ray absorption were adopted for materials of second-stage anvils, columns of an anvil guide and an X-ray window in a LaCrO3 heater to reduce X-ray absorption. As a result of the optimization, the P-T conditions of the in situ stress-strain measurements in the D-DIA apparatus were extended to 15.3 GPa and 1700 K. Using the developed technique, uniaxial deformation on wadsleyite was achieved to the strain of 19 % at the strain rate of 3.7 x 10^-5 s^-1 and at 15.3 GPa and 1700 K. In this study, the stress-strain measurements on wadsleyite were succeeded at the P-T conditions of the mantle transition zone and at controlled strain rate. The present study extended the P-T range of the measurements in the D-DIA apparatus from 9.6 GPa in early studies to 15.3 GPa at high temperature corresponding to interior of the earth. The experimental results demonstrate potential of the present deformation system composed of the D-DIA apparatus and the MA6-6 assembly as an important tool to investigate the creep strength of deep mantle minerals under the P-T conditions of an upper part of the mantle transition zone.

Keywords: wadsleyite, creep strength, mantle transition zone, deformation-DIA apparatus, in situ measurement, synchrotron

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SIT040-13 Room:104 Time:May 23 17:30-17:45

On the influence of whole-mantle heterogeneity on teleseismic tomography

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Teleseismic tomography has become a powerful tool to determine the 3-D upper mantle structure under a region covered by a seismic network since this approach was firstly proposed by Aki et al. (1977). A basic assumption of teleseismic tomography is that the lower mantle is homogeneous, thus the use of relative travel-time residuals is assumed to remove the effects of earthquake mislocation and the structural heterogeneities outside of the study area, and the relative travel-time residuals from the teleseismic events only reflect the 3-D structure under the seismic network. However, global tomography studies have revealed various scales of structural heterogeneities in not only the upper mantle but also the lower mantle, such as deep subducted slabs and mantle plumes. Thus the whole-mantle heterogeneities would contribute partially to the observed relative travel-time residuals, and as a result affect the determination of 3-D velocity structure under the study area. However, so far no one has addressed this issue and it is unclear how much the whole-mantle heterogeneity would influence the teleseismic tomography. In this study we have investigated this problem for the teleseismic tomography beneath the Japan Islands. We used about 45,000 P-wave data from 360 teleseismic events recorded by the J-Array and Hi-net stations, in addition to about 230,000 P-wave arrival times from 1180 local shallow and deep earthquakes under the Japan Islands. We calculated theoretical travel times from each teleseismic event to the stations in Japan in a 3-D whole-mantle P-wave velocity model (Yamamoto and Zhao, 2010) and the 1-D iasp91 Earth model. We found that the differential travel time for the two models (T3d-T1d) is in the range of -0.3 s to +0.3 s, though it is -0.2 s to +0.2 s for most of the rays, which is equal to or larger than the picking errors of the teleseismic data (0.1-0.2 s). Therefore the effect of whole-mantle heterogeneity on the teleseismic residuals is significant and so it should be corrected. We have taken into account this effect and obtained a better 3-D P-wave velocity structure down to 700 km depth beneath the Japan Islands. Our results show that the Philippine Sea slab has subducted aseismically down to 300-500 km depth under SW Japan. Low-velocity (low-V) anomalies are imaged clearly in the central part of the mantle wedge above the subducting Pacific slab. The low-V zones exist not only under the Honshu land area but also extend westward beneath the Japan Sea. We also imaged low-V zones which seem to be caused by the deep dehydration of the Pacific slab at 300-400 km depths. A low-V zone is revealed at depths of 500-700 km in the mantle beneath the Pacific slab under Southern Tohoku and Kanto, which may reflect an upwelling flow from the lower mantle.

Keywords: teleseismic events, tomography, mantle, heterogeneity, slab

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SIT040-14 Room:104 Time:May 23 17:45-18:00

Neutrino absorption tomography with IceCube detector

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The neutrino absorption tomography, using neutrino as a probe of Earth's density profile, has been expected to give an independent observation of core density and core-mantle boundary.

Neutrinos are elementary particles that rarely interact with materials. Due to their small cross section, most of them penetrate through the Earth without leaving any trace of existence.

However, since the cross section increases as the neutrino energy increase, some of high-energy neutrinos are absorbed inside the Earth. This absorption probability directly depends on number of target nucleons, thus it is also sensitive to density profiles of targets.

The advantage of the neutrino tomography is direct measurement of matter density: while other geophysics techniques depend on convoluted effect of density, temperature and chemical structure.

Nevertheless, the neutrino absorption tomography had been a future project due to following reasons.

1) It requires high-intensity neutrino beam with energy over ~10TeV.

2) Must use large volume neutrino telescope(s) in order to detect reasonable amount of neutrinos which rarely interact inside the telescope volume.

For 1), using atmospheric neutrino is one of the practical solutions. It is challenging, however, because the energy flux over a few ten TeV is not measured well yet. Also the event rate at the required energy is much less than the one of energy below TeV, which results in a long-term measurement.

For 2), the project needs to use at least a kilometer scale telescope. Now we have only one solution: using IceCube detector completed in January 2011.

The IceCube neutrino telescope, deployed in the depths between 1500m and 2500m at the South Pole glacier ice, started operation from 2005 with 60 optical sensors attached on 1 detector-string.

The deployment carried out within summer season at South Pole and 15~20 strings are deployed in each season. Meanwhile at north hemi-sphere, obtained neutrino data were analyzed for searching extraterrestrial neutrinos or measuring atmospheric neutrino spectrum.

From season 2007 to 2008, with 22 strings and 40 strings respectively, approximately 20000 neutrinos were observed.

In this study, we analyzed the 2007 and 2008 neutrino data and compared them with Monte-Carlo simulations based on several Earth models.

Our simulation with the Preliminary Reference Earth Model represents the data within statistic errors. It is the first indication of neutrino deficit due to the Earth's core with neutrino absorption tomography.

We also present future expectation of this analysis with 10 years operation of full-size IceCube.

Systematic uncertainty from atmospheric neutrino flux, energy reconstruction, detector calibration, and bed-rock density will be discussed as well as ongoing plans to reduce these systematics.

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Keywords: Neutrino absorption tomography, IceCube

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Reaction of hydrogen molecule and olivine under high pressure and high temperature condition

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The oxidation state of the Earth's mantle is reduced with depth, and the composition of C-O-H fluids is controlled by the oxidation state. In the deeper part of the upper mantle, H2-fluids exist in addition to H2O fluids. Many previous studies showed that influence of H2O to olivine. However, influence of H2 to olivine was not studied. High-pressure and temperature experiments of forsterite-hydrogen system were performed using Laser heated diamond anvil cell. A lever- and spring-type diamond anvil cell (DAC) was used in the high pressure experiment. For pressure measurements, a ruby fluorescence method was used. Heating experiments were performed with CO2 laser heating systems. After quenching, XRD and Raman spectroscopy measurements were performed at high pressure and room temperature.

Keywords: upper mantle, hydrogen, olivine, laser heated diamond anvil cell

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SIT040-16 Room:104 Time:May 23 18:15-18:30

Radially Anisotropic Shear Wave Structure of Australian Region from Multi-mode Surface Wave Tomography

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We developed a new three-dimensional shear wave speed model for the upper mantle beneath the Australian region from multi-mode surface waves. A large number of phase speed data from both Love and Rayleigh waves are extracted from three-component seismic records of seismic stations in the Australia and its surrounding region over the period between 1990 and 2008, using the networks reporting to IRIS, as well as portable seismic arrays deployed by the Australian National University.

We used a fully automated technique of multi-mode dispersion measurements with a nonlinear waveform fitting based on a direct model-parameter search using the Neighbourhood Algorithm. Over 6,000 paths for both Love and Rayleigh waves are collected to cover the entire Australian continent, which allow us to extract lateral heterogeneity as well as radial anisotropy with extended horizontal and vertical resolution. The path-specific phase speeds are inverted to produce multi-mode phase speed maps incorporating approximate finite-frequency effects via the surface-wave influence zone, within which surface waves can be considered to be coherent in phase. A 3-D radially anisotropic shear wave speed model is then derived from simultaneous inversions of local dispersion curves of multi-mode Love and Rayleigh waves.

The new 3-D model shows a good correlation of fast shear wave speed anomalies with regions of Archaean and Proterozoic cratons in the western and southern Australia down to a depth of about 200 km. Owing to the enhanced vertical resolution with the higher mode information, the subduction of the Australian plate in the north beneath Indonesia has also been mapped clearly. Three-dimensional distribution of radial anisotropy indicates faster SH anomaly than SV beneath the central and western Australia down to about 300 km depth, indicating possible effects of strong shear motion in the lithosphere-asthenosphere boundary beneath the continent.

Keywords: surface wave, tomography, anisotropy, continent, Australia