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

Yoshiyuki Tatsumi[1*], Toshihiro Suzuki[1], Haruka Ozawa[1], Kei Hirose[2], Takeshi Hanyu[1], Yasuo Ohishi[3]

[1]IFREE, JAMSTEC, [2]Tokyo Institute of Technology, [3]JASRI

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

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

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

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

Shigeaki Ono[1]*

[1]JAMSTEC

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

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

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

Suguru Takahashi[1*], Eiji Ohtani[1], Hidenori Terasaki[1], Yoshinori Ito[1], Ken-ichi Funakoshi[2], Yuji Higo[2]

[1]Graduate School of Science, Tohoku Univ., [2]JASRI

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

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

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

Kensuke Konishi[1*], Kenji Kawai[2], Robert J. Geller[1], Nobuaki Fuji[3]

[1]EPS, University Tokyo, [2]EPS, Tokyo Institute of Technology, [3]Universite de Toulouse; UPS-OMP; IRAP;, [4]CNRS; IRAP; 14, Avenue Edouard Belin, F-

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

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

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

Yozo Hamano[1*], Ataru Sakuraba[2]

[1]IFREE, JAMSTEC, [2]Univ. of Tokyo

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

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

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

Koki Idehara[1*], Satoru Tanaka[2], Nozomu Takeuchi[1]

[1]ERI, University of Tokyo, [2]IFREE, JAMSTEC

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

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

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

Study of melting phenomena under the deep mantle conditions

Naoya Nishitani[1*], Eiji Ohtani[1], Takeshi Sakai[2], Masaaki Miyahara[1], Naohisa Hirao[3], Yasuo Ohishi[3], Masahiko Nishijima[4], Motohiko Murakami[1]

[1]Tohoku Univ., [2]IIAIR,Tohoku Univ., [3]JASRI, [4]Tohoku Univ. IMR

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

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

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

Akiko To[1*]

[1]IFREE JAMSTEC

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.

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

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

Masao Nakada[1*], Shun-ichiro Karato[2]

[1]Kyushu University, [2]Yale University

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

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

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

Numerical simulations on fall of stagnant slabs into the lower mantle

Shoichi Yoshioka[1*], Aya Naganoda[2]

[1]RCUSS, Kobe University, [2]Earth and Planetary Sci., Kyushu Univ.

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.

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

Takayuki Ishii[1*], Hiroshi Kojitani[1], Masaki Akaogi[1]

[1]Gakushuin Univ.

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

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

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

Takaaki Kawazoe[1*], Yu Nishihara[1], Tomohiro Ohuchi[1], Norimasa Nishiyama[1], Yuji Higo[2], Ken-ichi Funakoshi[2], Tetsuo Irifune[1]

[1]Ehime University, GRC, [2]Japan Synchrotron Research Institute

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 10ˆ-5 sˆ-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

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

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

On the influence of whole-mantle heterogeneity on teleseismic tomography

Dapeng Zhao[1*], Takahiro Yanada[1], Yoshihiro Yamamoto[2]

[1]Tohoku University, [2]Ofunato High School

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

Kotoyo Hoshina[1*], Hiroyuki Tanaka[1]

[1]Earthquake Research Institute

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.

This study is supported by University of Wisconsin-Madison, IceCube group.

Keywords: Neutrino absorption tomography, IceCube

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

SIT040-15 Room:104 Time:May 23 18:00-18:15

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

Ayako Shinozaki[1*], Hisako Hirai[1], Tadashi Kondo[3], Hiroyuki Kagi[4], Takehiko Yagi[2]

[1]Ehime University, [2]ISSP Univesity of Tokyo, [3]Osaka University, [4]Univesity of Tokyo

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

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

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

Kazunori Yoshizawa[1*], B.L.N. Kennett[2]

[1]Faculty of Science, Hokkaido Univ., [2]RSES, Australian National Univ.

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

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

SIT040-P01 Room:Convention Hall Time:May 23 10:30-13:00

Melting experiments of the Martian mantle and origin of shergottite

Yoko Nagayo[1*], Kyoko Matsukage[1]

[1]Ehime University, GRC

The basaltic and olivine-phyric meteorites from the Martian surface, shergottites, are known to differ from the Earth's basalts in chemistry. The parent magma of Martian basalts are estimated to be enriched in Fe and depleted in Al. Basaltic rocks are generally considered to originate from liquid part of the mantle material which suffered partial melting. Therefore, these chemical variations in shergottites indicate that the Martian mantle also has Fe-rich and Al-poor composition. Melting experiments on Fe rich mantle have been performed at 1.5-3.0 GPa by Bertka and Holloway (1994) and at 3.0-10 GPa by Draper and his coworkers (e.g., Draper et al., 2001; Wasserman et al., 2001; Agee and Draper, 2004). Parent magmas of shergottite, however, could not be produced by partial melting in this pressure range (Agee and Draper, 2004). Here, we point out that the solidus temperature reported by Borg and Draper (2004) is higher than that by Bertka and Holloway (1994). The difference is more than 150 ^{0}C at 3.0GPa, although the chemical composition of starting materials was almost same in the both studies. In this study, we performed melting experiments of Fe-rich Martian mantle between 1.0 and 5.0GPa in more reliable experimental conditions, and discussed the origin of shergottite magma.

The DW Martian mantle composition model which is suggested by Dreibus and Wanke (1985) is used as our starting material in the system SiO_2-TiO_2-Al_2O_3-Cr_2O_3-FeO-MgO-CaO-Na_2O. We reduced the synthesized starting material in a gas mixing furnace, oxygen fugacity at QFM, 1000 ^{0}C for 5 h. Pt/Re double capsules are used for all our experiments for reduction of Fe-loss from the sample. We used multi-anvil apparatus for the experiments at 5.0 GPa and piston-cylinder apparatus (Takahashi lab. in Tokyo Tec.) at 1.0 and 2.5 GPa. The experimental conditions are 1300- 1700 ^{0}C in temperature and 1-24 h in duration. We used SEM-EDS to analyze the chemical composition and to identify the mineral phases. We also calculated the degree of melting with image-editing software.

In our experiments, the solidus temperature at 5.0 GPa is around 1500 ^{0}C and liquidus temperature is 1750 ^{0}C, which indicates that the solidus and liquidus temperature of this study is about 100 ^{0}C lower than Agee and Draper (2004). At 2.5 and 1.0 GPa, solidus temperature is approximately 1400 and 1300 ^{0}C respectively which is a little higher than Bertka and Holloway (1994). Phase relation shows a good agreement with Bertka and Holloway (1994), Agee and Draper (2004) except for spinel stability field that is wider in our experiment up to 1400 ^{0}C. The chemical composition of partial melt from our experiments has low in Si content and high in Mg/(Mg + Fe) atomic ratio, compared to the calculated data of the parent shergottite magma by previous studies (e. g., McSween et al., 1988; Schwandt et al., 2001; Harvey et al., 1993). In Al and Ca contents, parent shergottite magma is comparable with the partial melts of DW mantle from our experiments at 2.5 and 5.0 GPa, which is lowest pressure condition of garnet stability field in Martian mantle. Consequently, we estimate that the primitive magma of Mars could be generated between at 2.5 and 5.0 GPa where 200-400km deep in the Martian mantle if the DW mantle is a host material of basaltic shergottites.

Keywords: Mars, mantle, shergottite, partial melting, high pressure and temperature experiments

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

SIT040-P02 Room:Convention Hall Time:May 23 10:30-13:00

Density measurement of liquid Fe-C at high pressure and Implication for Earth's Outer core

Yuta Shimoyama[1*], Eiji Ohtani[1], Hidenori Terasaki[1], Keisuke Nishida[1]

[1]Tohoku University

Seismological and experimental studies show that the Earth's outer core is approximately 10% less dense than molten iron at corresponding pressure and temperature conditions, implying that some light elements exist in the core. Carbon is one of the plausible candidate of the light element in the core, because that the volatility of carbon is only significant at pressures less than 10^{-1} bar and the solubility of carbon in molten iron is large even at 1 bar. Based on the effect of pressure on carbon solubility into iron and thermodynamic calculation, 2-4 wt% carbon is estimated to be in the core. In this study, we measured the density of liquid Fe-3.5wt%C , which corresponds nearly eutectic composition, at 5-9GPa and 1923K using sink/float method. This method is applied using composite density marker which composed of Pt disk core and Al_2O_3 tube mantle. The present results revealed that the effect of pressure on the density of liquid Fe-C. If the density and the bulk modulus(K) are known, the compressional wave velocity, V_P, can be calculated. Therefore, comparing the calculated V_P value of liquid Fe-C with that of the PREM model (Dziewonski and Anderson, 1981), and we evaluated a possibility of existence of carbon in the core. The obtained results revealed that the addition of carbon to liquid Fe decreased the density whereas it did not affect the bulk modulus.

Keywords: high pressure, density, Bulk sound velocity, liquid Fe-C

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

SIT040-P03 Room:Convention Hall Time:May 23 10:30-13:00

Waveform inversion for S-velocity structure in the lowermost mantle beneath the Southern Pacific

Kei Hasegawa[1*], Kensuke Konishi[1], Robert J. Geller[1], Nobuaki Fuji[3], Kenji Kawai[2]

[1]EPS, University of Tokyo, [2]EPS, Tokyo Institute of Technology, [3]Universite de Toulouse,UPS-OMP;CNRS,IRAP

We conduct waveform inversion for the vertical profile of shear velocity in the D” layer beneath the Southern Pacific. We use the transverse component of relatively long period broadband waveforms (20-200s), obtained from IRIS for earthquakes from 1993 to 2010. We find lower S-velocity relative to PREM in the depth range from 0-150km above the core-mantle boundary (CMB), and higher S-velocity relative to PREM in the depth range from 150-300km above the CMB. This is consistent with a phase transition from perovskite to post-perovskite. The average S-velocity in D” is the same as or slightly faster than PREM, which is roughly consistent with previous global D” velocity models.

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

SIT040-P04 Room:Convention Hall Time:May 23 10:30-13:00

Ab initio lattice thermal conductivity of deep mantle minerals

Haruhiko Dekura[1*], Taku Tsuchiya[2], Jun Tsuchiya[1]

[1]SRFC, Ehime Univ., [2]GRC, Ehime Univ.

The core-mantle boundary heat flow depends on the thermal conductivity of the base of Earth's lower mantle. Direct measurement of thermal conductivity of minerals remains technically challenging at the deep mantle condition. On the other hands, *ab initio* computational technique based on the density functional theory (DFT) allows us to examine microscopic process of the transport phenomena including the lattice thermal conduction. Earlier theoretical works calculated the lattice thermal conductivity of MgO with *ab initio* molecular dynamics (MD) simulation or direct evaluation of third-order anharmonic force constants to compute phonon-phonon interaction (Nico de Koker, Phys. Rev. Lett. **103**, 125902, 2009, X. Tang and J. Dong, Proc. Natl. Acad. Sci. U.S.A. **107**, 4539, 2010). However, in these approaches, the simulation cell is often insufficient to accurately calculate the long wave-length phonon-phonon interactions. This leads to a lack of the decay channels for the phonons. For a more reliable way, the anharmonic coupling between phonon modes can be calculated within density functional perturbation theory (DFPT). In this approach, the higher-order force constants are calculated based on the perturbative scheme taking care only of the primitive cell. In this presentation, we show the phonon decay and the lattice thermal conductivity of MgO in the lower mantle conditions.
Research supported by Senior Research Fellow Center, Ehime University.

Keywords: first principles calculation, lattice thermal conductivity, phonon-phonon interaction, deep mantle minerals

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

SIT040-P05 Room:Convention Hall Time:May 23 10:30-13:00

Hydrous phase in water-saturated MORB at the lower mantle conditions

Keihou Ishio[1*], Tadashi Kondo[1], Takumi Kikegawa[2]

[1]Graduate School of Science, Osaka Univ, [2]IMSS KEK

Mantle minerals as water reservoir are important issue to consider the structure, dynamics and evolution of the Earth. We investigated the water saturated MORB system under high pressure and high temperature using laser-heated diamond anvil cell (LHDAC) combined with in-situ X-ray diffraction method at AR-NE1, KEK(Tsukuba, Japan). Starting materials were synthetic glass with a MORB component and distilled water. The experimental pressure and temperature range are up to 70GPa and 1700K, respectively. X-ray diffraction experiments were performed using monochromatic X-ray with 30keV and imaging plate detector. Pressures are determined by the eqution of state of gold. We found PhaseD exist in the heated sample with coexist phases of Ca-Perovskite, Mg-Perovskite, Stishovite, and CF-Phase, though no significant hydrous mineral has been reported In the previous experiments on dry and wet MORB. The decomposition of phase D was also observed above 60GPa. The appearance of phaseD seems to be related with small intensity from the Mg-perovskite phase. Bulk modulus of each phase was well consistent with the previous reports in the literature. However the absolute volume was slightly different from those in literature. The present results indicate that PhaseD, which could contain up to 19.wt% of water, is one of the candidate minerals as a water reservoir in subducting slab in the lower mantle condition if it was locally in water-saturated condition. The details of experiments and analysis will be presented with analysis of the recovered samples.

Keywords: LHDAC, MORB, Hydrous minetals, PhaseD, Lower mantle, KEK

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

SIT040-P06 Room:Convention Hall Time:May 23 10:30-13:00

Mg, Si-bearing delta-AlOOH as a reserver of water in the lower mantle

Itaru Ohira[1*], Eiji Ohtani[1], Takeshi Sakai[2], Masaaki Miyahara[1], Naohisa Hirao[3], Yasuo Ohishi[3], Masahiko Nishijima[4]

[1]Faculty of Sci., Tohoku Univ., [2]IIAIR Tohoku Univ., [3]JASRI, [4]IMR

Earth's lower mantle is mainly composed of $MgSiO_3$-perovskite. Additionally, subducting slabs transport water stored in hydrous minerals into the lower mantle. It has been considered that almost hydrous minerals decompose and dehydrate at the lower mantle. On the other hand, delta-AlOOH can be stable up to the CMB condition and be as a reserver of water transported into the deep lower mantle (e.g., Sano et al., 2008). However, it is unknown whether delta-AlOOH can coexist with $MgSiO_3$-perovskite in the lower mantle or not. In this study, we performed high pressure and temperature experiments in the hydrous $MgSiO_3$-Al_2O_3-H_2O system, and we evaluated the possibility of the coexistence of delta-AlOOH and $MgSiO_3$-perovskite in the lower mantle.

We synthesized a gel-sample, of which composition was 70 mol.% $MgSiO_3$-30 mol.% Al_2O_3. H_2O contents of the starting gel samples were 1.5 wt.% or 7.0 wt.%.

High pressure and temperature conditions were generated using a laser heated diamond anvil cell. X-ray diffraction experiments were performed at high pressure after quenched from 2000 K at BL10XU, SPring-8. The present results showed that delta-AlOOH and $MgSiO_3$-perovskite coexist up to 68 GPa at 2000 K. Chemical analyses of recovered samples were performed using STEM-EDS (JEM-3000F). The recovered sample from 68 GPa and 2000 K showed that $MgSiO_3$-perovskite coexisting with delta-AlOOH contains 3.1(12) mol.% Al_2O_3 and this delta-AlOOH contains about 50 wt.% $MgSiO_3$. In contrast, $MgSiO_3$-perovskite in the dry $MgSiO_3$-Al_2O_3 system can contain at least 25 mol.% Al_2O_3 (e.g., Liu, 1977). Present results revealed that the Al_2O_3 content in $MgSiO_3$-perovskite in the hydrous system is dramatically less than that in $MgSiO_3$-perovskite in the dry system because of the existence of delta-AlOOH. Moreover, the Al_2O_3 content in the hydrous system is less than that in $MgSiO_3$-perovskite in the pyrolite composition. This suggests that delta-AlOOH can coexist with $MgSiO_3$-perovskite in the lower mantle composition.

Therefore, it can be concluded that delta-AlOOH coexists with $MgSiO_3$-perovskite in the lower mantle if the lower mantle contains at least 1.5 wt.% water even along the lower mantle geotherm.

Keywords: Earth's lower mantle, $MgSiO_3$-perovskite, delta-AlOOH

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

SIT040-P07 Room:Convention Hall Time:May 23 10:30-13:00

Influence of iron on the plastic properties of MgSiO3 post-perovskite: a first-principle study.

Arnaud Metsue[1*], Taku Tsuchiya[1]

[1]Geodynamic Research Center, Ehime

The D" layer is one of the most enigmatic part of the Earth s interior and has major implications for its dynamics. This layer is characterized by a strong and inhomogeneous seismic anisotropy. This latter could be produced by combining the single-crystal elastic anisotropy and crystal preferred orientation (CPO) of (Mg,Fe)SiO{sub}3{/sub} post-perovskite phase. Some experiments have been done on the plasticity of poor-Fe-bearing and pure MgSiO{sub}3{/sub} post-perovskite and lead to textures of deformation dominated by the (100) and (110) slip planes (Merkel et al., 2007) and by the (001) slip plane (Miyagi et al., 2010). On the other hand, theoretical calculations on the dislocations mobility on pure MgSiO{sub}3{/sub} (Carrez et al., 2007; Metsue et al., 2009) suggested a texture dominated by the (010) slip plane. These results cannot explain the seismic observations in the whole D" layer. Consequently, in order to understand the seismic anisotropy of the whole D" layer, one should determined the effects of incorporated elements, such as iron, on the plastic properties of the post-perovskite phase.

In this study, we present the results of an atomic-scale computational study on the plastic shear of pure and Fe-bearing MgSiO{sub}3{/sub} post-perovskite at 120 GPa. We determine the response of 4 potential slip planes, (100), (010), (001) and (110), under a plastic shear through the calculation of the Generalized Stacking Faults (GSF) energies. The values of the GSF energy are obtained by shearing half of an infinite crystal over the other half for every slip plane, similarly to our previous studies for the post-perovskite phase (Carrez et al., 2007; Metsue et al., 2009). The calculation of the GSF energies provides also an estimation of the ideal shear stress (ISS); the maximum resolved shear stress that a perfect crystal can suffer without plastically deforming (Paxton et al., 1991). The GSF energies are determined with ab initio calculations based on the internally consistent LDA+U technique (Tsuchiya et al., 2006) to describe accurately the local interactions between the d-states in Fe. The U parameter is optimized at 120 GPa by using the linear response theory based on the constrained total energy variational principle (Cococcioni and de Gironcoli, 2005, Phys. Rev. B). In this study, Fe is incorporated as substitutional single-point defects close to the glide plane. Iron is treated with different oxidation states (+2 or +3) and different spin states (low or high). As a main result, we show that the incorporation of iron in the post-perovskite phase leads to a decrease of the ideal shear stress for all slip systems. In addition, the slip systems that exhibit the lowest ISS are the same in pure and Fe-bearing MgSiO{sub}3{/sub} post-perovskite.

Research supported by the Ehime Univ. G-COE program Deep Earth Mineralogy and JSPS Research Grants Nos. 20001005 and 21740379.

Keywords: post-perovskite, first-principle calculations, Stacking fault

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

SIT040-P08 Room:Convention Hall Time:May 23 10:30-13:00

High-pressure transitions of subducted continental crust at around 660-km discontinuity

Takayuki Ishii[1*], Hiroshi Kojitani[1], Masaki Akaogi[1]

[1]Gakushuin Univ.

It has been suggested that subducted slabs carry crust materials to the deep interior of the earth, and give a variety of influences on mantle dynamics. The slab mateials are composed of oceanic crust, harzburgite and peridotite. But it is suggested that continental crust and terrigenous and pelagic sediments may be subducted to the deep mantle with the slab. High-pressure phase relations of upper continental crust (UCC) have been studied from the uppermost mantle to the upper part of lower mantle (Irifune et al., 1994, Wu et al., 2009), but phase relations at around 660-km discontinuity of the interior of the earth have not been researched in detail yet. In this study, we have examined high-pressure phase relations of UCC at around 660-km conditions.

UCC sample was prepared by mixing SiO_2(66.07), TiO_2(0.50), Al_2O_3(15.21), K_2O(3.40), FeO(4.50), MgO(2.20), CaO(4.20) and Na_2O(3.90), where numbers in parentheses are contents in wt%. High-pressure experiments were made at 20.1-28.0 GPa and 1200-1800C with a Kawai-type 6-8 multianvil high-pressure apparatus. UCC and pressure marker (one of Mg_2SiO_4, $MgSiO_3$ and $MgAl_2O_4$) were packed in two holes in a Re capsule, kept simultaneously at desired pressure-temperature conditions for 2-3 hours, quenched and recovered after the run. Phase identification of each sample was made with a microfocus X-ray diffractometer, and compositional analyses of them were made with a SEM-EDS.

The asemblege of garnet (Gt) + clinopyroxene (Cpx) + $KAlSi_3O_8$-hollandite (Hol) + stishovite (St) + CAS phase (CAS) is stable to 21 GPa at temperatures higher than 1400C, and the assemblege of calcium ferrite (CF) + St + Gt + Ca-rich perovskite (Cpv) + CAS is stable in a range of 21-24 GPa. Gt and CAS decompose completely and CF + Hol + St + Cpv is stable at pressures higher than about 24 GPa. At 1200C, CAS does not exsit. At pressures higher than 23-24 GPa, recovered samples were easyly crushable. The fact indicates that Hol (II) probably transforms to Hol (I) during decompression. We will conduct mass-balance calculations from the compositions, compare a density with pyrolite mantle and discuss the influence on movement of the materials in the mantle.

Keywords: continental crust, 660km discontinuity, slab, high pressure experiment, pyrolite

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

SIT040-P09 Room:Convention Hall Time:May 23 10:30-13:00

A numerical model of three-dimensional mantle convection with long-lived cratonic lithosphere

Masaki Yoshida[1*]

[1]IFREE, JAMSTEC

The continental lithospheric mantle assists in the long-term survival of continental crust at Earth's surface and has a thick root or keel that extends hundreds of kilometers into the upper mantle. Geochemical and geochronological studies have revealed that some old cratons have survived at the Earth's surface for periods of more than three billion years despite later tectonic disturbances. The cratons are the keel of the continental lithosphere, and continental assemblages referred to as supercontinents have probably cyclically formed several times during Earth's history (see Yoshida and Santosh, 2011, Earth-Science Reviews).

However, in the numerical modeling of mantle convection, it is a challenging task to construct a numerical model to realize the longevity of cratonic lithosphere. Here, the dynamic role of a weak (low-viscosity) boundary zone (WBZ) between cratonic and oceanic lithospheres in the longevity of the cratonic lithosphere is investigated. The WBZ is assumed to consist of weak materials, deforming with time by mantle convection force. The three-dimensional numerical model presented herein makes it possible to model the cratonic lithosphere that survives for a sufficiently long geological timescale. An important factor in the longevity of cratonic lithosphere is the localized rheological (viscosity) contrast between the cratonic and oceanic lithospheres, i.e., the presence of a weak (low-viscosity) boundary zone (WBZ) that surrounds the cratonic lithosphere. The WBZ protects the cratonic lithosphere from being stretched by the surrounding convection force. This implies that the mechanical contrast between floating cratonic and oceanic lithospheres has played a significant role in the longevity of cratonic lithosphere itself throughout Earth's history. In addition to the presence of a WBZ, the higher viscosity of the cratonic lithosphere itself effectively contributes to the stability of the cratonic lithosphere.

There appears to be a relationship between the horizontal size and longevity of the cratonic lithosphere. The results of the present study are consistent with the fact that there are no Archean cratons of sizes larger than the scale of mantle convection in present-day Earth. Cratons that are sufficiently smaller than the convection scale are likely stable over the long geologic timescale, even if the continental keel is extensively eroded by younger magmatic and subduction-erosion processes.

Keywords: mantle convection, numerical simulation, cratonic lithosphere, supercontinent, plate motion, rheology

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

SIT040-P10 Room:Convention Hall Time:May 23 10:30-13:00

Melting experiment of hydrous upper mantle and origin of Mg- and Si-rich cratonic mantle

Mariko Iehisa[1*], Kyoko Matsukage[1]

[1]GRC.Ehime University

Mantle peridotite xenoliths from kimberlite pipes, which derived from the deep upper mantle up to ~250km depth from Archean cratons, give us some direct information about the geochemical evolution of crustal and mantle materials in interior of our planet. These peridotite xenoliths sometimes have unusual chemical, modal, and textual compositions (e.g., Boyd, 1989; Boullier and Nicolas, 1975). Garnet peridotites from more than 80 km in depth have quite different with chemistry from shallow mantle, such as oceanic and arc area (e.g., Dick et al., 1984; Boyd, 1986; Arai, 1994). For example, in oceanic peridotites from mid-ocean ridges, the chemical variation of shallow mantle can be explained by process of partial melting of pyrolitic lherzolite and subsequent melt extraction at depth of 30-80 km. The estimated maximum degree of melting (~30 %) of residual peridotite and the chemical feature of the constituent minerals, that was depleted in incompatible element (SiO_2, Al_2O_3, CaO) with respect to compatible elements (MgO, Cr_2O_3), indicate that the partial melting occurred at almost dry condition. On the other hand, the cratonic peridotites mainly consist of olivine, orthopyroxene, garnet and clinopyroxene, and characterized the extremely high amount of orthopyroxene (= high amount of SiO_2 component) with high Mg# (= Mg/(Mg + Fe) atomic ratio) (e.g., Boyd, 1989). These high-Si and -Mg harzburgite/lherzolite could not explain as residue of dry partial melting and melt extraction process (Walter, 1998). Here, based on melting experiments at high pressure, we suggest possibilities of the Si- and Mg-rich cratonic peridotites as residues by partial melting of pyrolitic lherzolite at hydrous condition at depth of 200-300 km.

Starting material is a pyrolite + H_2O. The powder of Al_2O_3, SiO_2, $CaCO_3$, Fe_2O_3, TiO_2, Cr_2O_3, Na_2CO_3, K_2CO_3, and NiO was mixed, and degas at 1273 K and the ambient pressure in atmosphere Then it was melted at 1773 K and quenched to form glass in the reducing furnace where the oxygen fugacity was controlled to QFM buffer. Finally, powder of MgO and $Mg(OH)_2$ is added to be the water contents of starting material as 2wt% and 8wt%. Experiments were performed by using multi Anvil type high-pressure apparatus (ORENGE 1000) of the Ehime University at the temperature of 1273-1872 K at the pressure of 5GPa and 7GPa.

In out experimental conditions, All products show a partial melting. The residual mineral assemblage is olivine + opx + cpx + garnet at lower temperature, At the experiments with 2 wt% H_2O, the solid phases resolved to liquid as a nest order, cpx, garnet, opx and olivine. On the other hand, the experiments of 8 wt% H_2O 8wt% the stability field of opx become wider with increasing pressure. It is noted that the liquidus phase not become olivine but opx at 7GPa. Actually, the opx/ol ratio of cratonic mantle xenoliths is known to be higher than that of mantle xenolith in other regions, and our results imply that water greatly influenced continental generation in the early earth. If our conclusion is correct, the Earth's mantle is very heterogeneous in water content, and water was one of the important components for formation of continental craton at early Earth.

Keywords: hydrous pyrolite, high pressure and temperature experiments, continent, craton, partial melting