

SIT004-01

Room:105

Time:May 25 10:45-11:15

A discussion on the cause of high electrical conductivity in the oceanic upper mantle

Hisashi Utada^{1*}, Kiyoshi Baba¹

¹ERI, University of Tokyo

Distribution of electrical conductivity in the oceanic upper mantle is estimated by inverting electromagnetic data obtained regionally by an array of electric and magnetic field measurements in the ocean basin. Then physical interpretation is made, sometimes jointly with seismological parameters, by referring to results of mineral physics. There are a number of possible ways to invert regional electromagnetic data in the form of one-dimensional (1-D), 2-D and 3-D models. Among them, the regionally averaged 1-D profile provides a mean feature of the study region and is considered as conservative but robust estimate that can be extracted from a regional observation. Here we show most recent result of seafloor EM study carried out in the Philippine Sea and western Pacific regions, installing total of 39 sites for 3 years (2006-2008) in the Stagnant Slab Project (Baba et al., 2010). Both profiles show high conductivity of about 0.3-0.5 S/m in the upper mantle under a low conductivity layer. The Philippine Sea profile reaches this value at the depth of 60-70 km, while it is about 200 km depth for the western Pacific profile. These two profiles are almost identical at depths greater than 200 km and down to the top of the transition zone. Baba et al. (2010) discussed the differences in these two conductivity profiles by considering the seafloor age (geothermal), the degree of (silicate) partial melt, and the water content. In this paper we make further discussion on the cause of the high conductivity in the upper mantle in terms of effects of silicate and carbonatite partial melts with reference to recent experimental results (Gaillard et al., 2008; Yoshino et al., 2010). We also refer to the calculation of the stability of partial melts by Hirschmann (2010), and examine whether observed profiles can be explained by the effect of partial melts and by existing knowledge. The two experimental results are not completely consistent with each other, and therefore lead us to different conclusions as follows:

(a) Yoshino et al. (2010) presented a diagram showing the melt fraction dependence of electrical conductivity of partially molten mantle both for silicate and carbonatite melts. We directly compared it to our observation and found that the high conductivity at 60-70 km depth of Philippine Sea result can be explained by 0.5 % partial silicate melt. However, if we take the melt fraction of 0.024 % at the boundary between stability regions of silicate and carbonatite melts (Hirschmann, 2010), conductivity values are expected to be as low as that of dry olivine, and therefore inconsistent to the observed profile.

(b) We calculated the melt fraction dependence of the partially molten mantle conductivity based on Gaillard et al. (2008), by assuming the Hashin-Strickman upper bound model. From this diagram, the high conductivity values both at 60-70 km and at 200 km can be explained by partially molten mantle either with 2-3 % silicate melt or with 0.02-0.04 % carbonatite melt. Explaining the observed profiles by the effect of partial silicate melt requires too high melt fraction and therefore seems difficult. On the other hand, observed profiles may be explained by the effect of partial carbonatite melt with melt fraction that could be stable at respective depths. However in this case, the consistency with seismological evidence (e.g. Kawakatsu et al., 2009) may still remain a problem.

Such a comparison as shown above does not give us a solid conclusion because of still insufficient knowledge. However, it is possible for us in principle to constrain a product of the melt fraction and the melt conductivity from electrical conductivity profiles. Furthermore if the melt fraction is constrained somehow by seismological observations, for example, electrical conductivity profiles will consistently constrain the melt conductivity, from which the volatile content in the melt that is responsible for the high conductivity can be inferred.

Keywords: oceanic upper mantle, electrical conductivity, ocean bottom observation, partial melt

SIT004-02

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H₂O storage capacity of the upper mantle and melting atop the 410 km discontinuity

Marc Hirschmann^{1*}

¹University of Minnesota

There is considerable evidence that partial melts are stable in regions of the upper mantle that are deeper than the plausible locus of dry melting of peridotite, and this is widely recognized to mean that volatile-enhanced melting is a common phenomenon in the convecting upper mantle. Among the most enigmatic of these regions are low shear-wave velocity regions atop the 410 km discontinuity, which are widespread regional features. Numerous seismic studies, principally using receiver functions and ScS reverberations, have detected anomalously slow regions in the 20-80 km thick interval above the 410 km discontinuity. Because these regions are commonly 3-8% slow relative to reference models, it is difficult to explain them without the presence of interstitial melt. Alternative explanations, such as enhanced hydration of nominally anhydrous minerals, do not seem to be able to account for the magnitude of the observed anomalies. Many, though not all, of the low velocity zones are associated with regions of present or recent subduction, suggesting that they mark regions of partial melt incited by advection of recycled volatiles into the upper mantle. H₂O and CO₂, alone or in combination, may be capable of inciting partial melting at these depths. Because the convecting mantle is reduced at these depths, and because CO₂ solubility in melts under reducing conditions is very small, CO₂ contributes negligibly to melt stabilization unless the low velocity regions are anomalously oxidized. Thus, hydrous melting is the most likely explanation for the observations.

Hydrous melting atop the 410 km discontinuity can occur if the local concentration of H₂O exceeds the storage capacity of peridotite. The storage capacity is the maximum concentration of H₂O that can be held in the nominally anhydrous minerals at a given temperature and pressure for the chemical system of interest. A critical point, therefore, is that the storage capacity will depend on the diversity and compositions of phases present. The concentrations of H₂O that can be stored in olivine at 12-14 GPa along the mantle adiabat approach 0.5 wt.%, but the presence of the full peridotite mineral assemblage stabilizes partial melt at diminished H₂O activity and severely reduces the H₂O storage capacity. New experiments conducted at 10-13 GPa indicate that olivine saturated with peridotite and with hydrous partial melt has 500-1800 ppm H₂O. These concentrations are similar to those that might be expected in recycled oceanic lithosphere at TZ depths or in plumes and are consistent with the hydrous melting hypothesis to explain regional observations of LVZ at 410 km. However, they are considerably greater than concentrations in typical convecting mantle sampled at ridges, and are therefore inconsistent with a global layer of melt at 410 km. Remaining challenges include accounting for the unexpectedly great thickness of observed layers, and constructing a petrologically and dynamically consistent explanation for the magnitude of shear wave anomalies, which are not easily reconciled with the fractions of melt that are petrologically likely or dynamically stable.

Keywords: Transition Zone, 410 km discontinuity, hydrous melting

SIT004-03

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Laboratory-based electrical conductivity profile of the mantle transition zone

Takashi Yoshino^{1*}, Tomoo Katsura², Akira Shimokuku¹

¹ISEI, Okayama Univ., ²BGI, Univ. Bayreuth

Recent laboratory electrical conductivity measurements of the main mantle constituent minerals have refined our understanding of the effect of water and iron content on electrical conductivity. However, there have remained inconsistency of conductivity data between different laboratories, especially effect of water on the conductivity (proton conduction). Karato and Dai (2009) claimed that our group's data, mostly based on low frequency measurements, used incorrect sample conductivity values, because their impedance spectroscopy for wet wadsleyite measured at high temperatures showed an additional tail at low frequencies. To clarify a cause of this discrepancy, we performed the impedance spectroscopic measurements for wadsleyite in a wide frequency range at low temperatures (< 1000 K) to minimize dehydration of samples. The results are quite consistent with ours measured at low frequencies, and did not show a large contribution of small amount of water to the conductivity and an additional tail at low frequencies due to the electrode reaction. It is concluded that the conductivity measurement at high temperatures (> 1000 K) leads to higher conductivity due to the grain boundary water generated by dehydration of sample.

Next we consider the electrical conductivity structure of the mantle transition zone based on our results. The electrical conductivity of the Earth's mantle is controlled by the coexistence of multiple mineral phases. Using these conductivity data of mantle minerals and geotherm models, the laboratory-based conductivity-depth profiles have been constructed of a 200 to 800 km depth range across the mantle transition zone. These profiles are based on mixing models of composite materials, which assume a pyrolytic composition, and they are a function of water content in main constituent minerals. The calculated conductivity values increase from 10-2 S/m at 200 km depth to 100 S/m at 800 km depth. Considering the conductivity change due to the phase change only, our model predicts similar values between olivine and wadsleyite, but they differ up to nearly one order of magnitude between wadsleyite and ringwoodite. In other words, if a conductivity jump accompanies the 410 km seismic discontinuity, it will not be due to the phase change but to a secondary effect, such as difference in water content. Instead, a notable conductivity jump appears at a depth of 520 km in the wadsleyite-ringwoodite transition with or without water. The present conductivity-depth profile in the transition zone agrees with that obtained from the geophysical observations beneath the Pacific Ocean in the case of the dry mantle transition zone. The absolute conductivity values obtained from the conductivity profiles beneath the Philippine Sea, where stagnant slab exists, are too high to be explained by the dry pyrolytic model, especially in the stability field of wadsleyite. Presence of water in the transition zone minerals is required to explain such high conductivity.

Keywords: electrical conductivity, mantle transition zone, water, olivine, wadsleyite, ringwoodite

SIT004-04

Room:105

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Mapping seismic heterogeneity and anisotropy in the mantle

Dapeng Zhao^{1*}

¹Tohoku University

Recently we have made new advances in tomographic imaging of the mantle heterogeneity and anisotropy, which shed new light on the mantle dynamics. We improved our global tomography model by adopting a flexible-grid parameterization to express the 3-D Earth structure (Zhao, 2009). Compared with the previous tomographic model (e.g., Zhao, 2004), the new model has a better resolution for the polar regions, which enables us to examine the mantle structure and dynamics in Arctic and Antarctica. The intraplate volcanoes in NE Asia (e.g., Changbai and Wudalianchi) are caused by the hot and wet upwellings in the big mantle wedge (BMW) above the stagnant slab in the mantle transition zone (Zhao, 2004; Zhao et al., 2009). Our new tomography model shows that the subducting Pacific slab becomes stagnant in the mantle transition zone under Western Alaska, Bering Sea, Sea of Okhotsk, Japan Sea, and Northeast Asia. Many intraplate volcanoes exist in these areas, which are located above the low-velocity zones in the upper mantle above the stagnant slab, suggesting that BMW exists in not only NE Asia but also in broad regions under the northern and western Pacific, and those intraplate volcanoes are related to the dynamic processes in the BMW above the stagnant slab. The Tengchong volcano in SW China is caused by a similar process in BMW above the subducting Burma microplate (or Indian plate). In contrast, the Hainan volcano in southernmost China is a hotspot fed by a lower-mantle plume associated with the Pacific and Philippine Sea slabs' deep subduction in the east and the Indian slab's deep subduction in the west down to the lower mantle (Zhao et al., 2011). We have also used P-wave anisotropy tomography and shear-wave splitting to map seismic anisotropy in the mantle under East Asia. The results show that the fast velocity direction in the upper mantle under East Asia is generally oriented in the NW-SE or E-W directions, suggesting the existence of mantle flow in the BMW, in consistent with the tomographic images and stress regime in the subducting slab as estimated from the focal mechanism solutions of deep earthquakes under the Japan Sea and East-Asia margin (Zhao et al., 2009, 2011).

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Keywords: mantle, heterogeneity, anisotropy, slab, deep earthquakes

SIT004-05

Room:105

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Elastic wave velocities of stishovite at high pressures

Ryo Negishi^{1*}, Yoshio Kono¹, Yuji Higo², Norimasa Nishiyama¹, Tetsuo Irifune¹

¹Geodynamics Research Center, Ehime Unive, ²Japan Synchrotron Radiation Research Ins

Stishovite is an important constituent of the Earth's mantle transition region, and therefore elastic wave velocity of stishovite, in conjunction with seismological observations, should give constraints on the mineralogy of the mantle transition region. Previous studies have measured elastic wave velocities of stishovite at high pressures to 3 GPa by ultrasonic technique (Li et al., 1996) and to 12 GPa by Brillouin scattering measurement (Jiang et al., 2009). However, the results are inconsistent each other. In addition, these studies were carried out at pressures lower than that of mantle transition region. We therefore need further elastic wave velocity measurement of stishovite at the pressure and temperature conditions of the mantle region.

Here we carried out elastic wave velocity measurement on sintered polycrystalline stishovite from 10.3 GPa to 17.5 GPa at room temperature by using ultrasonic technique in conjunction with synchrotron X-ray measurement. The polycrystalline stishovite sample was hot pressed at ~16 GPa and ~1470 K in a 3000-ton Kawai-type apparatus using SiO₂ glass rod as starting material. The bulk density measured by Archimedes method before high pressure experiment was 4.29(2) g/cm³, which was same density as that determined by X-ray diffraction measurement (4.280 g/cm³).

Simultaneous ultrasonic and in situ X-ray measurements were carried out at BL0401 beamline in SPring-8. Ultrasonic elastic wave velocity measurements were conducted using the pulse reflection method. Sample lengths at high pressures were directly determined from the X-ray radiography image. Pressure was determined by self-consistent manner using obtained elastic wave velocity and density of stishovite.

Pressure-volume relation of stishovite measured in this study is consistent with these of previous studies (e.g. Lakshtanov et al., 2005; Nishihara et al., 2005). Our obtained elastic wave velocities of stishovite are higher than that of low pressure ultrasonic measurement to 3 GPa (Li et al., 1996). For instance, P wave velocity (VP) at 3 GPa estimated from our high pressure data is 12.02 km/s, but that of Li et al. (1996) less than 11.8 km/s. In contrast, our results are almost consistent with previous Brillouin scattering measurement on single-crystal stishovite up to 12 GPa (Jiang et al., 2009).

Keywords: stishovite, elastic wave velocity measurement

Time:May 25 12:30-12:45

Anton Shatskiy^{1*}, Konstantin Litasov¹, Tomoo Katsura², Daisuke Yamazaki³, Eiji Ohtani¹

There are much direct and indirect evidences of carbonatitic and hydrous melt/fluid segregation in the deep mantle in the past Earth's history. One particular example is the source regions of carbonatites, kimberlites, and lamproites some of which originate from more than 250 km depth. Another example is the natural diamond forming medium which most probably was extremely enriched in water, carbonates, and alkalis. Despite of that, the average mantle concentrations of carbon and hydrogen do not exceed 100 and 120 wt ppm respectively, the volatile segregation in a broad mantle region should be involved to explain the local abundance of CO₂ and/or H₂O. Enrichment of these fluids in incompatible trace elements (specifically, K, Rb, Sr, Ba, light REE, Ti, Nb, Zr, P, U, and Th) also implies their long infiltration history through the large volumes of mantle rocks.

[illegible]

Keywords: mantle, diffusion, carbonate, water fluid

SIT004-07

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P-V-T equation of state of the calcium aluminosilicate CAS phase, up to 24 GPa and 2100 K

Steeve Greaux^{1*}, Yoshio Kono¹, Norimasa Nishiyama¹, Tetsuo Irifune¹

¹Ehime University

The CAS phase is a Ca-rich aluminosilicate that has been first observed with the composition of $\text{Ca}_{0.8}\text{Al}_{3.6}\text{Si}_{2.4}\text{O}_{11}$ (with small amount of Na_2O and K_2O) in the decomposition product of sediments and continental crust composition at P,T conditions of mantle transition zone [1]. Later experiments also found the CAS phase as a liquidus phase in melting experiments on Mid-Ocean Ridge Basalts (MORB) compositions at 26-27 GPa and ~2500 K [2, 3]. According to those former studies, the CAS phase could represent up to 10 vol% of the subducted continental crust or 30 vol% of the solid fraction of partially molten MORBs in the deep mantle. Also, naturally occurring CAS phase has also been discovered in shocked martian meteorites [4]. Thus, the CAS phase might be an important constituent mineral of sediments and basalts subducted in the deep mantle.

The pressure-volume-temperature relations of the CAS phase with the composition of $\text{CaAl}_4\text{Si}_2\text{O}_{11}$ was examined in situ up to 24 GPa and 2100 K by energy dispersive X-ray diffraction, using a Kawai-type multi-anvil press apparatus coupled with synchrotron radiation in SPring-8 (Japan). At 300 K, we found that the CAS phase would be ~25% more compressible than Ono et al. [5]. From our high-temperature data we report for the first time the thermoelastic parameters of the CAS phase and discuss its compressibility and thermal expansivity relative to the lattice parameters variation at high-P,T.

These new data enables the accurate estimate of density of the CAS phase in the deep mantle for various temperature profiles (i.e. adiabatic mantle or cold slab geotherms). Our results suggest that with increasing the mineral proportion of the CAS phase, the density of slabs would increase when subducted in the mantle transition zone. On the other hand, because of lesser densities compared to lower mantle minerals, the CAS phase is expected to remain buoyant in the lowermost part of the transition zone.

References

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Keywords: CAS phase, $\text{CaAl}_4\text{Si}_2\text{O}_{11}$, Thermal expansion, high-pressure, in situ X-ray diffraction

SIT004-08

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Determination of postspinel phase boundaries in Mg_2SiO_4 and $(\text{Mg}_{0.9}\text{Fe}_{0.1})_2\text{SiO}_4$ by in situ X-ray diffraction experiments

Yume Kinoshita^{1*}, Norimasa Nishiyama¹, Tetsuo Irifune¹, Yuji Higo², Ken-ichi Funakoshi²

¹Geodynamics Research Center, Ehime Unive, ²Japan Synchrotron Radiation Research Ins

We investigated postspinel phase boundaries in Mg_2SiO_4 and $(\text{Mg}_{0.9}\text{Fe}_{0.1})_2\text{SiO}_4$ between temperatures of 1673 and 2173 K by in-situ X-ray diffraction measurements at SPring-8. We did not observe effect of ferrous iron to the postspinel phase boundary, and they are expressed as $P \text{ (GPa)} = 26.42 - 0.0022 T \text{ (K)}$. The determined Clapeyron slope of -2.2 MPa/K is reasonably consistent with those determined by thermodynamic calculation (Akaogi et al., 2007) and first principles investigation (Yu et al., 2007), whereas it is inconsistent with recent experimental works which reported that the transition pressures are insensitive to temperature (Katsura et al., 2003; Fei et al., 2004). The postspinel transition pressure at 1873 K is calculated to be 22.4 GPa, which is about 1 GPa lower than that at 660 km depth, indicating effect of aluminum in pyrolytic composition to the transition pressure or uncertainty of MgO pressure scale. We can interpret topography of 660 km seismic discontinuity (plus-minus 20 km from the average) as temperature anomaly of plus-minus 370 K using the postspinel Clapeyron slope determined in the present study. The postspinel Clapeyron slope of -2.2 MPa/K can produce buoyancy for subducting slabs and the buoyancy is one of the main factors to let them stagnant on the 660-km discontinuity.

Keywords: postspinel, phase boundary, Clapeyron slope, 660 km seismic discontinuity

SIT004-09

Room:105

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Slab subduction processes in a depth range 400-1000 km around the Circum Pacific

Yoshio Fukao^{1*}, Obayashi Masayuki¹

¹IFREE/JAMSTEC

There have been many tomographic studies to sharpen the images of deeply subducted slabs but, to our knowledge, none of them addressed the possible unique role of the uppermost lower mantle in the processes of slab subduction. We made a systematic survey of the slab images around the Circum Pacific in our P-wave tomographic model to show that a subducting slab is now in one of the following four stages:

- A. Slab is stagnant above the 660.
- B. Stagnant slab begins to penetrate the 660.
- C. Penetrated slab is trapped in the uppermost lower mantle.
- D. Trapped slab begins to penetrate well into the deep lower mantle.

We interpret A to D as the successive stages of slab subduction through the mantle transition region from 400 to 1000 km depths. In particular, we emphasize C as a distinct stage of slab subduction. Although the 660 is often interpreted as not only the boundary of phase transition but also the boundary of viscosity contrast, the distinct stage C implies that viscosity increase does not occur sharply across the 660 but gradually through the uppermost part of the lower mantle.

Keywords: mantle dynamics, mantle viscosity

SIT004-10

Room:105

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Fate of stagnant slabs: Constraints from density and sound velocities of pyrolite and subducted slab materials

Tetsuo Irifune^{1*}, Kono Yoshio¹, Yuji Higo², Nishiyama Norimasa¹

¹GRC, Ehime Univ., ²JASRI, SPring-8

Seismological tomography images suggest that some slabs penetrate into the deep lower mantle, while others are trapped around the 660km seismic discontinuity, forming structures referred to as "megoliths" or "stagnant slabs". The latter class of slabs is believed to eventually fall into the lower mantle, because of the instability (flushing or avalanche) caused primarily by the density contrast between the slab and the surrounding mantle. This suggests that all slab material ultimately sinks deep into the lower mantle. Nevertheless, there are some locations where the stagnant slabs seem to spread over a certain distance along the 660km boundary, whose fate is not really understood. Our recent studies on the sound velocity changes in typical subducted slab and mantle lithologies demonstrated that the sound velocities of either pyrolite or piclogite (or eclogite) do not fit seismological models for the bottom part of the mantle transition region (MTR), suggesting that this part of the MTR is made of a layer of harzburgite, which is the major constituent of subducting slabs. Subducted harzburgite is intrinsically less dense than the surrounding pyrolite in the lower mantle, and can be buoyantly trapped at the bottom of MTR when thermally equilibrated with the mantle after stagnation. This would allow such stagnant slabs to stay in this region without flushing into the deeper mantle. Thus, the authors propose that the slabs subducted in the MTR may be classified into three types; 1) directly penetrating deeper into the lower mantle, 2) forming a "megolith" structure with subsequent flushing into the lower mantle, and 3) spreading horizontally over a certain distance until some thermal turbulences (either upward or downward convective motions) destroy the layered structure. The third class of the subducted slabs, mainly composed of harzburgite, may contribute to the relatively high sound velocities observed in the bottom region of the MTR.

Keywords: stagnant slab, flushing, harzburgite, pyrolite, megolith, mantle transition region

SIT004-11

Room:105

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Interconnected ferro-periclase in the subducting slab at the top of lower mantle

Daisuke Yamazaki^{1*}

¹Okayama University

Major phase transformation occurs from ringwoodite to (Mg,Fe)SiO₃ perovskite plus ferro-periclase when oceanic lithosphere sink into deep mantle across the 660 km discontinuity. After the transformation, material (rock) properties strongly depend on their two phase geometry, for example, grain-size, phase distribution, grain shape, lattice preferred orientation, and so on. The interconnection of ferro-periclase is a key factor on rheology and chemical heterogeneity because ferro-periclase is much weaker than (Mg,Fe)SiO₃ perovskite and chemical diffusivity of ferro-periclase is higher than that of (Mg,Fe)SiO₃ perovskite.

To investigate the interconnectivity of ferro-periclase after transformation from ringwoodite in the conditions of subducting slab, we carried out in-situ electrical conductivity measurement by means of high pressure experiment using a Kawai-type multi-anvil apparatus and 3D-textural observation on the recovered sample using FIB-SEM technique. The electrical conductivity of ferro-periclase is much higher than that of perovskite, suggesting that the conductivity of their aggregate is good indicator to estimate interconnectivity of ferro-periclase.

Our result suggested that the interconnected network of ferro-periclase was formed after phase transition from ringwoodite and remained for a while in the condition of cold subducting slab, leading that interconnected ferro-periclase plays important role on physicochemical properties of bulk rock. On the other hand, in the warm slab or regular mantle, ferro-periclase may be isolated in the aggregate. In this case, (Mg,Fe)SiO₃ perovskite mainly controls the bulk properties.

SIT004-12

Room:105

Time:May 25 15:45-16:15

Channel Flow in transition zone and bounds on lower-mantle lateral viscosity contrast

David Yuen^{1*}, Nicola Tosi², Z. Q. Wu³, Renata M. Wentzcovitch⁴

¹Dept. Geol. Geophys., Univ. Minnesota, ²German Aerospace Center, ³Dept. Earth and Planetary Sciences, USTC, ⁴Dept. Chem. Eng. Mater. Sci. U.Minnesota

Recent high-resolution seismic imaging of the transition-zone thickness beneath the Hawaiian hotspot by the M.I.T.-Purdue group (Cao et al., 2010), using curvelet transform of multiple scattered S waves, has shown convincingly a considerable uplift of the 660 km discontinuity west of Hawaii without a correspondent depression of the 410 km discontinuity. Such a structure is consistent with the geodynamical scenario of a deep-mantle plume first deflected horizontally as a channel flow at 660 km depth and the reentrance into the upper mantle away from its lower mantle source, as a secondary plume aligned with the present-day location of the hot-spot. Using a cylindrical model of mantle convection featuring multiple phase transitions and pressure-dependent thermodynamic properties according to recent mineral physics evidence both taken experimentally and computationally, we investigate the conditions under which such a peculiar plume morphology can be realized. We have employed a temperature- and pressure-dependent thermal expansivity based on tabulated results from first-principles calculations. We focus on the magnitude $\Delta\eta_T$ of the lateral viscosity contrast due to temperature variations and show that this factor plays a first-order role on the dynamics of plumes if pressure-dependent thermal expansivity and conductivity are taken into account. For small values ($\Delta\eta_T \sim 10$), large-scale upwellings are generated at the bottom thermal boundary layer that have enough buoyancy to pass undisturbed the endothermic transition at 660 km depth in an essentially vertical fashion. For higher values ($\Delta\eta_T \sim 10^2$ - 10^3) mantle layering becomes more pronounced, plumes are thinner and weaker, still with enough buoyancy to reach the 660 km discontinuity but not to penetrate it. Instead, they travel horizontally along the 660 km boundary following the top part of lower mantle convection cells and rise again through the upper mantle at a distance from their parent plume also controlled by $\Delta\eta_T$. Our findings argue for the importance of using a temperature-dependent viscosity in numerical models that feature also pressure- and temperature-dependent thermodynamic properties and on the possibility of using plume dynamics as imaged from seismic waves to bound the temperature viscosity contrast in the lower mantle to be between one hundred and a few hundred.

Cao Q., R.D. van der Hilst, M.V. de Hoop, S. Shim. Complex plume dynamics in the transition zone underneath the Hawaii hotspot: seismic imaging results. DI23C-02, AGU Fall Meeting 2010, San Francisco.

SIT004-13

Room:105

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Two-Dimensional numerical simulations of mantle convection with chemical heterogeneity and continental drift

Masanori Kameyama^{1*}, Masashi Fukuda¹

¹Geodynamics Research Center, Ehime Univ.

We conducted numerical experiments of mantle convection in order to study the generation of ascending plumes in the presence of chemical heterogeneity and continental drift. In this study, we consider a convection of fluid with variable physical properties such as viscosity, thermal expansivity and conductivity, under the extended Boussinesq approximation, in a model of a two-dimensional rectangular box of 2900km height and the aspect ratio (width/height) of 12. The mantle materials are modeled by a mixture of two component fluids with different density. The convecting motion of fluid is driven by not only a thermal but also a chemical buoyancy coming from the variation in the content of denser component fluid. In addition, we impose a block of highly viscous fluid of 11600km width along the top surface, as a model of a supercontinent. We also take into account the effects of a drifting motion of supercontinent, by allowing a coherent (rigid) motion of continental block in the horizontal direction driven by the overall convection in the mantle. Our preliminary calculations showed that, when the effect of negative chemical buoyancy is sufficiently large, several dome-like structures of dense materials occur at the base of the mantle. The dome-like structures form broad regions of high temperature, which are quite similar to the large low shear-velocity provinces (LLSVPs) in the lowermost mantle of the Earth.

Our calculations demonstrated that the thermal and chemical state in the deep mantle described above is significantly affected by the presence of the continental block at the top surface. In particular, owing to a strong “blanketing effect”, both thermally and chemically, caused by the continental block, a pile of dense and hot materials firmly develops beneath the initial position of the continent. The thermochemical pile, once it forms beneath the continental block, remains strong enough to dominate the overall convection in the mantle, causing intense ascending flows in its neighborhood. In addition, we found that, only when an appropriate amount of high density component (around 10% of the entire volume) is present in the mantle, convective flows can simultaneously yield the occurrence of continental drift and the long-term survival of LLSVPs.

Furthermore, from the observations of the temporal variations in convective planforms, we found that the thermochemical pile beneath the initial continental position is almost immobile for more than several gigayears: The pile of dense material remains stationary even after the continental block is swept away by the ascending flows originating from the root of the pile. This finding suggests that, considering the effect of chemical heterogeneity, the cycles of aggregation/dispersal of supercontinents are not necessarily associated with cyclic changes in convection patterns in the mantle, as opposed to the “1-2-1 model” proposed by Zhong et al. (2007).

Keywords: mantle convection, numerical simulation, chemical heterogeneity, supercontinent cycle, LLSVP, ascending plume

SIT004-14

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Effects of iron on the thermoelastic properties of MgSiO_3 perovskite

Arnaud Metsue^{1*}, Taku Tsuchiya¹

¹Geodynamic Research Center, Ehime

$(\text{Mg,Fe})\text{SiO}_3$ perovskite is thought to be the most abundant phases in the Earth lower mantle. Mineral physical studies on this phase is therefore of significant importance in investigating structure and dynamics of the Earth deep mantle. However, due to some technical difficulties for the iron-bearing phases, its high-P,T thermodynamics are yet to be well understood both experimentally and theoretically. In particular, all the ab initio studies on $(\text{Mg,Fe})\text{SiO}_3$ perovskite conducted so far are limited at the static condition in contrast to pure MgSiO_3 .

Here, we present the results of a computational study on the thermodynamic properties of Fe-bearing MgSiO_3 perovskite up to 150GPa. We perform density functional calculations beyond conventional methods based on the internally consistent LDA+U technique (Tsuchiya et al., 2006, Phys. Rev. Lett.) to describe local interactions between the d-states in Fe in more appropriately, that give rise to Hubbard splitting. In this study, Fe is incorporated as substitutional single-point defects, which can be present in the different oxidation states (+2 or +3) and different spin states (low or high). We calculate the phonon dispersion relations of the iron-bearing phases based on the direct method, where the force constant matrices are determined by directly applying small but finite atomic displacements, similarly to our previous study in Fe-bearing MgSiO_3 post-perovskite (Metsue and Tsuchiya, 2011, under review). Then, we determine several important thermodynamic quantities such as the vibrational entropy, free energy, heat capacities, bulk moduli and thermal expansion coefficient within the quasiharmonic approximation. These results are compared to those reported by Tsuchiya et al. (2005, J. Geo. Res.) for pure MgSiO_3 perovskite. In addition, we show that our results are in good agreement with previous experimental studies on Fe-bearing perovskite (Andrault et al., 2001, EPSL; Lundin et al., 2008, PEPI; Catalli et al., 2010, EPSL). This study points the fact that a low concentration of iron, irrespective of the spin state, affects mainly the low phonon frequency ranges of the perovskite and thus has limited effects on its thermodynamic properties.

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

Keywords: perovskite, equation of states, thermodynamic properties, phonon spectra, first-principle calculations

SIT004-15

Room:105

Time:May 25 17:00-17:30

The Importance of Mineral Physics for Understanding Mantle Dynamics and Seismic Structure

Paul Tackley^{1*}, Takashi Nakagawa¹, Frederic Deschamps¹, James Connolly¹

¹Dept. Earth Sciences, ETH Zurich, ².

Phase transitions have a first-order influence on the mantle, yet mantle dynamics calculations typically only include one or two major transitions despite the complexity of phase diagrams for mantle mineralogy. In our recent work, phase assemblages of mantle rocks calculated from the ratios of six oxides (CaO-FeO-MgO-Al₂O₃-SiO₂-Na₂O) by free energy minimization are used to calculate the material properties density, thermal expansivity, specific heat capacity, and seismic velocity as a function of temperature, pressure, and composition, which are incorporated into a numerical thermochemical mantle convection model in a 3-D spherical shell. The advantage of using such an approach is that thermodynamic parameters affecting dynamics and seismic velocities are included implicitly and self-consistently, obviating the need for ad hoc parameterizations. We test the sensitivity of convective behaviour and resulting mantle structure to the compositions of mid ocean ridge basalt (MORB) and harzburgite. Results indicate that thermo-chemical structures are quite sensitive to variations in MORB composition of the order 1-2% oxide fraction, particularly FeO and Al₂O₃. Differences occur in (i) the amount of compositional stratification around 660 km depth caused by the inversion of the MORB-harzburgite density difference between about 660 - 740 km depth, which is different in magnitude and depth extent between the different tested compositions, and (ii) in the degree of MORB segregation above the CMB, which is related to differences in the MORB-harzburgite density difference in the deep mantle. Comparing model spectra to those of seismic tomography, in all cases there is too much heterogeneity at mid lower mantle depths compared to typical seismic tomographic models, which implies that less CMB basalt segregation occurs in Earth than in the models. This probably indicates the need for better thermodynamic data for minerals at deep mantle pressures and temperatures.

Keywords: mantle convection, plate tectonics, mineral physics, numerical simulation

SIT004-16

Room:105

Time:May 25 17:30-18:00

Density profile of pyrolitic lower mantle

Ryosuke Sinmyo^{2*}, Kei Hirose¹, Yasuo Ohishi³

¹Tokyo Institute of Technology, ²Universitaet Bayreuth, ³JASRI

Density profile of pyrolite at lower mantle high-pressure (P) and -temperature (T) conditions was investigated by using laser-heated diamond-anvil cell up to 117 GPa and 2800 K. The density was determined from chemical composition and unit-cell volume of each constituent mineral (MgSiO₃-rich perovskite, ferropericlase and CaSiO₃-rich perovskite). The chemical compositions of coexisting phases were analyzed by transmission electron microscope, and their volumes were obtained by in-situ X-ray diffraction measurements. To avoid extensive chemical segregation during laser-heating, sample was coated by gold that worked as a laser absorber (Sinmyo and Hirose 2010 PEPI). Results of chemical analyses show that Mg-Fe (total Fe) partitioning coefficient between MgSiO₃-rich perovskite and ferropericlase [$K^* = (\text{Fe}^*/\text{Mg})_{P_v}/(\text{Fe}^*/\text{Mg})_{F_p}$] is about 0.6, slightly higher than the value previously reported in the pyrolitic bulk composition (Murakami et al. 2005). The lower K^* value in the previous study may be attributed to the chemical heterogeneity in the sample induced by strong temperature gradient during laser heating. The calculated density profile of pyrolite is indeed in good agreement with the PREM model within experimental errors, in contrast with the mismatch reported by the previous study (Ricolleau et al. 2009). Our results support the lower mantle has pyrolitic bulk composition, and thus it is not necessary to suppose the chemically stratification in the lower mantle.

SIT004-17

Room:105

Time:May 25 18:00-18:15

Dynamical response of the low viscosity post-perovskite in thermo-chemical mantle convection in a 3-D spherical shell

Takashi Nakagawa^{1*}, Paul Tackley¹

¹Institute of Geophysics, ETH Zurich

Both high pressure experiment and theory suggested that the rheological property of post-perovskite phase could be much weaker than of perovskite, which could have $O(10^{-3})$ to $O(10^{-4})$ [Hunt et al., 2009; Ammann et al., 2010]. Recent our study indicated that the scale of heat flux across the core-mantle boundary and thermo-chemical anomalies were the larger-scale when the post-perovskite is weaker than the perovskite [Nakagawa and Tackley, 2011]. Other important physical response caused by the low viscosity post-perovskite is to check the geoid anomalies and anisotropic features induced by flow in the post-perovskite phase. Several previous studies indicated that the viscosity reduction due to the post-perovskite phase transition could affect the large-scale geoid anomalies [Tosi et al., 2009; Gosh et al., 2010]. In addition, high pressure mineral physics also implied that the weak post-perovskite could induce the anisotropic feature in the deep mantle [Yamazaki et al., 2006; Shim, 2008]. Here we test two important physical response caused by the low viscosity post-perovskite in thermo-chemical mantle convection simulations in a 3-D spherical shell varying the density difference at the core-mantle boundary that would affect thermo-chemical structures in the deep mantle. Comparing between the weaker post-perovskite and regular post-perovskite, the amplitude of geoid anomalies is not very different but the scale of geoid would be somewhat organized to be the larger-scale when the viscosity of post-perovskite is weaker than of perovskite. The anisotropic structure would also affect to enhance the horizontal flow structure then making an alignment to the horizontal direction when the low viscosity post-perovskite is assumed, which could be related to the anisotropic structure in the deep mantle.

Keywords: Postperovskite, thermochemical mantle convection, geoid, anisotropy

SIT004-18

Room:105

Time:May 25 18:15-18:30

Ocean bottom geophysical observation on the seafloor near the Society hot spot, French Polynesia

Daisuke Suetsugu^{1*}, Hajime Shiobara², Hiroko Sugioka¹, Aki Ito¹, Takehi Isse², Kiyoshi Baba², Takafumi Kasaya¹, Noriko Tada¹

¹IFREE/JAMSTEC, ²ERI/Univ. Tokyo

The South Pacific region is characterized by a broadly elevated seafloor known as the South Pacific superswell, which suggests the presence of a large-scale mantle plume beneath the South Pacific, called the South Pacific superplume. The geometry, origin depth, temperature, and composition of the superplume remain controversial, however, mainly due to the lack of seismological data that documents the mantle structure beneath the South Pacific. To obtain a better seismic image of the superplume, we deployed temporary broadband seismographs on oceanic islands and the seafloor in the South Pacific since 2002. In the first experiment from 2002-2005, we deployed 10 broadband ocean-bottom seismographs (BBOBS) over the French Polynesian region. The seismic image obtained from the data indicates that large-scale low-velocity anomalies (on the order of 1000 km in diameter), indicative of the superplume, are located from the bottom of the mantle to a depth of 1000 km, and small-scale low-velocity anomalies (on the order of 100 km in diameter) are present above it. The small-scale anomalies may be narrow plumes generated from the top of the dome. Narrow plumes beneath the Society hot spot are best resolved by the data, although the spatial resolution is still not sufficient to understand how the narrow plumes reach from the top of the superplume to the hot spot. In the second experiment from Feb. 2009 to Dec. 2010, we deployed 9 BBOBS and 9 ocean-bottom electro-magnetometers (OBEM) near the Society hot spot to obtain a clear image of the ascending narrow plumes beneath the hot spot. Simultaneous observation with seismic and electro-magnetic sensors should enable not only to determine geometry of the plumes, but also to investigate thermal and compositional heterogeneities associated with the plumes. The observation was planned and conducted by a Japan-France research collaboration. The installation and recovery of the BBOBS and OBEM were carried out with the JAMSTEC research vessel MIRAI and the Tahitian tuna-fishing boat FETU MANA, respectively. The observation was successfully completed and the 1.5 year-long data were recovered. In the session, we will present an overview of the observation and data and very initial results of the 2009-2010 data.

Keywords: Ocean bottom observation, hot spot

SIT004-P01

Room:Convention Hall

Time:May 26 14:00-16:30

Texturing in the Earth's inner core due to preferential growth in its equatorial belt

Philippe CARDIN^{1*}, Renaud DEGUEN², Sebastien MERKEL³, Ainhoa LINCOT¹

¹ISTerre, Grenoble, France, ²EPS, Johns Hopkins University, USA, ³UMET, Lille, France

We propose an extension of the model by Yoshida et al. (1996), where deformation in the inner core is forced by preferential growth in the equatorial belt, by taking into account the presence of a stable compositional stratification. Stratification inhibits vertical motion, imposes a flow parallel to isodensity surfaces, and concentrates most deformation in a shallow shear layer of thickness proportional to $B^{-1/5}$, where B is the dimensionless buoyancy number. The localization of the flow results in large strain rates and enable the development of a strong texture of iron crystals in the upper inner core. We couple our dynamical model with a numerical model of texture development and compute the time evolution of the lattice preferred orientation of different samples in the inner core. With sufficient stratification, texturing is significant in the uppermost inner core. In contrast, the deeper inner core is unaffected by any flow and may preserve a fossil texture. We then investigate the effect of an initial texture resulting from solidification texturing at the ICB. In the present inner core, the deformation rate in the shallow shear layer is large and can significantly alter the solidification texturing, but the solidification texture acquired early in the inner core history can be preserved in the deeper part. Using elastic constants from ab initio calculations, we predict different maps of anisotropy in the modern inner core. A model with both solidification texturing and subsequent deformation in a stratified inner core produce a global anisotropy in agreement with seismological observations, both in magnitude and geographical distribution, with a weak anisotropy in the uppermost layer and stronger anisotropy in the deeper parts.

Keywords: Inner core, Iron, anisotropy, texturing

SIT004-P02

Room:Convention Hall

Time:May 26 14:00-16:30

Diffusion of Co, Mo in FeNi alloy at high pressure

Shuangming Shan^{1*}, Meili WANG², Takashi YOSHINO¹, Daisuke YAMAZAKI¹

¹ISEI, Okayama University, Japan, ²Peking University, Beijing 100871, China

Seismic observations have shown that the PKIKP waves propagate faster in the north-south direction than in the equatorial plan (Poupinet et al., 1983), which might be caused by dislocation creep (Van Orman, 2004). On the other hand, observation of the seismic velocity structure at the top of the Earth inner core shows that the eastern hemisphere is faster than in the western hemisphere (Niu & Wen, 2001), and they proposed that this might be caused by intrinsic chemical heterogeneity during inner core formation or temperature heterogeneity at the base of outer core. Siderophile elements (SEs) can partition into the inner core during the inner core-forming processes and its distribution can cause the chemical heterogeneity. Iron-nickel alloys are the principal constituents of the Earth core, and their chemical diffusion properties are important for understanding physical and chemical processes in the Earth inner core. If we could obtain diffusivity of SEs in Fe-Ni alloy, the chemical heterogeneity in the inner core and creep mechanism might be solved.

In this study, we measured diffusion coefficients of Mo, Co in fcc FeNi alloy at different conditions to determine pressure dependence on diffusivity. We conducted the experiments in four steps: 1) Synthesis of the Fe-Ni alloys of starting materials by piston cylinder (PC) apparatus at 1400 degree C and 1 GPa. 2) Diffusion runs by the piston cylinder at 1 GPa, and the Kawai-type multi-anvil apparatus (KMA) at different conditions of 7 GPa, 15 GPa and 22GPa and at different temperature conditions of 1200, 1400, 1600 degree C for 1~30 hours. 3) Analysis of diffusion profiles by electron probe micro-analyzer (EPMA). 4) Determination of the diffusion coefficient by fitting the diffusion profiles to Crank function using non-linear least squares method.

Our results show that: 1) Pressure has a negative effect on diffusivity of Co and Mo, and activation volumes are similar to those of Pd, Re and Au. 2) Temperature has a large positive effect on diffusivity, and activation energies are larger than those of Pd, Re and Au. 3) Atomic number has no effect on diffusivity of SEs, and diffusion coefficients of different SEs keep in same level. 4) Diffusion can not make the original heterogeneity of inner core became homogeneous.

Keywords: tracer diffusion, siderophile elements, high pressure

SIT004-P03

Room:Convention Hall

Time:May 26 14:00-16:30

Toward mineralogical interpretation of LLSVP: High-P,T elasticity of deep mantle materials

Jun Tsuchiya^{1*}, Taku Tsuchiya²

¹SRFC Ehime Univ., ²GRC Ehime Univ.

Seismological studies have clarified that although most part of the lower mantle is fairly homogeneous, substantial heterogeneities exist at the bottom a few hundred km. They, in particular low-velocity anomalies observed beneath central-Pacific and Africa often called large low shear velocity provinces (LLSVP), attract great interest, since to clarify nature of them G is a key to understanding of chemical and dynamical properties of the Earth's mantle. Although they would be produced associated with temperature and/or compositional heterogeneities, details are still largely unknown.

Elastic property of possible mantle constituents is one of the most important properties to clarify this issue. So many studies on the high-P,T elasticity of minerals have been performed to date. However, those are still limited for some major phases in the lowermost mantle condition, such as Mg-perovskite, post-perovskite, periclase, and Ca-perovskite. We therefore performed new ab initio simulations on the high-P,T elasticity of some other phases, which are expected not to be abundant in the average silicate mantle but to be substantial when considering differentiated materials. We will discuss possible compositional heterogeneity by constructing mineralogical models of the deep mantle based on the obtained elasticity.

Research supported by JSPS Grant-in-Aid for Scientific Research Grants 20001005 and 21740379 and the Ehime Univ G-COE program "Deep Earth Mineralogy".

Keywords: LLSVP, elasticity, first principles

SIT004-P04

Room:Convention Hall

Time:May 26 14:00-16:30

Seismological and mineral physical joint modeling on seismic anisotropy above/below D''

Yusuke Usui^{1*}, Taku Tsuchiya¹

¹Geophysical Research Center, Ehime Univ.

Many studies have reported a $V_{SV} < V_{SH}$ anisotropy in various places of the D'' layer. Shear wave splitting in the D'' layer beneath the Antarctic Ocean regions was observed by analyzing broad-band seismographs recorded at several recent permanent and temporary seismic stations in Antarctica. The lattice preferred orientation (LPO) of post-perovskite (PPv) and MgO phases are thought to be a major source of the D'' anisotropy. However, we detected the anisotropy even above the D'' discontinuity in these regions unlike previous studies. Perovskite (Pv) and MgO should be instead considered to explain the anisotropy above the D'' layer. Although the deformation mechanisms of the mantle minerals under high-P,T condition are still under debate, mineral physics modeling helps us to know likely LPO directions. In order to clarify the origin of the anisotropy, the seismological and mineral physical (in particular first principle calculations) joint modeling would be an important approach. We first construct new transverse isotropic (TI) shear wave velocity models by the seismic waveform modeling, which have a velocity discontinuity atop the D'' layer and some anisotropy even above the discontinuity. Then we calculated the elastic anisotropy of polycrystalline aggregates (Pv + MgO) and (PPv + MgO) in several different LPO directions with a different degree by means of ab initio high pressure elasticities. Preliminary results suggest that a transversely isotropic aggregate (TIA) of Pv with [100] and MgO[100] vertical directions with unexpectedly small LPO can reproduce the observed anisotropy above the D'' discontinuity. TIA of PPv[001] is possible to be an origin of the anisotropy below the discontinuity. Although PPv[010] is thought to be the major cause in previous works, our results suggest that only complete TIA of PPv[010] can explain the observations. The most likely case is TIA of MgO[100] model. Though the amount of MgO is much smaller than that of PPv and Pv, significantly small LPO can reproduce the anisotropy, indicating MgO is much anisotropic. We conclude that MgO is highly possible to be an origin of the anisotropy. Regional variations will be also demonstrated.

Research supported by JSPS Grant-in-Aid for Scientific Research Grants 21740330 and the Ehime Univ G-COE program "Deep Earth Mineralogy".

Keywords: Anisotropy, Lowermost mantle, Shear wave splitting, Seismic observation, Numerical modeling

SIT004-P05

Room:Convention Hall

Time:May 26 14:00-16:30

X-ray absorption spectroscopy of iron-bearing minerals under high pressure.

Atsuhiko Fujii^{1*}, Tadashi Kondo¹, Shigefumi Matsumoto¹, Keiichi Ishio¹, Hironori Nakao², Yuichi Yamasaki²

¹Graduate school of science, Osaka Univ., ²KEK-IMSS

The Earth's mantle contains significant amount of iron. Iron in the mantle is observed to undergo high-spin to low-spin transition and change of valence state in the lower mantle condition, which affect seismic velocity and oxidation state of mantle minerals. Experimental evidences of the spin transition have been suggested from a small change of compression property or disappearance of satellite peak in X-ray emission spectrum. Change of the valence state has been observed by electron or Mossbauer microscopy for the recovered samples. These methods are not conventional and take much time for measuring. Therefore, we have been challenging with another experimental method, X-ray absorption spectroscopy (XAS). This method can be combined easily with diamond anvil cell (DAC) for in situ measurement at high pressures. The X-ray absorption experiments under high pressure were performed at the BL-3A in KEK-PF (Tsukuba, Japan). The beam line is suitable for XAS with DAC because high intensity monochromatic X-ray of around 7keV from insertion device was focused with collimator and exposed to tiny area of the sample. The absorption of the samples were measured by transmission geometry with two ionization chambers. Several samples such as iron oxides, olivine and garnet were used as standard material to check the absorption edge to 20-30 GPa. We compressed also (Mg_{0.87}Fe_{0.13})O sample to 74 GPa for detect a spin transition. We found that the balance state is distinguishable even at pressures under the right conditions. The details of experiments and analysis will be presented.

Keywords: X-ray absorption, diamond anvil cell, mantle

SIT004-P06

Room:Convention Hall

Time:May 26 14:00-16:30

Numerical investigations of the effects of spatial variations in physical properties on the mantle convective patterns

Arata Miyauchi^{1*}, Masanori Kameyama¹, Hiroki Ichikawa¹

¹Geodynamics Research Center, Ehime Univ.

We performed a linear stability analysis on the onset of thermal convection of fluid in the presence of spatial variation of physical properties such as viscosity, thermal expansivity and conductivity. The viscosity of the fluid is exponentially dependent on temperature, while thermal expansivity and conductivity are linearly dependent on pressure (or depth). The planar layer model geometry is employed. The top and bottom boundary conditions for velocity are taken to be either free-slip or rigid surface while the temperature are fixed on the boundaries. Velocity and temperature distributions are solved for infinitesimal perturbations for given horizontal wave number. We seek for the condition for the onset of convection by changing the values of Rayleigh number and wave number. Then, we examine the influence on incipient convection patterns of the magnitude in spatial variation in physical properties.

Our analysis successfully reproduced the transition in flow patterns into the 'stagnant lid' regime where a thick and stagnant lid of cold fluid develops at the top surface because of the very strong temperature dependence of viscosity. These flow patterns are quite similar to those obtained in finite-amplitude convection. Moreover, we found that the presence of spatial variation in thermal expansivity and conductivity, together with the strong temperature dependency in viscosities, changes the convective planform and moderately affects the onset of stagnant lid regime. In the presentation, the details of numerical results would be shown and discussed for describing the nature of the stagnant lid convection.

Keywords: mantle convection, linear stability analysis, temperature-dependent viscosity, pressure-dependent thermal expansivity, pressure-dependent thermal conductivity, stagnant-lid convection

SIT004-P07

Room:Convention Hall

Time:May 26 14:00-16:30

Fe distribution between (post-)perovskite and ferropericlas

Yoshinori Tange^{1*}, Taku Tsuchiya¹

¹Geodynamics Research Center, Ehime Unive

Thermochemical properties in the Earth's deep mantle is still not completely understood. Fe distribution in major lower mantle phases of (post-)perovskite and ferropericlas is of particular importance, because Fe has several substantial effects on density, elasticity, electric and thermal conductivity. Many high-pressure experiments have tackled this issue to date, but the results at the moment seem less converged both experimentally and theoretically. This is originated mostly in multiple complexities related to the valence state, spin state, and incorporation mechanism of Fe. These lead to pressure-induced charge disproportionation reaction and high-to-low spin transition of Fe, all of which need to be considered for understanding the behavior of Fe comprehensively. In this study, we conducted ab initio density functional computations of the Fe distribution in several complex, more realistic situations including multiple phase and also Al-bearing cases. Although we will report details in the presentation, the calculations so far indicate strong effects of the disproportionation of Fe in Pv and spin transition in Fp. They are more remarkable than expected and have opposite contributions. We anticipate that the predicted behaviors should be observed experimentally.

Keywords: lower mantle, Fe distribution, charge disproportionation, spin transition

SIT004-P08

Room:Convention Hall

Time:May 26 14:00-16:30

Improvement of a semi-dynamical numerical model of a subduction zone in a 3D sphere and its applications

Manabu Morishige^{1*}, Satoru Honda¹, Paul J. Tackley²

¹Earthquake Research Institute, ²ETH Zurich

In this presentation, we present a semi-dynamical subduction zone model in a three-dimensional spherical shell and its applications. The approach we take to enable one-sided subduction at a given angle is to impose velocity on the top surface and in a small three-dimensional region around the shallow plate boundary. The velocity imposed in the region around the plate boundary is determined based on the idea that mass conservation inside the region is satisfied. We can also easily incorporate trench migration kinematically in the model. The advantage of the model is that it allows us to use constraints from as many as possible observations, such as surface plate velocity, shape of the trench and subduction angle in the shallow part, which makes it easier for us to compare the results with observations. Therefore, the model is useful for studying a specific subduction zone where the plate kinetics are well constrained.

As applications of the model, two cases are considered. First, mantle flow around a slab edge is considered, and we find that the effect of Earth curvature on mantle flow is small by comparing our model with a similar one in a rectangular box. If, however, we model a broader area or deeper processes, the effect of Earth curvature may become large and hence important. Second, the case with non-Newtonian rheology is considered using the improved model. One difficulty that may arise in considering non-Newtonian rheology is the treatment of the singularity near the edge of the region around the plate boundary. The effect of the singularity is, however, suppressed by ramping the velocity imposed around the region. The calculation with non-Newtonian rheology may be useful particularly if we study seismic anisotropy.

Keywords: subduction zone, non-Newtonian rheology, 3D sphere, mantle flow

SIT004-P09

Room:Convention Hall

Time:May 26 14:00-16:30

Metastable postspinel and post-garnet transitions in pyrolite: an implication for multiple seismic discontinuities

Nanako Kamegata^{1*}, Norimasa Nishiyama¹, Tetsuo Irifune¹

¹Geodynamics Research Center, Ehime Univ.

Postspinel and post-garnet transformation experiments were carried out at pressures between 22 and 27 GPa at a temperature of 1873 K using synthesized polycrystalline sample with pyrolite composition which consists of ringwoodite and majorite garnet. We observed that three discontinuous transitions occur in the ringwoodite + majorite garnet polycrystalline sample: (1) disproportionation of MgSiO₃-rich perovskite (MPv) with small amount of alumina and CaSiO₃-rich perovskite from majorite garnet at about 22 GPa; (2) postspinel transition producing alumina-free MPv and magnesiowustite at about 23 GPa; (3) transition of alumina-rich majorite into alumina-rich MPv that should be accompanied by formation of an aluminous phase at 27 GPa. The presence of the observed transitions in three steps in metastable pyrolite is very different from the equilibrium transitions studied in previous studies: postspinel transition is sharp and postgarnet transition proceeds gradually in a binary loop in MgSiO₃-Mg₃Al₂Si₃O₁₂ system. The equilibrium transition can explain features of 1D earth models such as PREM: the sudden increase of velocities at 660 km depth corresponds to the postspinel transition and the increase of the velocities with steeper gradient between 660 and 720 km to gradual transition of majorite garnet. The results of the present study suggest that the metastable transformations in pyrolite explain the regionally observed splitting of 660 km discontinuity, especially beneath subduction zones: the postspinel transition causes the discontinuity near 660 km depth (which can be deeper than 660 km depth because of low temperature of subducting slab); the shallower and deeper discontinuities might be caused by the metastable transformations of majorite garnet.

Keywords: metastable transformation, pyrolite, multiple seismic discontinuities, 660 km depth

SIT004-P10

Room:Convention Hall

Time:May 26 14:00-16:30

Electrical conductivity measurements of hydrous minerals under high pressure

Xinzhuan Guo^{1*}, Takashi Yoshino¹, Takuo Okuchi¹, Ikuo Katayama², Daisuke Yamazaki¹

¹ISEI, Okayama University, ²Hiroshima University

The electrical conductivity measurements of hydrous minerals (including natural talc rocks and serpentinites, synthesized $\text{Mg}(\text{OH})_2$ and $\text{Mg}(\text{OD})_2$, and synthesized dense hydrous magnesium silicates) were conducted using an impedance analyzer under high pressures generated by a 1000-ton Kawai-type multi-anvil high pressure apparatus. The electrical conductivity anisotropy of deformed natural talc rocks and serpentinites was investigated in the frequency range of 10^{-3} - 10^6 Hz and temperature range of 500-1000 K along three directions: the direction parallel to lineation of oriented minerals (X direction), the direction perpendicular to lineation on the foliation plane (Y direction), and the direction perpendicular to the foliation (Z direction) at 3 GPa. The electrical conductivities of $\text{Mg}(\text{OH})_2$, $\text{Mg}(\text{OD})_2$ and phase A polycrystals were measured in the frequency range of 10^{-1} - 10^6 and temperature range of 500- 750 K at 3 GPa, 3 GPa and 10 GPa, respectively. For talc rocks and serpentinites, the electrical conductivities parallel to the X direction and the Z direction are the highest and the lowest, respectively. The electrical conductivity anisotropy for the talc rocks is stronger than that for the serpentinite. The electrical conductivity anisotropy of natural deformed talc rocks and serpentinites strongly depends on the crystal structure and orientation of minerals during deformation. The electrical conductivity increases in orders of talc, serpentine, phase A (similar with serpentine), deuterium brucite and hydrogen brucite, indicating the dependence of the electrical conductivity on water contents in the structures. The activation enthalpy of talc rock is the lowest (0.59 eV) in the X direction and the highest (0.68 eV) in the Z direction. The activation enthalpies of the serpentinite in different directions show the consistent value, 0.74 eV, for the experiments using Mo electrodes. In the case of using Ni electrodes, the activation enthalpies are 0.70 eV, 0.66 eV and 0.68 eV for the measurements in X, Y and Z direction respectively. The higher electrical conductivity and the lower activation enthalpy of the serpentine using Ni-NiO buffer are attributed to the higher $f\text{O}_2$ of Ni-NiO buffer. The activation enthalpies of $\text{Mg}(\text{OH})_2$, $\text{Mg}(\text{OD})_2$ and phase A are 0.86 eV, 0.81 eV and 0.68 eV respectively. Furthermore, grain interior conductivity, grain boundary conductivity and electrode reaction can be recognized from the impedance arcs. Relationship between logarithm of electrical conductivity of grain boundary and reciprocal temperature shows the linear relationship as well as the grain interior conductivity. The total electrical conductivities are reduced by the grain boundary conductivities.

Keywords: Electrical conductivity, Talc rocks, Serpentinites, Brucite, Phase A, Anisotropy

SIT004-P11

Room:Convention Hall

Time:May 26 14:00-16:30

Adjoint tomography of East Asia

Masayuki Obayashi^{1*}, Yoko Tono¹, Seiji Tsuboi¹, Daisuke Suetsugu¹

¹IFREE, JAMSTEC

We use spectral-element and adjoint methods to image upper mantle P-wave and S-wave speed heterogeneities in East Asia. We take one chunk from global mesh of spectral-element method and compute synthetic seismograms with accuracy of about 10 second. The study area involves the convergent boundaries of the Pacific, Indo-Australian and Philippine-sea plates and the slab subducted from the boundaries show a complex morphology. We use GAP-P2 mantle tomography model (Obayashi et al., 2009) as an initial 3D model and try to use as many broadband seismic stations available in this region, including Ocean Bottom Seismographs deployed in Philippine sea, as possible to perform inversion. Before accumulating finite frequency adjoint kernels for seismic velocity structure, we estimated influences of the initial 3D model on the focal mechanism and hypocenter location. We chose earthquakes occurred at various locations and depths in this region from Global CMT catalog. We picked up time windows for P and S waves that give decent match between data and synthetics for 3D model and determine the best fit solutions for source mechanism and hypocenter. We found that the redetermined solutions do not differ much from the Global CMT solutions, which shows that the Global CMT solutions can be used as initial solutions in the inversion. We then use the time windows for P and S waves to compute adjoint sources and calculate adjoint kernels for seismic velocity structure. Our first result of the inversion will be shown at the meeting.

Keywords: mantle, tomography, spectral element method, adjoint method