The Earth’s internal structure explained from a viewpoint of the condensed matter physics

*Shinji Karasawa[1]

1.Miyagi National College of Technology Professor emeritus

Pressure in the Earth increases with increasing depth. The potential energy of electron of substances is lowered by the contraction caused by the pressure. When it comes to the state of lower energy, the substance releases the extra energy. By the way, a meteorite crash forms a crater. Substances concerned with the crater will be heated at an instant by the impulsive contraction. But, the energy of the heat is absorbed by the expansion at immediately after. The energy of the collision is able to change the form of substance at a limited area. But, the main part of the heat source on inner Earth is explained as the resultant of accumulation of substances. That is, the steady-state temperature in center of the Earth is 7000℃ at the highest. It is corresponds to the electronic states of 0.63 eV. The resultant electronic state is able to describe the circumstances as follows.

The interactions among electronic orbits increase according to increase of depth in the Earth. The state of the substance is adapted to the situation by replacement of adjacent atoms caused by thermal motion. The interactions among those electronic orbits are possible to produce the lower energy state. The state with the low energy produces the extra energy. The extra energy contributes to the heat source of inner Earth. The energy of the heat together with substance is transported from the place with high temperature. That is the mantle convection. The mantle that is beneath the oceanic crust carries the heat more than the mantle under the continental plate. So, the magma emerges onto the ocean floor.

The core of Earth's interior structure can be explained depending on the nature of the substance. The liquidity with good electric conductivity in outer core of the Earth is explained by the degenerated state of electron that is occurred by a quantum resonance among overlapped orbits. The degenerated state of electron changes to the lower symmetry according to Jahn-Teller-Theorem. This state of the lowest energy corresponds to the solid state of inner core that makes possible to propagate a transverse wave.

The proposing concrete explanations are as follows. (1) Heat source of the mantle convection, (2) Heat source of volcano in the sea plate subduction zone, (3) Metallic state on the outer core of the Earth, (4) Solid state on the inner core of the Earth, (5) The formation of the solar system, and (6) The formation of terrestrial planets. The details are presented at the website: (https://www.youtube.com/watch?v=GMmvjU2CdKM&feature=youtu.be).

Keywords: Mantle convection, Outer core, Inner core, Adiabatic compression, Degenerated state of electron, Jahn-Teller-Effect

The deep lunar interior with a low-viscosity zone: Revised constraints from recent geodetic parameters on the tidal response of the Moon

*Yuji Harada[1,2], Sander Goossens[3], Koji Matsumoto[4], Jianguo Yan[5], Jinsong Ping[6], Hirotomo Noda[4], Junichi Haruyama[7]

1.SSI, MUST, 2.ERI, UT, 3.CRESST, UMBC, 4.NAOJ, NINS, 5.LIESMARS, WHU, 6.NAOC, CAS, 7.ISAS, JAXA

We revisit the constraints on the deep lunar interior with a possible low-viscosity zone at the core-mantle boundary obtained from our previous forward modeling of the tidal response of the Moon, by comparing a numerical model with several tidal parameters that have been improved or are newly determined by recent geodetic observations and analyses from GRAIL (gravity), LRO (shape), and LLR (rotation). Our results are in principle consistent with the latest data and lead to a thicker low-viscosity layer (with an outer radius of about 540 to 560 km, which is much larger than that of about 500 km in our earlier investigation) which reaches just below or inside the place where many seismic nests of deep moonquakes are located.

Keywords: viscosity, Moon, interior, tide, Love number, quality factor

Seafloor subsidence and mantle dynamics

*Claudia Adam[1], S King[1], M Rabinowicz[2], Valerie Vidal [3], A Jalobeanu[4], Masaki Yoshida[5]

1.Virginia Polytechnic Institute and State University, 2.GET, Observatoire Midi-Pyrénées, Toulouse, 3.Laboratoire de Physique, ENS Lyon, 4.Bayes Map Solutions, LLC, Castro Valley, CA, 5.Department of Deep Earth Structure and Dynamics Research, Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

The subsidence of seafloor is generally considered as a passive phenomenon related to the conductive cooling of the lithosphere since its creation at mid-oceanic ridges. Recent alternative theories suggest that the mantle dynamics plays an important role in the structure and depth of the oceanic lithosphere. However, the link between mantle dynamics and seafloor subsidence has still to be quantitatively assessed. Here we provide a statistic study of the subsidence parameters (subsidence rate and ridge depth) for all the oceans. These parameters are retrieved through the positive outliers method, a classical method used in signal processing. We also model the mantle convection pattern from the S40RTS tomography model. The density anomalies derived from this model are used to compute the instantaneous flow in a global 3D spherical geometry, and the induced dynamic topography.

The variations of the mid-oceanic ridge depths are well recovered by the modeled dynamic topography. The systematic fit of the bathymetry allows the recovery of the subsidence rate, from which we derive the effective thermal conductivity, k_{eff}. This parameter ranges between 1 and 7 $Wm^{-1}K^{-1}$. We show that departures from the $k_{eff}=3\ Wm^{-1}K^{-1}$ standard value are systematically related to mantle convection and not to the lithospheric structure. Regions characterized by $k_{eff}>3\ Wm^{-1}K^{-1}$ are associated with the uplift of mantle plumes. Regions characterized by $k_{eff}<3\ Wm^{-1}K^{-1}$ are related to large scale mantle downwellings such as the Australia-Antarctic Discordance (ADD) or the return flow from the South Pacific Superswell to the East Pacific rise. This demonstrates that the mantle dynamics plays a major role in the shaping of the oceanic seafloor. In particular, the parameters generally considered to quantify the lithosphere structure, such as the thermal conductivity, are not only representative of this structure but also incorporate signals from the mantle convection occurring beneath the lithosphere.

Effect of along-trench slab dimension on subduction-induced upper mantle flow: Insights from 3-D laboratory models

*Vincent Strak[1,2], Wouter Pieter Schellart[1]

1.Monash University, 2.Earthquake Research Institute

Three-dimensional self-evolving subduction models with various along-trench dimensions have been quantitatively analysed in the laboratory by means of a stereoscopic Particle Image Velocimetry (sPIV) technique. The purpose was (1) to provide information on the pattern of the upper mantle flow induced by subduction, particularly focusing on the location and magnitude of upwellings around the lateral slab edges and in the mantle wedge, (2) to study the evolution of mantle upwellings in terms of location and magnitude, and (3) to study the effect of along-trench slab dimension on upwelling location and magnitude. The model results show that 4 types of upwelling are generated by subduction in a Newtonian upper mantle. One of these upwellings occurs laterally away from the sub-slab domain and could potentially trigger decompression melting, thereby explaining the occurrence of a certain type of intraplate volcanism. Two other significant upwellings are observed in the mantle wedge. The tested along-trench slab dimensions were comparable to slabs of narrow (e.g., Calabria) to wider (e.g., Tonga-Kermadec-Hikurangi) subduction zones. The results indicate that both the location and magnitude of the upwelling occurring laterally away from the sub-slab domain are affected by the along-trench slab dimension, with wider slabs producing faster and more focused upwellings that are located closer to the lateral slab edges. The models also seem to show that the along-trench slab dimension controls the intensity of upwellings in the mantle wedge.

Keywords: Subduction, Mantle flow, Upwellings

Seismic structure and dynamics beneath eastern Tibet: Insight into large earthquakes and Tengchong volcano

*Lei Jianshe[1], Dapeng Zhao[2]

1.Key Laboratory of Crustal Dynamics, Institute of Crustal Dynamics, China Earthquake Administration, 2.Department of Geophysics, Tohoku University

We review recent studies of seismic tomography and earthquake sequences, and discuss their implications for seismotectonics and mantle dynamics beneath eastern Tibet. The crustal structures in the source areas of the 2008 *Ms* 8.0 Wenchuan and the 2013 *Ms* 7.0 Lushan earthquakes are similar and exhibit prominent low-velocity (low-V) and high-Poisson's ratio anomalies in the source areas, indicating that in addition to compositional variations, fluid-filled rock matrices exist in the Longmenshan fault zone, which may have influenced the nucleation of the two earthquakes. Significant low-V anomalies are revealed between the Wenchuan and Lushan mainshocks, which may explain why their aftershock zones extend northward and southward, respectively. The relocated aftershocks of the 2011 *Ms* 5.8 Yingjiang and the 2014 *Ms* 6.5 Ludian earthquakes show a conjugate-shaped distribution, which may explain why the two moderate-sized earthquakes caused heavy damage. The large earthquakes in eastern Tibet are located at boundaries of low- or high-velocity anomalies in the upper mantle. The structural heterogeneities in the crust and upper mantle are associated with hot and wet upwelling and corner flows in the big mantle wedge above the subducting Indian slab beneath eastern Tibet, as well as slab dehydration, which affect the seismogenesis in the region.

Keywords: Seismci structure, Mantle dynamics, Eastern Tibet, Large earthquake, Tengchong volcano

Transformational Faulting as a Deep-Focus Earthquake Mechanism: Correlating In-Situ Acoustic Emission Locations at High P-T with Post-Mortem Fault Imaging Using Synchrotron X-Ray Microtomography in Controlled Deformation Experiments

*Yanbin Wang[1], Lupei Zhu[2], Feng Shi[1], Tony Yu[1], Mark L Rivers[1], Alexandre Schubnel[3], Nadege Hilairet[4], Fabrice Brunet[5]

1.Center for Advanced Radiation Sources, University of Chicago, Chicago, IL, USA, 2.Department of Earth Sciences, St. Louis University, St. Louis, MO, USA, 3.Laboratoire de Géologie, CNRS UMR 8538, Ecole Normale Supérieure, Paris, France, 4.Université des Sciences et Technologies de Lille, Lille, France, 5.CNRS-ISTerre, Université de Grenoble, Grenoble, France

One of the possible mechanisms responsible for deep-focus earthquakes occurring at depths below 350 km is faulting induced or triggered by phase transformation from metastable olivine to its high-pressure phases (wadsleyite and ringwoodite, both are related to the general spinel structure) in the mantle transition zone. We have studied transformational faulting from olivine to spinel in Mg_2GeO_4, a close analog of the silicate olivine $(Mg,Fe)_2SiO_4$, using a high-pressure deformation apparatus in conjunction with in-situ acoustic emission (AE) monitoring [1]. Synchrotron X-ray microtomography (XMT) [2] was used to image the samples recovered from high-pressure deformation experiments, with spatial resolution of ~0.005 mm. In this study, we establish spatial correlations between AE events observed during in-situ deformation experiments and faults imaged by XMT post-mortem. The nature of high-pressure experiments limits the sample size to the order of 2 mm in linear dimensions, and the acoustic system we used has a maximum sampling rate of 50 MHz (i.e., 20 ns between adjacent sampling points), which limits spatial resolution of AE locations to about 0.3 mm. This makes it difficult to locate AE events accurately. A well-developed double-difference cross-correlation (CC) algorithm (hypoDD –[3]) developed for seismological studies has been successfully adapted in the analysis of AE locations, improving AE allocation spatial resolution by a factor of ~10. This algorithm also helps separate events with various waveforms, which are related to different fault planes and faulting directions. The CC algorithm classifies AE events into various groups. Events within each group share common characteristics and may be considered occurring within the same faulting mechanism. These groups of events display excellent correlations with faults imaged by XMT, with two major groups of AE events correlating well with two conjugated faults in XMT images. Furthermore, time sequence of AE events can be examined to investigate details of formation of macroscopic faults from the micro AE events. These results help understand the dynamic process of transformational faulting.

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Keywords: Deep-focus earthquakes, High P-T deformation, Acoustic emission, Synchrotron x-ray diffraction and imaging, Earthquake mechanisms

Behavior of basalt-carbonate melts at high pressures

*Yoshio Kono[1], Hiroaki Ohfuji[2], Vincenzo Stagno[2], Curtis Kenney-Benson[1], Yanbin Wang[3], Guoyin Shen[1]

1.Carnegie Institution of Washington, 2.Ehime University, 3.The University of Chicago

Knowledge of the occurrence and mobility of carbonate-rich melts in the Earth’s mantle is important for understanding the deep carbon cycle and related geochemical and geophysical processes. Recently, Kono et al. (2014) find that viscosities of carbonate melts are surprisingly low, in the range of 0.006-0.010 Pa s, which are ~2 to 3 orders of magnitude lower than those of basaltic melts in the upper mantle. As a result, the mobility of carbonate melts (defined as the ratio of melt-solid density contrast to melt viscosity) is ~2 to 3 orders of magnitude higher than that of basaltic melts. Such high mobility of carbonate melts may have significant influence on several magmatic processes, such as fast melt migration and effective melt extraction beneath mid-ocean ridges. However, the behaviour of carbonate-rich silicate melt may be complex, as demonstrated in the reported immiscible behaviour of silicate-carbonate melts. To predict potential implications of carbonate-rich silicate melt as they migrate up in the upper mantle, the stability should be investigated at those pressures. Here we investigate behavior of basalt-dolomite melts with 20-61 vol.% dolomite compositions at high pressures to 7.3GPa by using newly developed X-ray phase contrast imaging technique in Paris-Edinburgh cell at beamline 16BMB, HPCAT, in the Advanced Photon Source. We find that basalt plus 32-61 vol.% dolomite becomes single melt at pressure >~5.5 GPa, while it separates into silicate-dominant melt plus CO_2 at lower pressures. The abrupt change of stability of carbonate-rich silicate melt may play a role of paramount importance in migration velocity of upwelling carbonate-silicate magmas due to separation of carbonate component from silicate melt, with 2-3 orders of magnitude difference of viscosity between basalt and carbonate melts.

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Keywords: carbonate, melt, high pressure

Stagnant slab formation and evolution inferred from kinematic and geometrical observations of the subduction zone

*Tomoeki Nakakuki[1]

1.Department of Earth and Planetary Systems Science, Graduate School of Science, Hiroshima University

Seismic tomography revealed variable slab structure in the mantle transition zone (e.g., Fukao et al., 2009). Numerical modeling that incorporates phase transition at the 660 km depth and trench migration succeeded to simulate formation and avalanche of the stagnant slab (Christensen, 1996; Torii and Yoshioka, 2007; Nakakuki et al., 2010). Mechanisms to control structure of the transition zone slab are still controversial (e.g., Karato et al., 2001; King et al., 2015), since we have not sufficiently understood relationship of the slab dynamics with tectonic features in the actual subduction zone (cf. Billen, 2010). In this study, subduction zone geometric and kinematic observations are analyzed aiming to construct a scenario for the stagnant slab formation and evolution. The data, which are compiled by Lallemand et al. (2005) and (2008), include absolute motions of the subducting plate, the overriding plate and the trench based on a global plate motion model (SB04) constructed by Steinburger et al. (2004), slab depths, and slab dip angles.

Important observations connected to the stagnant slab dynamics are summarized as follows. (1) Most of upper mantle slabs are retreating with the velocity larger than 1 [cm/yr]. (2) In the subduction zone with the slab penetrating at the depth between 660 to 1200 km, trench motion is advance (e.g., Mariana, Java) or retreat with the slower velocity (< 1 [cm/yr], e.g., north Kuril) than that in the subduction zone with the upper slab. (3) Back-arc extension often occurs in the subduction zone in which the maximum slab depth is 660 km (e.g., Tonga). (4) Dip angles of the upper and lower mantle slabs become steeper with the age. (5) Stagnant slabs are classified into 2 types. (i) The first type has young age (< 60 [Ma]), slow subducting plate motion (the slab descending motion occur as if the plate peeled and fell off from the surface (e.g., New Hebrides). (ii) The second type has old age (> 100 [Ma]) and dip angles obviously shallower (< ~50 [deg], e.g., south Kuril, Japan) than those of the slab penetrating into the lower mantle.

These results indicate important relationship of the slab dip angle and trench migration to the slab structure varying with the sinking depth. The following scenario emerges as a possible explanation for the stagnant slab mechanics. (1) A relatively young slab with shallow dip angle and trench retreat collides to the 660 km phase transition. (2) The slab start stagnates at 660 km, and the slab rollback is further enhanced. (3) When the dip angle of the stagnating slab is shallow, the slab retains the stagnation at the 660 km after the trench retreat is declined. (4) When the dip angle is steepened and/or the trench advance is generated owing to increase of subducting plate age or collision of the continent, the slab penetrates into the lower mantle.

Keywords: stagnant slab, mantle transition zone, plate kinematics, subduction zone

Messengers from the deep: Fossil wadsleyite-chromite microstructures from the Mantle Transition Zone

*Takako Satsukawa[1], William L Griffin[2], Sandra Piazolo[2], Suzanne Y O'Reilly[2]

1.Department of Geophysics, Division of Earth and Planetary Sciences, Kyoto University,
2.CCFS&GEMOC, Department of Earth and Planetary Sciences, Macquarie University

Investigations of the Mantle Transition Zone (MTZ; 410-660 km deep) by deformation experiments and geophysical methods suggest that the MTZ has distinct rheological properties, but their exact cause is still unclear due to the lack of natural samples. Here we present the first direct evidence for crystal-plastic deformation by dislocation creep in the MTZ using a chromitite from the Luobusa peridotite (E. Tibet). Chromite grains show exsolution of diopside and SiO_2, suggesting previous equilibration in the MTZ. Electron backscattered diffraction (EBSD) analysis reveals that olivine grains co-existing with exsolved phases inside chromite grains and occurring on chromite grain boundaries have a single pronounced crystallographic preferred orientation (CPO). This suggests that olivine preserves the CPO of a high-pressure polymorph (wadsleyite) before the high-pressure polymorph of chromite began to invert and exsolve. Chromite also shows a significant CPO. Thus, the fine-grained high-pressure phases were deformed by dislocation creep in the MTZ. Grain growth in inverted chromite produced an equilibrated microstructure during exhumation to the surface, masking at first sight its MTZ deformation history. These unique observations provide a window into the deep Earth, and constraints for interpreting geophysical signals and their geodynamic implications in a geologically robust context.

Keywords: Mantle transition zone, chromitite, olivine, CPO, EBSD, microstructure

Mantle transition zone beneath a normal seafloor in the northwestern Pacific: Electrical conductivity, seismic discontinuity, and water content

*Tetsuo Matsuno[1], Daisuke Suetsugu[2], Hisashi Utada[1], Kiyoshi Baba[1], Noriko Tada[2], Hisayoshi Shimizu[1], Hajime Shiobara[1], Takehi Isse[1], Hiroko Sugioka[3], Aki Ito[2]

1.Earthquake Research Institute, The University of Tokyo, 2.Japan Agency for Marine-Earth Science and Technology, 3.Kobe University

We conducted a joint electromagnetic (EM) and seismic experiment to probe the mantle structure below a normal seafloor around the Shatsky Rise in the northwestern Pacific. Specifically for the investigation of the mantle transition zone (MTZ) structure, we deployed our state-of-the-art instruments in two arrays to the north and south of the Shatsky Rise for 5 years from 2010 to 2015. Here we report the result of analyses of EM and seismic data obtained in the joint experiment as well as in previous studies. From the EM data analysis, a 1-D profile of electrical conductivity was obtained for two observational arrays. The thickness of the MTZ was also obtained by the P-wave receiver function analysis, from which temperature profiles in the MTZ below two arrays were then estimated. We found that the northern array provides EM and seismic data with much higher quality than the southern array, and therefore meaningful estimation of MTZ water content is possible for the northern array. We estimated water content based on profiles of electrical conductivity and temperature obtained by our geophysical observation and electrical conductivities of dry and wet MTZ minerals (wadsleyite and ringwoodite) obtained by mineral physics. The result of the forward modeling study indicated that the upper limit of water content below the northern array is 0.5 wt.% or 0.05 wt.%, depending on different results of laboratory experiments for water effects on electrical conductivities. The lower limit of water content was not constrained by our data.

H-D inter-diffusion in Fe-free wadsleyite: implication for multiple hydrogen mechanism

*Wei Sun[1], Takashi Yoshino[1], Naoya Sakamoto[2], Hisayoshi Yurimoto[3]

1.Research Group of Physics of the Earth's Interior at the Institute for Study of the Earth's Interior, Okayama University, 2.Isotope Imaging Laboratory, Creative Research Institution, Hokkaido University, 3.Department of Natural History Sciences, Hokkaido University

It has been proposed that concentration and speciation of water-derived species in minerals may adjust in response to changes of points defect condition [*Demouchy and Mackwell*, 2006], To lift the veil of Fe effect on hydrogen diffusion and isotopic differentiation, a sets of H-D inter-diffusion experiments were conducted in Fe-free wadsleyite single crystal couples at various temperatures, 16 GPa and compared with our former study on Fe-bearing wadsleyite. Distinguish with symmetric profiles in Fe-bearing condition, H-D inter-diffusion in Fe-free wadsleyite revealed evidently asymmetric properties and it indicates deuterium diffuses about 1 order faster than hydrogen in Fe-free wadsleyite. Both magnitude and anisotropy of H-D inter-diffusion in Fe-free condition are largely different with Fe-bearing condition, which strongly demonstrated a multiple hydrogen mechanism proposed by *Karato* (2013) association with free proton migration in interstitial sites. Simulation model suggests free proton migration in interstitial sites dominates the hydrogen diffusion in Fe-free condition and asymmetric properties might owe to the distinguished jumping probabilities from Mg sites to interstitial sites between hydrogen and deuterium.

Keywords: inter-diffusion, wadsleyite, asymmetric, multiple

High-pressure phase relations in the system $MgCr_2O_4$-Mg_2SiO_4 with implications to ultra-high pressure chromitites in ophiolites

*Masaki Akaogi[1], Yuki Anegawa [1], Airi Kawahara[1], Takayuki Ishii[1], Hiroshi Kojitani[1]

1.Department of Chemistry, Faculty of Science, Gakushuin University

Podiform chromitites which are enveloped by dunite are commonly found in harzburgite in ophiolites. It is interpreted that the podiform chromitites were formed through reaction between harzburgite and melt at a shallow upper mantle level. However, some podiform chromitites recently found in Luobusa ophiolites, Tibet, were interpreted to be derived from the deep mantle, because the chromitites contained diamond and coesite as inclusions. Yamamoto et al. (2009) and Arai (2013) suggested that the chromitites originally consisted of calcium-ferrite (CF) structured phase in the deep mantle and that they transformed to spinel-structured chomites during upwelling.
We have recently determined phase relations in $MgCr_2O_4$ at pressure up to 28 GPa and temperature to 1600 ^oC. Magnesium chromite ($MgCr_2O_4$) with the spinel structure first transforms to a two-phase assemblage of modified ludwigite (mLd)-type $Mg_2Cr_2O_5$ + corundum-type Cr_2O_3 at 13-15 GPa, and the two phases combine into a calcium-titanate (CT) phase at 16-20 GPa (Ishii et al., 2015). Because chromite minerals in natural podiform chromitites are enveloped in olivine crystals, we have extended our experimental study to the system $MgCr_2O_4$-Mg_2SiO_4 to examine phase relations and mutual solubilities in the high-pressure phases.
High-pressure high-temperature experiments were performed in composition of 50mol%$MgCr_2O_4$.50mol%Mg_2SiO_4 up to 26 GPa at 1600 ^oC using a Kawai-type mulitianvil apparatus. Phase identification of the synthesized samples were made using micro-focus and powder X-ray diffractometers. Composition analysis was performed using a scanning electron microscope with an energy-dispersive X-ray spectrometer. At pressure below about 14 GPa, Mg_2SiO_4 forsterite coexists with $MgCr_2O_4$-rich spinel. At 14-19 GPa, a three-phase assemblages, mLd + garnet (Gt) + wadsleyite (Wd) becomes stable. This assemblage changes into $MgCr_2O_4$-rich CT + ringwoodite at about 20 GPa, which further changes into an assemblage of $MgSiO_3$-rich bridgmanite (perovskite) + CT + periclase at about 23 GPa. The mLd composition was close to $Mg_2Cr_2O_5$, while Gt has a middle composition between $Mg_4Si_4O_{12}$ and $Mg_3Cr_2Si_3O_{12}$. Solubility of Mg_2SiO_4 component in CT increases with pressure to about 20 mol% at 26 GPa. These results implies that, when podiform chromitites are subducted into the deep mantle, $MgCr_2O_4$ spinel and forsterite react to form mLd + Gt at 14-19 GPa which corresponds to pressure range of the upper part of the mantle transition zone. Also, if CT phase containing substantial Mg_2SiO_4 component goes upward from the deep mantle, it decomposes into the assemblage containing mLd + Gt at 14-19 GPa. To the best of our knowledge, mLd + Gt in association with chromite have not yet been found in the natural chromitites. Therefore, we suggest that possible occurrence of mLd and/or Gt coexisting with chromite is an important indicator which shows that the chromitites were derived from the depth at least upper-part of the transition zone.

Keywords: high pressure , chromitite, phase relation

Boron doped diamond heater in the Kawai-type apparatus

*Longjian Xie[1], Akira Yoneda[1], Eiji Ito[1]

1.Institute for Study of the Earth Interior , Okayama University

Boron doped diamond (BDD) heater has attracted special attention because of its high melting point and X-ray transparency. In the previous studies, graphite boron composite (GBC) was usually used as a precursor of BDD. In the present study, we firstly investigated the application of pre-synthesized BDD cylinder and BDD powder as cylindrical heaters in the Kawai-type apparatus at 15 GPa. BDD with 0.5 and 3.0 wt % was synthesized at 15 GPa and 2100 ^{o}C. The BDD powders were grinded from BDD blocks by using Nano Polycrystalline Diamond mortar at GRC, Ehime Univ.; SEM image showed that the grain size of diamond is about 1 μm. Both kinds of heaters showed good stability and high reproducibility. The BDD heater with 0.5 wt % boron (resistivity:~0.001Ω.m at 1500 ^{o}C) showed semi-conductive behavior, i.e. decreasing resistance with increasing temperature. However, the BDD heater with 3.0 wt % boron showed lower resistivity (about 0.00016 Ω.m at 1500 ^{o}C) and metallic behavior, i.e. increasing resistance with increasing temperature. This electrical characteristic enables us to adjust the boron concentration of BDD to get the desired resistivity. We succeeded to generate temperature about 3500 ^{o}C by using small heater (1.5 mm outer diameter, 1 mm inner diameter, 6 mm length) with TiC electrode. Temperature higher than 1800 ^{o}C was estimated by input power according to its temperature–power relationship. The pressure generation efficiency by assembly using BDD heater was checked by *in-situ* X ray experiments at SPring-8. Compared with assembly using GBC heater, the use of BDD heater has lower efficiency of pressure generation in the beginning stage of compression, while has higher efficiency in the later stage. It is obvious that the BDD heater is more advantageous than GBC heater, because it is free from the complicated temperature–power relationship and pressure drop associated with graphite to diamond conversion.

Keywords: Diamond synthesize, Boron doped diamond heater, Ultrahigh temperature, Multi-anvil apparatus

Melting relations in the $MgO-MgSiO_3$ system under the lower mantle condition using a CO_2 laser heated diamond anvil cell

*Satoka Ohnishi[1], Yasuhiro Kuwayama[2], Toru Inoue[2]

1.Graduate School of Science and Engineering, Ehime University, 2.Geodynamics Research Center, Ehime University

Seismological observations of the ultralow-velocity zones (ULVZs) suggest the presence of partial melts above the core-mantle boundary (CMB). Knowledge of the melting relations in the lower mantle is a key to understand the chemical differentiation at the base of the mantle. While melting relations of mantle materials at relatively low pressure (below 30 GPa) have been extensively studied using a multi-anvil apparatus (e.g. Ito *et al.*, 2004 *Phy. Earth Planet. Inter.*), the melting experiments at higher pressures are still limited. Only in a few model rock compositions, such as peridotite and mid-oceanic ridge basalt (MORB), the experiments were conducted under the CMB conditions using a laser-heated diamond anvil cell (LHDAC) (e.g. Fiquet *et al.*, 2010 *Science,* Andrault *et al.*, 2014 *Science*). Since chemical heterogeneity of both major elements (Mg, Si, Fe, Al...) and minor ones (e.g. alkalis and volatiles) should have a large effect on the melting behavior, the melting phase diagrams as a function of composition are fundamental to understand the nature of the ULVZs. For melting relations in a binary system $MgO-MgSiO_3$, which is a major component in the lower mantle, the experiment up to only 26 GPa was performed (Liebske and Frost, 2012 *Earth Planet. Sci. Lett.*). So, further studies at higher pressure corresponding to the deep lower mantle condition are required. In this study, we determined the melting relations in the $MgO-MgSiO_3$ system above 30 GPa using a LHDAC. Glasses of several different compositions in the $MgO-MgSiO_3$ system (from 37 to 45 mol% SiO_2) were used as the starting materials. A CO_2 laser heating system was used to heat the sample directly. The recovered samples were polished and analyzed by a dualbeam focused ion beam (FIB) and a field emission scanning electron microscope (FE-SEM), respectively. The eutectic compositions and the liquidus phases were determined on the basis of chemical and textural analysis of the quenched samples. Our results show that the eutectic composition at 30 GPa is about 44 mol% SiO_2 and it becomes about 40 mol% at 50 GPa. Above 50 GPa, it is predicted to become relatively constant, consistent with the previous result by Liebske and Frost (2012). From these results, MgO-rich melt layer may be generated by partial melting of the bulk mantle, such as pyrolite composition (i.e. 42 mol% SiO_2), at the base of the mantle.
The present result should provide basic information for better understanding on the melting relations at deep mantle conditions.

Phonon properties of the lower mantle minerals by inelastic x-ray scattering

*Hiroshi Fukui[1], Akira Yoneda[2], Takashi Yoshino[2], Alfred Q.R. Baron[3]

1.Graduate School of Material Science, University of Hyogo, 2.Institute for Study of the Earth's Interior, Okayama Univeristy, 3.RIKEN SPring-8 Center

Inelastic x-ray scattering is a useful technique to obtain phonon properties of lower mantle minerals with single crystal samples. We would like to discuss what kind of information can be derived from IXS spectra and how to do it with treating bridgmanite and ferropericlase as examples.

Keywords: lower mantle , phonon, inelastic x-ray scattering

Three-dimensional mantle convection and material cycling with continental dispersal and coalescence

*Ryunosuke Yanagi[1], Masaki Yoshida[2]

1.Tokyo Institute of Technology, 2.JAMSTEC

The Earth is unique among the solar terrestrial planets, having the continents and the abundant liquid water on its surface. In this study, we have developed a three-dimensional mantle convection model that incorporates these two features into the numerical program, and investigate how the flow-temperature field and water distribution occur under the circumstances of continental dispersal and coalescence. In this numerical simulation of 3-D spherical mantle convection, supercontinent is introduced in the model set up in order to study how continental dispersal and coalescence happens and affect the structures of the interior. In addition, water is also introduced, considering water solubility of mantle rocks. The results show that water is transported to broader regions effectively once continental dispersal occurred, due to enhanced flow velocity associated with increased horizontal temperature gradient partly with the blanketing effect beneath the supercontinent. This process distributes the water in a spatially wide region as a “migrating entrance” of water into the mantle. Once the water subducts with the cold down-going flow and reaches CMB (core mantle boundary), then it horizontally spreads to be heated up. In some case, dehydration of Phase H may occur to generate a fluid that migrates upward and hydrate the overlying mantle, which occurs near the boundary between the cold continental domain and the warmer oceanic domain, yet within the hydrated cold domain beneath the (super)continent region. This mechanism, together with the near-surface process described above, may create a hydrous domain beneath the continental region where a rather uniform hydration may prevail. Therefore, the effective redistribution with a global scale structure can be created simultaneously. Such a mechanism could be important to account for the observed geochemical mantle hemispheres.

Keywords: continental dispersal and coalescence, material cycling

Numerical simulations on the upwelling plumes in the mantle of super-Earths in 2-D axisymmetric geometry

*Masanori Kameyama[1]

1.Geodynamics Research Center, Ehime University

We carried out numerical simulations on the upwelling plumes in the mantle of the Earth and that of super-Earths. The objects of our study are (1) to confirm the validity of our program which is newly developed for this study by comparing our numerical results with those of earlier studies on the upwelling plumes in the Earth's mantle and (2) to examine the effects of temperature-dependent viscosity and internal heating rate on upwelling plumes in the mantle of super-Earths. In this study, we consider a major upwelling plume at the center of 2-D axisymmetric model. We have carried out two series of numerical simulations. In a first series, we calculated thermal convection in an incompressible Boussinesq fluid under the conditions identical to those in earlier studies. In a second series, we performed simulations under the conditions for the mantle of super-Earths using the truncated anelastic liquid approximation (TALA).

In the first series of our simulations, we obtained the results similar to earlier ones, such as the increase in the heat flow at the top and bottom boundaries in proportion to Ra^{13}, demonstrating the validity of the numerical simulation in this study. Furthermore, the second series of our study of the mantle of super-Earths showed that (1) temperature-dependence of viscosity tends to reduce plume heat transport, and (2) the variation of compressibility does not affect the detail of the loss of plume heat flux during their ascent. We also found that heat can flow downward into the core when the chondritic rate of internal heating is present in the mantle of super-Earths, demonstrating significant effects of the internal heating rate on the convection and thermal state in the mantle of super-Earths.

Keywords: super-Earths, mantle convection, internal heating

First-principles study of solid iron-hydrogen alloys under high pressure

*Koichiro Umemoto[1], Kei Hirose[1]

1.Earth-Life Science Institute, Tokyo Institute of Technology

Hydrogen and iron are two of major constituents of the Earth and planetary interiors. The crystal structure of solid FeHx is one of the most fundamental information in order to understand properties of planetary cores. Recently, hydrogen-rich phases, FeH_2 and FeH_3, were experimentally synthesized [1]. The crystal structure of FeH_3 was clarified by comparing experimental compression curve with calculated one. On the other hand, the structure of FeH_2 remains unclear. It is mainly because the hydrogen positions are quite difficult to be determined by x-ray diffraction measurements. Ref. 1 proposed the crystal structure of FeH_2, but it is less consistent with its experimental compression curve. Here we report the results of first-principles calculations on FeH_2. We find the new hydrogen positions which lead to more stable structure than proposed by Ref. 1 and reproduces experimental compression curve very well. Our new structure will be essential for constraining the amount of hydrogen in iron alloys.

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Keywords: Iron-hydrogen alloys, First principles, Crystal structure at high pressure