Core Mantle Coevolution

Abstracts of Poster presentation

International School March 7-10, 2019, Hida, Japan

-Thermal evolution, energy sources and associated heterogeneity-

MEXT Grant-in-Aid for Scientific Research on Innovative Areas
Interaction and Coevolution of the Core and Mantle
Toward Integrated Deep Earth Science

Poster List <Poster Session : March 8th & 9th, 21:00- >

1-min presentation 1 (March 7th, 18:10 –)

1 Norikatsu Akizawa (The University of Tokyo)
"Ancient, highly depleted mantle beneath French Polynesia archipelago constrained by rhenium-osmium isotope and highly-siderophile element compositions of mantle xenoliths"

2 Irene Bonati (Tokyo Institute of Technology)
"Modeling Ultralow Velocity Zones as a thin chemically distinct layer at the core-mantle boundary"

3 Hitoshi Gomi (Okayama University)
"Electrical resistivity and thermal conductivity of fcc Fe: Implications for the Mercury's core"

4 Anselme Borgeaud (The University of Tokyo)
"3-D S-velocity structure of the mantle transition beneath Central America using waveform inversion"

5 Yuuki Hagiwara (Hokkaido University)
"Fluid inclusion as a potential geobarometer: Determination of the depth provenance of mantle xenoliths"

6 Li-Wei Chen (UC Berkeley)
"An application of source stacking followed by cross-correlations for global waveform tomography using the Spectral Element Method"

7 Thibaut Clarté (ENS Lyon)
"Thermo-Compositional Convection in Magma Oceans"

8 Shinnosuke Aoyama (Niigata University)
"Sulfur isotopic signature of granitoids: link to the crustal evolution through Earth's history"

9 Haruhiko Dekura (Ehime University)
"Ab initio lattice thermal conductivity of ferropericlase"

1-min presentation 2 (March 8th, 20:30 –)

10 Nozomi Kondo (Ehime University)
"Major element composition of the Hadean crust and mantle chemical evolution in the early Earth"

11 Xuejing He (The University of Tokyo)
"Equation of State of Schreibersite Fe2.15Ni0.85P"

12 Wang Ran (Okayama University)
"Electrical conductivity of diaspore, epsilon-FeOOH and delta-AlOOH"

13 Sebastian Ritterbex (Ehime University)
"Ab-Initio Investigation of Iron Diffusion Properties with Implications for Inner Core Plasticity"

14 Adrien Morison (ENS Lyon)
"Dynamics and evolution of the primitive mantle with magma oceans"

15 Atsuro Okamoto (The University of Tokyo)
"Viscosity of lower mantle estimated from the common diffusivity of creep and grain growth"

16 Vancliff Hengyi Su (National Central University)
"The multi-fault rupture process of 1935 Hsinchu-Taichung Earthquake, Taiwan revealed from dynamic modeling"

17 Yasuhiro Kuwayama (The University of Tokyo)
"Density and sound velocity of iron in the Earth's core conditions"

18 Shiori Morii (The University of Tokyo)
"Distribution and formation of radiocesium in environment derived from Fukushima Dai-ichi nuclear disaster, focusing on radiocesium-bearing micro particle"

1-min presentation 3 (March 9th, 20:30 –)

19 Yuki Suzuki (The University of Tokyo)

“Anisotropy and flows at the lowermost mantle beneath the Northern Pacific revealed by waveform inversion”

20 Ryo Tsuruoka (Osaka University)

“Density measurement of liquid metal at high pressure using X-ray absorption method with externally heated diamond anvil cell”

21 Lena Yokokura (Hokkaido University)

“Is there substantial evidence for the big mantle wedge hypothesis?”

22 Chikara Shito (Tohoku University)

“In-situ X-ray diffraction study on beta-CrOOH at high pressure and high temperature”

23 Liang Yuan (Tohoku University)

“Ultralow-velocity zones possibly explained by light element-enriched iron compounds”

24 Youyue Zhang (Okayama university)

“Effect of iron content on thermal conductivity of olivine with implications for cooling history of rocky planets”

25 Ingrida Semenec (Queen’s University)

“Geo-neutrinos at SNO+”

26 Laura Sammon (University of Maryland)

“Improving geoneutrino predictions from jointly constrained local crustal models”

Ancient, highly depleted mantle beneath French Polynesia archipelago constrained by rhenium-osmium isotope and highly-siderophile element compositions of mantle xenoliths

Norikatsu Akizawa*[1], Akira Ishikawa[2], Katsuhiko Suzuki[3], and Tetsu Kogiso[4]

[1]Atmosphere and Ocean Research Institute, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba, 277-8564, Japan
[2]Department of Earth and Planetary Sciences, Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro, Tokyo, 152-8550, Japan
[3]Research and Development Center for Submarine Resources, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 2-15 Natsushima, Yokosuka, Kanagawa 237-0061, Japan
[4]Graduate School of Human and Environmental Studies, Kyoto University, Yoshida-Nihonmatsu, Sakyo, Kyoto, 606-8501, Japan

E-mail address of the presenter: akizawa@aori.u-tokyo.ac.jp

Mantle xenoliths can provide lithological and geochemical information of the inaccessible mantle. In order to better characterize the lithological and geochemical characteristics of the mantle, we conducted extensive sampling of mantle xenoliths throughout French Polynesia archipelago: Tahiti, Moorea, and Rurutu islands. We collected 42 mantle xenoliths: 1 lherzolite, 14 harzburgites, 22 dunites, 3 wehrlites, and 2 orthopyroxenites. Here, we present whole-rock rhenium-osmium isotope and highly-siderophile element (Os, Ir, Ru, Pt, Pd, and Re) compositions in addition to whole-rock major-element compositions. Osmium isotope ratio ($^{187}Os/^{188}Os$) of the mantle xenoliths ranges from 0.1172 to 0.1464, where the harzburgites show a statistical bimodal distribution with unradiogenic ($^{187}Os/^{188}Os < 0.125$) and radiogenic ($^{187}Os/^{188}Os > 0.125$) compositions. The harzburgites with unradiogenic $^{187}Os/^{188}Os$ are depleted with regards to whole-rock major-element compositions (< 1.22 wt% Al_2O_3), and chondrite-normalized patterns of highly-siderophile elements. Considering the lithological variation of the mantle xenoliths used herein, the mantle is considerably heterogeneous beneath French Polynesia archipelago. In particular, the contrasting isotopic compositions of the harzburgites suggest different mantle reservoirs, from which the harzburgite xenoliths were derived. We propose a possibility that the harzburgites with unradiogenic $^{187}Os/^{188}Os$ are impinged mantle material beneath normal oceanic lithosphere due probably to ascending plumes.

Modeling Ultralow Velocity Zones as a thin chemically distinct layer at the core-mantle boundary

Irene Bonati, John W. Hernlund
Earth-Life Science Institute, Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro, Tokyo 152-8550, Japan
irene.bonati@elsi.jp

Seismically detected ultralow velocity zones (ULVZs) at the core-mantle boundary (CMB) reflect the dynamical state and geological evolution of the silicate-metal frontier of Earth's deep interior. Modeling the evolution of ULVZs presents, however, a number of difficulties, such as the necessity of fine scale resolution and the treatment of large viscosity contrasts. Here we extend the study of ULVZs using a lubrication theory approach and apply it to numerical and analytical models of mantle convection in the CMB region. A generic model of a thin low viscosity ULVZ layer embedded between an overlying convective viscous mantle and an underlying inviscid core can explain several features that are consistent with seismic inferences, such as the absence of ULVZs in some regions and an elongated shape where they are concentrated. The model explains how the topography of ULVZs tends to saturate as they become thicker, due to the non-linear feedback between viscous aggregation beneath upwelling mantle currents and gravitational relaxation. Implementing the ULVZ equation in mantle convection models indicates that ULVZs are preferentially concentrated beneath long-lived plumes, and may not exist below newly formed plume roots. The presence/absence of ULVZs, as well as their shapes, may provide important insights into the dynamical state of the lowermost mantle.

Electrical resistivity and thermal conductivity of fcc Fe: Implications for the Mercury's core

Hitoshi Gomi, Takashi Yoshino
Institute for Planetary Materials, Okayama University, Misasa, Tottori 682-0193, Japan.
hitoshi.gomi@okayama-u.ac.jp

Electrical resistivity and thermal conductivity of face-centred cubic (fcc) Fe are calculated by using the Korringa-Kohn-Rostoker (KKR) method combined with the Kubo-Greenwood formula. Two types of scattering mechanisms are considered: (1) phonon scattering and (2) magnetic scattering. The former is approximated by means of the alloy analogy model of atomic displacements, and the latter is represented by the local magnetic disorder (LMD) approach. Both of these two effects are treated within the coherent potential approximation (CPA), which is implemented in the AkaiKKR package. The contribution of the magnetic scattering is important at ambient pressure, and calculated electrical resistivity and thermal conductivity are consistent with experimental data. However, the local magnetic moment is quenched at high pressure. Based on the present first-principles calculations, we modelled the depth increasing thermal conductivity of Mercury's core, which is consistent with the thin layered dynamo model of the weak magnetic fields.

3-D S-velocity structure of the mantle transition zone beneath Central America using waveform inversion

Anselme F. E. Borgeaud[1*], Kenji Kawai[1], Robert J. Geller[1]
[1]University of Tokyo
*anselme@eps.s.u-tokyo.ac.jp

Abstract……………………………………………

Travel-time tomography studies have reported various modalities of subduction of slabs around the mantle transition zone (MTZ), but the causes of this variability are still controversial. In order to place additional constraints on the modality of subduction in and near the MTZ, we apply waveform inversion to S-wave triplications due to the 410 and 660 km discontinuities, and infer the regional 3-D S-velocity structure in the depth range 330–820 km beneath Central America and the Gulf of Mexico. We use ~3,600 transverse component records at epicentral distances 10–30˚ from 20 intermediate focus earthquakes beneath Central America recorded at stations of the USArray and other smaller networks. We filter the records between 20–100 s, and use the portions of the waveforms from 10 s before to ~40–80 s after the arrival of the direct S-wave, thereby including the S-wave triplications while excluding the sS depth phase. We correct the data for the structure above our target region using previous S-velocity models; we show that the results of the inversion do not depend heavily on which correction is used. Resolution tests confirm that we can resolve small-scale structure in the target region. Our inferred models show that the Cocos slab penetrates into the lower-mantle, but with important variations along the Middle America Trench in the subduction modality of the slab. We suggest that this variability could be due to the thermal structure of the Cocos slab, and to the interaction of the slab with a lower-mantle plume.

Fluid inclusion as a potential geobarometer: Determination of the depth provenance of mantle xenoliths

Yuuki Hagiwra*[1] and Junji Yamamoto[2]

[1] Graduate School of Science, Hokkaido University, Kita 10 Nishi 8, Kita-ku, Sapporo, Hokkaido 060-0810, Japan
[2] The Hokkaido University Museum, Kita 10 Nishi 8, Kita-ku, Sapporo, Hokkaido 060-0810, Japan

E-mail address of the presenter: hagi@eis.hokudai.ac.jp

Fluid inclusions, if they satisfy several criteria, contain information about the environment prevailing at the time of formation of the fluid inclusions (Roedder, 1984). Therefore, accurate measurements of the residual pressure of the fluid inclusions at a given temperature can indicate the depth provenance of the rocks from the equilibrium temperature of the rocks and the equation of state of the fluid. However, to assess re-equilibration processes of the fluid inclusions, one must obtain physicochemical information of fluid inclusions of various sizes including very small ones because the fluid retentivity depends on the fluid inclusion size. Particularly with respect to the residual pressure, the most reliable size range of fluid inclusions for density calculation is close to submicrometer order because higher pressure retentivity is associate with smaller fluid inclusions. Therefore, in this study, we measured the residual pressure of the fluid inclusions by Raman based barometer, which can be applied to small fluid inclusions. By using this method, we measured the residual pressure of fluid inclusions in submicron to 10 μm in mantle xenoliths from Ennokentiev, Sikhote-Alin, Far Eastern Russia.

Raman spectra were acquired using excitation by a diode pumped solid-state laser (532 nm, Gem 532; Laser Quantum), and using a spectrometer with 75 cm focal length (Acton SP-2750; Princeton Instruments, Inc.) and a CCD camera (1650 × 200 pixels, 16 μm width, iVac; Andor Technology). The laser power was ~10 mW at the sample. The respective sizes of the fluid inclusions were measured using a 2000× objective (VH-ZST; Keyence Co.) with a digital microscope (VHX-5000; Keyence Co.). The fluid inclusion size was measured automatically by identifying the outline of a fluid inclusion using the brightness contrast.

The results show that the residual pressure of the fluid inclusion systematically changes depending on the diameter of the fluid inclusion, and the smaller the fluid inclusions are, the higher the pressure retentivity is. The fluid density vary from 0.94 to 1.08 g/cm^3. The depth provenance calculated from EOS of CO_2 and equilibrium temperature is 0.87–0.62 MPa. To explain this variation, we calculated size dependence of thermoelastic equilibrium between fluid inclusion and host mineral based on the formulation of Zhang (1998). However, thermoelastic equilibrium can not explain the large density variation (~10%) since its contribution to the density variation is only on the order of 0.01%. Additionally, we assessed the effect of size dependent brittle fracture on the fluid density. Although we can successfully explain general fluid density trend, to explain the whole data, effect of plastic deformation and fluid diffusion should be added to the simple brittle fracture model.

An application of source stacking followed by cross-correlations for global waveform tomography using the Spectral Element Method

Li-Wei Chen[1], Barbara Romanowicz[1,2,3]
1. UC Berkeley
2. Collège de France Paris
3. Institut de Physique du Globe, Paris

Accurate synthetic seismic wavefields can now be computed by using the spectral element method (SEM), which helps constructing of 3D earth models by seismic waveform tomography and has been shown to help improve resolution, However, the heavy computational costs represent a challenge for further resolution improvements. These costs can be reduced by implementing a source stacking method (Capdeville et al., 2005, GJI), in which multiple earthquake sources are simultaneously triggered in only one teleseismic SEM simulation. Thus, this method can potentially reduce the computational costs by several orders of magnitude.

One issue with this approach is that the summed wavefield is dominated by the large amplitude fundamental mode surface waves. The windowing and weighting schemes used in conventional waveform tomography cannot be applied and it could possibly lead the loss of resolution at depth. Romanowicz et al. have addressed this issue in 2013 by computing the cross-correlation wavefield between pairs of stations before each inversion iteration. Although the Green's function between the two stations is not reconstructed as well as in the case of ambient noise tomography, it is still possible to apply the same processing to the 3D synthetics and to the data, and the source parameters are known to a good approximation. By doing so, we can separate time windows with large energy arrivals corresponding to fundamental mode surface waves, and apply a weighting scheme to bring out the contribution of overtones and body waves. Also, the normal mode perturbation theory is used for computing the gradient and Hessian rather than an adjoint approach, so there is no cross-talk effect in the inversion step.

Here we present the results of testing this approach for a synthetic global long period (400-60s) 3-component waveform dataset computed for 273 globally distributed events in a toy 3D radially anisotropic upper mantle model which contains shear wave anomalies at different scales. We demonstrate the results of inversion of 10,000 s stacked time series using source stacking with and without noise, and cross-correlations. It is worth to mention the comparisons of different parameters in global full-waveform tomography are practically unattainable using conventional SEM-based waveform tomography.

THERMO-SOLUTAL CONVECTION IN MAGMA OCEANS

Thibaut Clarté, Nathanaël Schaeffer, Stéphane Labrosse
ISTerre, Université Grenoble Aples, LGL, ENS de Lyon
thibaut.clarte@ens-lyon.fr

Because of giant impacts, the history of the Earth's mantle may have begun with a period during wich it is largely molten, the magma ocean era. We should understand the cooling and freezing of such an ocean to obtain information about mantle differentiation and the beginning of plate tectonics.
Current models for magma oceans usually make the hypothesis of a compositionally well mixed isentropic liquid. Indeed the low viscosity of such an ocean and the huge radiative heat flow at the top should lead to vigourous convection. Nevertheless, fractionnal crystallization of liquid at the bottom of the liquid may produce a basal enrichement in FeO of the ocean (making it denser) possibly ending up with the formation of a stably stratified layer. Whether or not this happens depends on the competition between the destabilising thermal buoyancy and the stabilising compositional one. With that question in mind, we have developed a model for direct numerical simulations of rotating thermosolutal convection in a 3D spherical geometry.

We have decided to focus on the consequences of two physical processes –possibly underwent by magma oceans– on the dynamics and on the properties of heat and solute transports. These phaenomena are the fractional crystallization of the liquid inducing basal enrichment in iron oxyde and the radiative equilibrium between the ocean and an atmosphere.

Considering the thermodynamics of crystallization at the bottom, we obtain a linear relationship between the heat and solute fluxes at the bottom, a condition that we implemented in the numerical code. For the top boundary, radiative equilibrium is taken into account by imposing a linear relation between temperature and heat flux (Robin condition).

An exploration of parameter space (mainly Rayleigh, Ekman and Biot numbers) has been conducted. Influence of Robin boundary conditions and thermo-solutal coupling on convection is separately discussed.

Sulfur isotopic signature of granitoids: link to the crustal evolution through Earth's history

Shinnosuke Aoyama
Faculty of Science, Niigata University
aoyama@geo.sc.niigata-u.ac.jp

Sulfur is mainly present as oxidized sulfur (sulfate) and reduced sulfur (sulfide) in the ocean and crust, the surface environments. The surface sulfur finally returns back to the mantle through subduction process, but a part of sulfur is recycled to the surface as dehydration and arc magmatism in subduction zones. Sulfur isotopic signature of granitoids is potentially a useful tracer for the origin of the recycled sulfur in subduction zones, and linked to the crustal evolution through Earth's history. In the presentation, I report compiled sulfur isotopic signature of granitoids through Earth's history, from Early Archean granitoids (aged ca. 4.0 Ga) to Phanerozoic granitoids (aged ca. 100 Ma). Sulfur isotopic signature of granitoids through Earth's history is expected to show surface sulfur isotopic signature and regime of the crustal formation.

TITLE: *Ab initio* lattice thermal conductivity of ferropericlase

Authors: Haruhiko DEKURA* and Taku TSUCHIYA
Affiliation: Geodynamics Research Center, Ehime University
E-mail address of the presenter: dekura.haruhiko.mf@ehime-u.ac.jp

Abstract: Determination of lattice thermal conductivity (κ_{lat}) of lower mantle (LM) minerals is a key to understanding the dynamics and evolution of the earth's deep interior. Some recent experimental studies have shown that κ_{lat} of MgO is substantially reduced by Fe incorporation (Manthilake et al., 2012; Goncharov et al., 2015; Ohta et al., 2017; Hsieh et al., 2017). However, those experimental measurement remains technically challenging at the deep mantle condition. In this study, we investigate κ_{lat} of ferropericlase (FP) in the LM pressure and temperature conditions, based on the *ab initio* anharmonic lattice dynamics techniques with fully solving the phonon Boltzmann transport equation (Dekura and Tsuchiya, 2017) combined with the internally consistent LDA+*U* technique for more precisely describing the Fe-O bond (Wang et al., 2015). Calculations demonstrate strong negative solid solution effects of low-spin Fe on κ_{lat} of FP, as a linear decrease in $\log \kappa_{\text{lat}}$ with increasing the Fe concentration. Our detailed analyses indicate that such strong effects occur primarily due to the substantial changes in harmonic properties. The κ_{lat} of FP with 12.5% iron at the core-mantle boundary condition (136 GPa and ~4000 K) is estimated to be ~12 $Wm^{-1}K^{-1}$ which is ~60% smaller than the Fe-free system (~30 $Wm^{-1}K^{-1}$, Dekura and Tsuchiya, 2017).

TITLE

Major element composition of the Hadean crust and mantle chemical evolution in the Early Earth

Author(s)

Nozomi M. Kondo[1,2], Tetsu kogiso[1]

Affiliation(s)

[1]Graduate School of Human and Environmental Studies, Kyoto University
[2]Geodynamics Research Center, Ehime University

E-mail address of the presenter

kondo.nozomi.xg@ehime-u.ac.jp

Abstract

Introduction: The mantle composition and dynamics have been evolved through formation and re-mixing of crust. Therefore, in order to understand the history of the mantle chemical and dynamical evolution, we have to know the initial condition of the crustal formation and recycling. Previous studies have investigated the crustal formation in the early Earth from zircons <4.4 Ga, and from isotopic record in the Archean rocks (ex. Nebel et al. 2014; Rizo et al, 2013). These clues have suggested formation of the primary crust from mantle melting before 4.4 Ga, formation of the evolved crust (secondary, …) from melting of pre-existing (primary, …) crust and re-mixing of these crusts. However, the rock record before 4.0 Ga (the Hadean) has never or scarcely found, and therefore, the major element composition of the Hadean crusts have been unrevealed. The major element composition controls physical properties such as density and viscosity of melt and crust, and these physical properties in turns controls the formation and recycling of the crust. Therefore, in this study we constrained the major element composition of the Hadean primary and secondary crust and discussed about the formation and fate of these Hadean crusts.

Strategy: We combined the Sm-Nd isotope systematics and high-pressure melting experiments in order to constrain the major element composition of the Hadean primary and secondary crust. For the primary crust, we firstly estimated melting condition of mantle at the Hadean silicate (mantle and crust) differentiation from the Sm-Nd systematics in the early Archean rocks, that have higher and lower ^{142}Nd/^{144}Nd ratio than that of the present mantle. The ^{142}Nd/^{144}Nd anomalies are distinct in the early Archean rocks, and diminish from the late Archean to the present. Due to the short half-life of the ^{146}Sm (68 Myr), the parent nuclide of the ^{142}Nd, the ^{142}Nd/^{144}Nd anomalies and diminishing of them have been interpreted as the Sm/Nd fractionation at the Hadean silicate differentiation and re-mixing of the Hadean depleted mantle (high Sm/Nd and ^{142}Nd/^{144}Nd ratio) and enriched crust (low Sm/Nd and ^{142}Nd/^{144}Nd ratio). Since the degree of the Sm/Nd fractionation depends on two variables, the timing and melting condition of the Hadean silicate differentiation, we can constrain these two variables from two Sm-Nd systematics, ^{146}Sm-^{142}Nd and ^{147}Sm-^{143}Nd systems. Then, we estimated the major element composition of the melt generated at the Hadean silicate differentiation from the melting condition constrained from the Sm-Nd systematics and data of high-pressure melting experiments of a primitive mantle (Fallon et al. 2008; Hirose & Kushiro 1993; Walter 1998; Davis et al. 2011; Kondo et al. 2016) . For the secondary crust, we conducted high-pressure melting experiments of synthesized starting material with the hydrous primary crust composition, using piston-cylinder high-pressure apparatus at

Graduate School of Human and Environmental Studies, Kyoto University, and determined the major element composition of melt.

Result and discussion: For the Hadean primary crust, **t**he estimated melting condition at the Hadean silicate differentiation was extremely small melt fraction at shallow upper mantle pressures. Then, as the result, the major element composition of the melt was estimated to be Ti-basaltic at 1 GPa, Ti-K-rich picritic at 3 GPa, and Ti-Fe-P-rich komatiitic at 7 GPa. Then, we discussed the probable composition of the Hadean primary crust to be Ti-Fe-P-rich komatiitic by estimating the condition of the Hadean mantle (mantle potential temperature, tectonics, and thickness of lithosphere). We also discussed the formation of the Hadean primary crust by estimating the density and viscosity of the Ti-Fe-P-rich komatiitic melt. For the Hadean secondary crust, the solidus and melting phase relation of the hydrous Hadean primary crust was determined from 1-3 GPa, and the major element composition of the melt was revealed to be Ti-Fe-P rich mafic. Then, we discussed the subduction and melting of the hydrous Hadean primary crust by comparing the solidus and subduction P-T pass of the early Archean and the present subduction zones. We also discussed the formation of the Hadean secondary crust by estimating the density and viscosity of the Ti-Fe-P rich mafic melt.

Summary: We constrained the major element composition of the Hadean primary and secondary crust by combining the Sm-Nd systematics and high-pressure melting experiments. The Hadean primary crust would have formed at extremely small melt fraction and had Ti-Fe-P-rich komatiitic composition. The Hadean secondary crust would have formed subduction-related melting of the hydrous Hadean primary crust and had Ti-Fe-P-rich mafic composition.

Equation of State of Schreibersite $Fe_{2.15}Ni_{0.85}P$

Xuejing He[1,*], Jiazeng Guo[2], Xiang Wu[3], Shengxuan Huang[1], Fei Qin[1], Xiangping Gu[4], Shan Qin[1]
[1] Key Laboratory of Orogenic Belts and Crustal Evolution, MOE, School of Earth and Space Sciences, Peking University, Beijing 100871, P.R. China
[2] Institute of Jewelry and Jade Carving, Nanyang Normal University, Nanyang 473061, P.R. China
[3] State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan 430074, P.R. China
[4] School of Geosciences and Info-Physics Institute, Central South University, Changsha 410083, P.R. China
xuejinghe@pku.edu.cn

Abstract

Phosphorus is thought to be an important light element existing in planetary cores. The phosphorus abundance is evaluated to be ~0.20 wt% in the Earth's core, and ~0.32 wt% in the Martian core. To fully understand its existence in planetary cores, structural and physical properties of iron-nickel phosphides should be investigated under high pressure and high temperature. $(Fe,Ni)_3P$-schreibersite is observed as a common accessory in the veinlet of iron and stony-iron meteorites, so that it is of significance to discuss and constrain the properties of planetary cores. The equation of state of a natural single-crystal schreibersite, $Fe_{2.15}Ni_{0.85}P$, has been studied up to ~50 GPa at room temperature in a diamond anvil cell using *in situ* synchrotron-radiation X-ray diffraction. The sample kept its tetragonal structure ($I\bar{4}$) up to the highest pressure with no observation of phase transition. Experimental results have shown that the magnetic collapse of $Fe_{2.15}Ni_{0.85}P$ is

weakened because of the substitution of nickel, leading to an isotropic axial compressibility. The pressure-volume data were fitted by a third-order Birch-Murnaghan equation of state, yielding K_0 = 184(4) GPa, K_0' = 4.1(2), V_0 = 365.9(1) Å^3, and a second-order Birch-Murnaghan equation of state, yielding K_0 = 185(1) GPa, K_0' = 4.0(fixed), V_0 = 365.8(1) Å^3. The density of $Fe_{2.15}Ni_{0.85}P$, along with several iron sulfides and iron phosphides has been calculated under relative pressure-temperature conditions of the Martian core. The comparison with that of γ-Fe and a density model of the Martian core evidences that nickel and phosphorus dopant would result in density reduction of iron sulfides, suggesting that $(Fe,Ni)_3(S,P)$ might be a possible compound existing in the Martian core.

Electrical conductivity of diaspore, δ-AlOOH and ε-FeOOH

Ran Wang*, Takashi Yoshino
Institute for Planetary Materials, Okayama University
Email address: ranwang @s.okayama-u.ac.jp

FeOOH and AlOOH are dominant hydrous phases in sedimentary rocks deposited in the sea or lake basins which were considered to be possibly related to the deep water cycle by slab subduction. Therefore, understanding of the electrical conductivity behaviors of these phases are essential to explore the nature and dynamic process of the Earth's interior. In this study, electrical conductivity of diaspore (α-AlOOH), δ-AlOOH and ε-FeOOH was measured by impedance spectroscopy with a frequency range from 10^{-1} to 106 Hz at pressures up to 15, 20 and 12 GPa and temperatures of 1200, 1200 and 1000 K well below the dehydration temperatures of these phases under the relevant pressures. For diaspore at 8, 10, and 12 GPa, the relationship between electrical conductivity and reciprocal temperature could be well fitted by the Arrhenius formula: $\sigma = \sigma_0 \exp[-(\Delta E+P\Delta V)/kT]$ and shows the pre-exponential factor (σ0), activation energy (ΔE) and activation volume (ΔV) of 55.94 ± 1.16 S/m, 0.547 ± 0.016 eV and 1.683 ± 0.123 cm3/mol, respectively. However, data of diaspore obtained below 6 GPa could not be fitted by the Arrhenius formula, which was thought to be due to the remnant of free water in the sample caused by heating to insufficient temperature to proceed dehydration of interstitial water. Thus, it is quite difficult to measure the electrical conductivity of diaspore at low pressures. The electrical conductivity of diaspore increased with pressures ranging from 8 to 12 GPa by half order of magnitude and then the conductivity change with pressures from 12 to 15 GPa became negligibly small. The dominant conduction mechanism of diaspore is regarded as proton conduction. δ-AlOOH and ε-FeOOH show one and two orders of magnitude higher electrical conductivity than diaspore. Due to isostructural CaCl2-type hydroxide structure, δ-AlOOH and ε-FeOOH display the nearly identical activation enthalpy (0.384 ± 0.007 eV, 0.330 ± 0.048 eV) which is relatively lower than that of diaspore.

Ab-Initio Investigation of Iron Diffusion Properties with Implications for Inner Core Plasticity

Author(s)
Sebastian Ritterbex and Taku Tsuchiya
Affiliation(s)
Geodynamics Research Center, Ehime University, Japan
E-mail address of the presenter
ritterbex.sebastian_arthur_willem.us@ehime-u.ac.jp

Abstract

The mechanical properties of the Earth's inner core are essential for understanding its evolution and dynamics. However, little is known about the mechanical properties of iron at inner core conditions. Therefore, long-standing questions remain open about the viscous strength of the inner core (Yoshida et al., 1996; Karato, 1999), about the origin of its seismic anisotropy (Deuss, 2014) and about its rotational dynamics (Buffett, 1997). All these issues rely on plastic deformation of the inner core, which is barely constrained.

Under conditions of the Earth's deep interior, the rate of plastic deformation is expected be constrained by atomic diffusion. Experimental studies on diffusion in iron-nickel alloys all rely on extrapolation to inner core conditions (Yunker and Van Orman, 2007; Reaman et al., 2012). Here, we investigate vacancy diffusion in iron at the appropriate inner core conditions. We use a density functional approach to calculate all quantities entering the diffusion coefficient and quantify the self-diffusion coefficient of hcp iron according to transition state theory (TST).

Vacancy diffusion controls many deformation mechanisms such as dislocation creep, an effective strain producing mechanism in metals. Here, we derived a creep model (Weertman, 1955; Nabarro, 1967) to quantify the rate limiting bounds of climb-controlled dislocation creep in hcp iron and provide the first theoretical estimates of the viscosity of the inner core.

Dynamics of the primitive mantle in interaction with magma oceans

A. Morison, S. Labrosse, D. Bolrão, A. Rozel, M. Ballmer, R. Agrusta, R. Deguen, T. Alboussière, P. Tackley

ENS de Lyon, LGLTPE. ETH Zürich.
adrien.morison@ens-lyon.fr

Accretional energy and short-lived-elements radioactive heating involved in planets formation is thought to be sufficient to melt the primitive mantle entirely, resulting in a global magma ocean. Depending on how the temperature profile in the magma ocean compares with the solidus temperature, the crystallization of the magma ocean might start from the bottom of the primitive mantle or somewhere in the middle. At some point in its history, the solid mantle might then have been surrounded by magma oceans above and/or below it.

We propose here to study the dynamic and evolution of the primitive solid mantle surrounded by magma oceans. We solve numerically the equations of solid-state convection in the solid part of the mantle. This model is coupled to 1D models of crystallization of the magma oceans to self-consistently compute the thickening of the solid part as heat is evacuated from the mantle. We take into account fractional crystallization at the phase change boundary.

Moreover, the boundaries between the solid and the magma oceans are phase-change interfaces. Convecting matter in the solid arriving near the boundary or getting away from it forms a topography which can be erased by melting or freezing. Hence, provided the melting and freezing occurs rapidly compared to the time needed to build the topographies by viscous forces, dynamical exchange of matter can occur between the solid mantle and the magma oceans. We take this effect into account in our model with a boundary condition applied to the solid.

We find that the boundary condition allowing matter to cross the interfaces between the solid and the magma oceans greatly affects the convection patterns in the solid as well as its heat flux. Larger-scale convection patterns are selected compared to the classical case with non-penetrative boundary conditions; and the heat transfert in the solid is more efficient with these boundary conditions. This affects the long term thermal evolution of the mantle as well as the shape of chemical heterogeneities that can be built by fractional crystallization of magma oceans.

TITLE: Viscosity of lower mantle estimated from the common diffusivity of creep and grain growth

Author(s): Atsuro Okamoto*, Takehiko Hiraga
Affiliation(s): The University of Tokyo
E-mail address of the presenter: aokamoto@eri.u-tokyo.ac.jp

Abstract: Grain-size reduction caused by the post-spinel transformation and subsequent grain growth during the whole mantle convection should control viscosity of the lower mantle, if it deforms by diffusion creep which is a grain-size sensitive mechanism. Thus, to estimate viscosity of the lower mantle, grain growth has to be taken into consideration.

We have recently conducted high-temperature creep and grain growth experiments on forsterite + periclase aggregate, a good analog material of the lower mantle and found that grain boundary diffusivities extracted from both creep and grain growth rates are essentially identical. This results indicate that the creep and grain growth in polymineralic rocks are controlled by a common diffusion mechanism.

When creep and grain growth rates are determined by the common diffusivity, grain size and viscosity of the aggregate can be described in terms of material constants, diffusivity and time. We applied these relationships to the lower mantle to calculate grain size and viscosity at each depth and age of the mantle during one cycle of the whole mantle convection. Calculations show that grain size and viscosity in downwelling mantle are ~0.2 mm and 10^{18} ~ 10^{20} Pa·s while those in upwelling mantle are ~0.2-7 mm and 10^{18} ~ 10^{23} Pa·s. Thus, we predict a large viscosity variation within lower mantle. The viscosity profile estimated from a joint inversion of convection and glacial rebound data is well within such variation.

TITLE
The multi-fault rupture process of 1935 Hsinchu-Taichung Earthquake, Taiwan revealed from dynamic modeling

Author(s)
Heng-Yi Su[1], Ming-Hsuan Yen[1], David Douglas Oglesby[2], Kuo-Fong Ma[1]
Affiliation(s)
[1]National Central University, Taiwan
[2]University of California Riverside, CA, United States
E-mail address of the presenter
hengyi.vs@gmail.com

Abstract

The severe Hsinchu-Taichung Earthquake with local magnitude of 7.1 occurred on April 21st ,1935. Understanding the physical rupture process of this event can shed light on the future identification on fault system from multiple faults for seismic hazard potential evaluation. Historical data in geological investigation and modeling from geodetic leveling data suggests this event involved two major faults: the Shihtan reverse fault and the Tuntzuchiao right-lateral strike-slip fault, both with ruptures to the surface. The hypocenter, however, did not appear to have been on either of these structures, suggesting the existence of unobserved blind fault. Yen (NCU, MS thesis, 2016) performed a finite-fault inversion that constructed a possible fault model by comparing the synthetic and observed surface displacement, and leveling data. The optimum model suggested the event was resulted from a fault system, which consists of four segments, including both reverse and strike slip fault, with the rupture-jumping between two blind faults that have opposite direction of dip, and thus increasing separation with depth. In this study, we propose two possible fault models and both associated with a heterogeneous pre-stress designed to produce slip similar to that of the inversion result. First model is modified from Yen’s study. We further assume a linking fault between two blind faults as our second model. Through further refinement, the correlation between the slip pattern derived from the dynamic model and inversion model, along with the jumping phenomenon, are used as critical factors in evaluating the reasonableness of our dynamic rupture model. The result shows both two models can engender the comparable slip distribution and amount with the inversion result, and the comparable theoretical magnitude with historical record. However, two models yield to very distinct difference in the moment rate functions, which might be keen to our further examination of the historical 1935 Omori records. Our ongoing work includes the influence of fault geometry, such as the location and connectivity of the blind faults, and simulating the seismogram combining the low frequency motions (frequency-wavenumber method) and high frequency motions (EXSIM, Stochastic Finite-Fault Ground-Motion Simulation Algorithm) to reveal the source characteristics of the 1935 earthquake.

Density and sound velocity of liquid iron at Earth's core conditions

Y. Kuwayama[1*], G. Morard[2], Y. Nakajima[3], K. Hirose[1,4] et al.
[1]U. Tokyo, [2]IMPMC, [3]Kumamoto Univ., [4]ELSI Tokyo Tech.
[*]kuwayama@eps.s.u-tokyo.ac.jp

Abstract……………………………………………

The Earth's core is composed mostly of liquid iron but includes substantial amounts of light elements, in particular in its liquid outer part (Birch, 1952). The identification of core light elements is of great importance because it has wide implications for Earth building blocks, core formation process, thermal structure, mechanism for core convection and geodynamo, etc. While density (ρ) and sound velocity (V_P) are primary observables of the outer core (Dziewonski & Anderson, 1981) and thus keys to constraining its composition, they have not been examined for liquid pure iron by static compression experiments to high pressure and temperature relevant to the Earth's core.

Earlier shock-wave experiments measured the ρ and V_P (equivalent to bulk sound velocity, V_Φ, in a liquid) of molten iron between 278 and 397 GPa, corresponding to pressures near the bottom of the outer core (Anderson & Ahrens, 1994; Brown & McQueen, 1986). Since the shock compression can generate high P-T only along the Hugoniot path that intersects the melting curve of iron around 270 GPa (Brown & McQueen, 1986), it is impossible to conduct measurements of liquid iron at lower pressures.

In this study, we measured the ρ and V_p of liquid iron up to the core pressure, using a laser-heated diamond-anvil cell combining with in-situ x-ray diffraction measurements and high resolution inelastic x-ray scattering spectroscopy at SPring-8. Combining with previous shock-compression data, its P–T–ρ–V_P relation is obtained over entire liquid core conditions. The results show that the outer core (with T_{CMB} = 4000 K (Lay et al., 2008)) exhibits 7.5–7.6% lower ρ and 4.3–3.7% higher V_P than liquid pure iron, which will be an important constraint on the maximum amount of light elements in the Earth's core.

TITLE: Distribution and formation of radiocesium in environment derived from Fukushima Dai-ichi nuclear disaster, focusing on radiocesium-bearing micro particle

…………………………………………

Author: Shiori Morii
Affiliation: Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo
E-mail address of the presenter: morii@eqchem.s.u-tokyo.ac.jp

Abstract…………………………………………

March 11th, 2011, Fukushima Daiichi nuclear power plant accident happened. Radioisotopes of cesium (^{134}Cs, ^{137}Cs) were included in fall out.
The half-life of radio cesium is relatively long (^{134}Cs: 2.06 years, ^{137}Cs: 30.2 years) and those nuclides are still in the environment.

At first, those radioactive materials are considered to exist in water-soluble state in aerosol (Kaneyasu et al., 2012). However, it was revealed that radio cesium is also included in water-insoluble glass particle (Adachi et al., 2012). Those particles are called "Radiocesium bearing micro particle."

Because of its water-insoluble characteristic, the particle may be adsorbed to the lung or cavitas nasi, the particle may exist for long time. This may cause topical internal exposure.

In this research, non-woven fabric mask which worn by general citizen in Fukushima prefecture in the spring of 2012 was investigated, especially focused on cesium bearing micro particle. Purpose of this research is to grasp distribution and formation of this particle

Anisotropy and flows at the lowermost mantle beneath the Northern Pacific revealed by waveform inversion

Yuki Suzuki[1], Kenji Kawai[1], Robert J. Geller[1]
[1]School of science, The University of Tokyo
E-mail: yuki.s@eps.s.u-tokyo.ac.jp

Abstract

The D″ region is the lowermost several hundred km of the mantle immediately above the core-mantle boundary (CMB) and its base is in contact with the liquid outer core composed of iron alloy. Since the D″ region is the thermal boundary layer (TBL) at the base of the Earth's mantle, and the solidus of its constituent materials is thought to be close to the mantle geotherm, vertical and lateral variations of temperature and chemical composition associated with the Earth's thermal evolution are expected. Since chemically and thermally distinct subducted slabs would interact with the hot TBL above the CMB, and disturb the lowermost mantle, understanding the thermal, chemical and dynamical evolution processes of the D″ region under subduction zones is essential to better understand the Earth's evolution.

The D″ region beneath the northern Pacific is of particular geodynamical interest, because the paleo-Izanagi and present Pacific plates have been subducting beneath the northwestern margin of Laurentia since ~250 million years ago (Müller et al. 2016), which implies that paleo-slabs could have reached the lowermost mantle. Suzuki et al. (2016) inferred the detailed three-dimensional S-velocity structure in the lowermost 400 km of the mantle beneath the northern Pacific. They hypothesized a prominent sheet-like lateral high-velocity, interpreted as paleo-slabs, and a prominent low-velocity anomaly block immediately above the CMB below the high-velocity anomalies, which they interpreted as a TBL. In order to verify the above hypothesis and obtain geodynamical information, we infer 3D anisotropic structure beneath the northern Pacific in this study.

We conduct waveform inversion (Kawai et al. 2014, GJI) to infer the variation of the values of the TI (transverse isotropic, i.e. radial anisotropic) elastic constants ***L*** and ***N*** (Note that ***L*** is related to V_{SV} and ***N*** is related to V_{SH} when the shear wave propagates horizontally) straightforwardly in the lowermost mantle beneath the Northern Pacific, using a total of ~18,000 (~9,000 transverse and ~9,000 radial component) broadband body-wave seismograms. We used deep- and intermediate-focus events recorded at epicentral distances $70^\circ \leq \Delta \leq 100^\circ$ at seismic stations of the USArray. The data are filtered in the period range of 20 to 200 s (i.e. 0.005 to 0.05 Hz) using a Butterworth bandpass filter. By using an S/ScS time window which is sensitive to the D″ structure we could image small-scale structure with finer resolution than previous tomographic studies.

The observed anisotropy is interpreted as due to deformation-induced alignment of crystal caused by mantle flow for either Mg-perovskite (Mg-Pv), Mg-post-Perovskite (Mg-pPv), Ferro-periclase (Fp) or a combination thereof. When we assume the dominant glide system of each mineral under the lowermost mantle condition, the inferred 3D anisotropic structure is interpreted as horizontal flow which would be related to subducted paleo-slabs are dominant in this region, and we find vertical flow which would be related to the plume induced by slab sinking.

Density measurement of liquid metal at high pressure using X-ray absorption method with externally heated diamond anvil cell

Ryo Tsuruoka[*1], Hidenori Terasaki[1], Seiji Kamada[2], Fumiya Maeda[3], Tadashi Kondo[1], Naohisa Hirao[4]
[1]Department of Earth and Space Science, Graduate School of Science Osaka University
[2]Frontier Research Institute for Interdisciplinary Sciences, Tohoku University
[3]Department of Earth and Planetary Materials Science Graduate School of Science, Tohoku University
[4]Japan Synchrotron Radiation Research Institute

E-mail address of the presenter: tsuruoka@ess.sci.osaka-u.ac.jp

Abstract
To understand compression behavior of a liquid metal and to determine its equation of state (EOS), it is important to measure its densities at high pressures and high temperatures. Gallium (Ga), which is easy to treat as liquid metal for its low melting temperature (302.9 K at 1 atm) has been reported to have some thermodynamic anomalies. The densities of Ga at high pressures have been reported based on the measurement of volume changes (Lyapin et al. 2008), that of liquid structures (Yu et al. 2012), and that of sound velocity (Ayrinhac et al. 2015). However, its compression behavior has large differences between these studies. In this study, we measured densities of liquid Ga at high pressure using an X-ray absorption method with an externally heated diamond anvil cell (EHDAC).
High pressure was generated using a symmetric DAC with a lever-arm frame. Diamond anvils with a culet size of 600 μm were employed. Ga sample and reference materials (KBr, RbBr) were placed in each hole drilled on a pre-indented Re gasket. The reference materials were used for the calibration of X-ray absorption and for determination of experimental pressures (Takubo et al. 2018). The Re gasket was coated with Al_2O_3 to avoid a reaction with the Ga sample. High temperature was generated using two heater cartridges which consists of Pt-Rh wire coils and zirconia insulator. X-ray absorption measurements were carried out with monochromatic X-ray of 30 keV at BL10XU beamline in SPring-8. Intensities of incident and transmitted X-rays were detected using an ion chambers and a photo-diode, respectively. Experimental pressures were determined from XRD patterns of KBr and RbBr collected using a flat panel detector.
The densities of liquid Ga were measured up to 4 GPa and 433 K. The density of liquid Ga at 4 GPa and 433 K is obtained as 6.53(7) g/cm^3. This density is consistent with the density reported by Ayrinhac et al. (2015).

Is there evidence for big mantle wedge hypothesis?

Lena Yokokura, Junji Yamamoto**, Junji Torimoto***, Takeshi Kuritani****, Naoto Takahata*****, Yuji Sano*****

Graduate School of Science, Hokkaido University, Japan
** The Hokkaido University Museum, Japan
*** Ore Genesis Research Unit, Project Team for Development of New-Generation
***Research Protocol for Submarine Resources, JAMSTEC, Japan
****Department of Earth and Planetary Sciences, Graduate School of Science, Hokkaido University, Japan
******The University of Tokyo, Atmosphere and Ocean Research Institute, Japan

l_yokokura@eis.hokudai.ac.jp

Abstract

In northeastern Asia, seismic tomographic images suggest the existence of a subducting Pacific plate. However, this is not well supported by rheological data. Measurements of the noble gas isotopic compositions are effective for differentiation of the subducted slab and lithospheric mantle. Peridotite xenoliths were collected from northeastern China, which is regarded as backarc in eastern Asia. Major element compositions of constituent minerals of the xenoliths show typical of the lithospheric mantle. Noble gas results showed that the $^{3}He/^{4}He$ and $^{40}Ar/^{36}Ar$ ratios are, respectively, 0.14–6.45 Ra and up to 1509. Although $^{3}He/^{4}He$ and $^{40}Ar/^{36}Ar$ ratios lower than those of mid-oceanic ridge basalt (MORB) are common for sub-continental lithospheric mantle (SCLM), extremely low $^{3}He/^{4}He$ ratios such as those below atmospheric value have been found distinctively from convergent plate margins. Results suggest that both the radiogenic $^{3}He/^{4}He$ and atmospheric $^{40}Ar/^{36}Ar$ ratios originated from the subduction-related fluid infiltrating into the backarc lithosphere. This suggestion supports the big mantle wedge hypothesis that the subducted Pacific plate which reaches the upper mantle lower mantle boundary influences volcanos in backarc regions.

In-situ X-ray diffraction study on β-CrOOH at high pressure and high temperature

Chikara Shito[1*], Keitaro Okamoto[1], Yuki Sato[1], Ryuji Watanabe[1], Tomonori Ohashi[1], Kazuhiro Fuchizaki[2], Takahiro Kuribayashi[1] and Akio Suzuki[1]
[1]Tohoku university [2]Ehime university
[*]chikara.shito.r4@dc.tohoku.ac.jp

A distorted rutile-type $M^{3+}OOH$ is characterized by O-H···O hydrogen bonds in *a*–*b* plane and an edge-sharing $M^{3+}O_6$ octahedral chain along the *c*-axis. Recently, pressure-induced H-bond symmetrization was experimentally observed in δ-AlOOH. In addition, anisotropic stiffening behaviors, i.e. changes in compression behaviors related to H-bond symmetrization, were reported in distorted rutile-type $M^{3+}OOH$ (M = Al, Ga, In). However, the stiffening behavior was not observed in β-CrOOH, which is already stiffened at ambient condition.

An in-situ X-ray diffraction study of β-CrOOH was conducted up to 6.2 GPa and 700 K to clarify temperature effects on compression behaviors of β-CrOOH. The *P*-*V*-*T* data fitted to a second-order Birch-Murnaghan equation of state yielded the following results: K_{T0} = 191(4) GPa, $(\partial K_T/\partial T)_P$ = −0.04(2) GPa K^{-1} and $\alpha = 3.3(2) \times 10^{-5}$ K^{-1}. The values of α and $(\partial K_T/\partial T)_P$ were similar to those of ε-FeOOH and RhOOH under the *P*-*T* conditions of this study. At 300 K, *a*-axis became less compressible at pressures between 1–2 GPa, where the slope of *a*/*b* and *a*/*c* turned to positive. Under high temperature conditions, similar change in axial ratio was observed at higher pressure than 1–2 GPa. We found that the pressure where the slope of axial ratio changes increases with temperature.

Ultralow-velocity zones possibly explained by light element-enriched iron compounds

Liang Yuan[1], Eiji Ohtani[1], Xiang Wu[2], Shengxuan Huang[3], Daijo Ikuta[1], Tatsuya Sakamaki[1], Seiji Kamada[1], Hiroshi Fukui[4,5], Satoshi Tsutsui[6], Hiroshi Uchiyama[6], Daisuke Ishikawa[5,6], Naohisa Hirao[6], and Alfred Q. R. Baron[5]

[1]Department of Earth and Planetary Materials Science, Graduate School of Science, Tohoku University, Sendai 980-8578, Japan
[2]State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan 430074, China
[3]Key Laboratory of Orogenic Belts and Crustal Evolution, MOE, Peking University and School of Earth and Space Sciences, Peking University, Beijing 100871, China
[4]Center for Novel Material Science under Multi-Extreme Conditions, Graduate School of Material Science, University of Hyogo, Hyogo 678-1297, Japan
[5]Materials Dynamics Laboratory, RIKEN SPring-8 Center, Hyogo 679-5148, Japan
[6]Japan Synchrotron Radiation Research Institute (JASRI), SPring-8, Hyogo, 679-5198, Japan

E-mail address of the presenter: Liang Yuan (yuan.liang.s4@dc.tohoku.ac.jp)

The core–mantle boundary (CMB) is the most fundamental chemical discontinuity in the Earth. Recent experiments showed that, when water meets iron at the CMB, hydrogen-bearing iron peroxide FeO_2H_x can be produced. The results indicate that water can interact with iron metal very differently than it does on the surface of the earth. Seismic waves speeds in this hydrogen bearing iron peroxide are much slower compared with lower-mantle silicate solid phases, and therefore it may help explain the seismic anomalies at the CMB. Given the steep geothermal gradient across the CMB, the hydrogen-bearing iron peroxide FeO_2H_x likely undergoes high-temperature decomposition into anhydrous iron oxides (e.g., Fe_2O_3) and fluids. We measured the sound velocity of Fe_2O_3 post-perovskite (ppv) through inelastic X-ray scattering up to 132 GPa and 1,800 K, relevant to the lowermost mantle. Combined with first-principles investigations, we are able to show that Fe_2O_3 ppv has very low sound velocities and strong anisotropy with respect to lower-mantle silicates. Therefore, both hydrogen-bearing iron peroxide FeO2Hx and post-perovskite Fe_2O_3 are candidate phases for ultralow-velocity zones at the CMB.

Funding acknowledgment: This work was supported by the JSPS Japanese–German Graduate Externship.

Effect of iron content on thermal conductivity of olivine with implications for cooling history of rocky planets

Youyue Zhang*[1], Takashi Yoshino[1], Akira Yoneda[1], Masahiro Osako[2].

[1]Institute for Planetary Materials, Okayama University, Misasa, Tottori 682-0193, Japan

[2]Division of Physical Sciences, National Museum of Nature and Science, 3-23-1, Hyakunincho, Shinjuku-ku, Tokyo 169-0073, Japan

*Presenter E-mail address: zhangyouyue@s.okayama-u.ac.jp

Abstract:

Knowledge of thermal transport properties of mantle materials is essential for understanding the thermal state and dynamics of the Earth and planetary interiors. Previous studies have suggested that temperature and pressure dependences of thermal conductivity can affect mantle convection and plate tectonics involving subduction dynamics. Olivine is the most abundant mineral in the Earth's upper mantle and chemical composition of olivine in the Earth's upper mantle is characterized by high forsterite content around Fo_{90}. For other terrestrial planets, Mercury is believed to have a FeO-poor mantle along with end member silicates, whereas olivine in the Martian mantle would be more Fe-rich, speculated to be Fo_{67}. Recent studies suggested that surface of some asteroids is dominated by olivine of composition from Fo_{49} to Fo_{70}. Hence, the effect of Fe content in olivine on thermal conductivity could be significant for understanding the thermal structure and cooling history of these terrestrial planets and asteroids.

In this study, thermal conductivity and diffusivity of olivine were determined simultaneously by combining multi-anvil high pressure experimental technique and pulse heating method. Thermal properties of olivine with six different Fe contents (Fo, Fo_{90}, Fo_{70}, Fo_{50}, Fo_{31}, Fo_0) were measured under the Earth's upper mantle condition in a 5000-ton Kawai type multi-anvil press. The minimum λ was found to be at composition near Fo_{31}; the absolute λ value of Fo_{31} is about 65% lower than that of Fo. Small amounts of minor elements can strongly reduce the thermal conductivity at low temperature; λ value of Fo_{90} is about 50% of Fo at room temperature. As temperature increases, the difference in λ among olivine samples with various Fe contents tends to become smaller. Thermal conductivities of polycrystalline olivine have smaller absolute values and weak pressure and temperature dependences, compared with those of natural single crystal olivine determined by previous studies. Heat capacity of olivine calculated from λ and κ is independent of pressure and is controlled by nearly constant thermal expansion coefficient of Fo_{70} and Fo_{50} with increasing temperature. Smaller λ of olivine aggregate with high Fe content would produce thicker crust in the Fe-rich Mars, while heat in the Fe-poor Mercury can escape faster than the other terrestrial planets. Olivine-dominant asteroids with high Fe concentration could have longer cooling history and lower thermal inertia on the surface.

Geo-neutrinos at SNO+

Ingrida Semenec
Queen's University, SNO+ collaboration
i.semenec@queensu.ca

SNO+ is a multipurpose liquid scintillator neutrino detector. It is located 2km underground at SNOLAB in Sudbury, Canada. The primary objective of SNO+ is to search for $0\nu\beta\beta$ decay in Te-130. However, studies into other physics topics will be performed, including geo-neutrinos.

Geo-neutrinos are antineutrinos that are generated in the Earth's crust and mantle from β-decaying isotopes. SNO+ can observe geo-neutrinos coming from Uranium and Thorium decay chains via inverse beta decay reaction with protons in liquid scintillator. The expected geo-neutrino event rates at SNO+ are ~19.7 events/year for neutrinos originating from ^{238}U and ~5.5 events/year for neutrinos originating from ^{232}Th, for the 20TW Earth composition model.

Measured geo-neutrino flux will be compared with KamLAND and Borexino results for global analysis. The combined measurements will hopefully help to distinguish between current Earth composition models.

Improving geoneutrino predictions from jointly constrained local crustal models

Laura Sammon*1, William F. McDonough1,2

1. Geology Department, University of Maryland, College Park, MD 20742, USA
2. Research Center for Neutrino Science and Department of Earth Sciences, Tohoku University, Sendai 980-8578, Japan

*lsammon@umd.edu

Radioactive decay of U and Th produce geoneutrinos, electron antineutrinos ($\bar{\nu}_e$). Detection of these particles can constrain the amount of radiogenic heat production in Earth and Earth's abundance of heat producing elements (HPE). About half of the geoneutrino signal comes from the crust surrounding the detector. In order to constrain the signal coming from Earth's mantle, we predict the signal coming from the crust and apply a correction. Amphibolite and granulite facies xenoliths and terrains serve as analogues to the deep crust, which we cannot sample directly. By applying thermodynamic principles to geochemical observations from these samples, we can predict seismic wave speeds in the deep crust. Comparing predictions to high resolution seismic inversions, we determine the SiO_2 content as a function of depth and temperature within the crust. Trends among SiO_2, U, and Th allow us to infer HPE content near geoneutrino detectors and produce more accurate geoneutrino flux predictions.