Tohoku University Global COE Program
"Global Education and Research Center for Earth and Planetary Dynamics"

External Review 2011

Activity Report of Researchers

Solid Earth Research Group
Dynamics of Earth and Planetary Interiors

Tohoku University

Members

Project Members: *(**Sub-Group Leader)*

Department of Earth Sciences

Eiji Ohtani (**, Prof., Earth Material Sci., Dr.Sc., Project Leader)

Michihiko Nakamura (Assoc. Prof., Petrology, Dr.Sc., Vice-Chair of Education Com.)

Akio Suzuki (Assoc. Prof., Earth Material Sci., Dr.Sc., Vice-Chair of Intl. Exchange Com.)

Research Center for Prediction of Earthquakes and Volcanic Eruptions, and Department Geophysics

Depeng Zhao (Prof., Seismology, Dr.Sc., Chair of Intl. Exchange Com.)

Haruo Sato (Prof., Seismology, Dr.Sc., -2011.3.31)

Graduate School of Environmental Studies

Noriyoshi Tsuchiya (Prof., Geo-Engineering, Dr. E., Vice-Chair of Education Com.)

Associate Members:

Yasuhiro Kudoh, Motohiko Murakami, Takahiro Kuribayashi, Hidenori Terasaki (-2011.3.31), Hirokazu Fujimaki, Kenichi Ishikawa, Satoshi Osozawa, Noritoshi Suzuki (Department of Earth Sciences), Akira Ishiwatari (Center for Northeast Asian Studies), Toshiro Nagase (The Tohoku University Museum), Takeshi Sakai (International Advanced Research and Education Organization -2011.3.31, Department of Earth Sciences 2011.4.1-), Akira Hasegawa, Haruo Sato (2011.4.1-), (Research Center for Prediction of Earthquakes and Volcanic Eruptions, and Department of Geophysics), Hiroshi Asanuma, Nobuo Hirano, Atsushi Okamoto, (Graduate School of Environmental Studies)

Activity Report for External Review (2010-2011)

Dynamics of Earth and Planetary interiors Research Sub-group

Activity Reports

Project Members:

Associate Members:

COE Researchers

Eiji Ohtani

Title/Affiliation	Professor / Department of Earth Sciences, Graduate School of Science, Tohoku University
Specialized Field	Mineral Physics, High Pressure Geochemistry
Research Subject	Dynamics of the earth and planetary interior, High pressure research

The Purpose of Research and Outline of Accomplishments:

(1) Core: Significant progress has been made in the research of the Earth's core. We successfully conducted determination of the melting temperatures of Iron-light elements alloys. We have generated pressures exceeding 250 GPa and T > 3500 K, and clarified that the stable phase of Fe-Si and FeNiSi alloys is hcp phase under the present experimental conditions. We also determined the eqution of state of FeNiSi alloys to the pressures exceeding the center of the Earth, 375 GPa, and confirmed that we have generated high temperature, about 700 K at the pressure. Bsed on the measurements, we estimated the compositional range of the inner core in the Fe-Ni-S system.

(2) Sound velocity measurement of iron, Fe-Ni-Si alloy, Fe_3S, and FeH at high pressure by the inelastic X-ray scattering: We made sound velocity measurement of FeNiSi and Fe up to the pressures up to 145 GPa, Fe_3S up to 50 GPa, and FeH up to 70 GPa by using inelastic X-ray scattering combined with the diamond anvil cell experiments at BL35XU. Based on the sound velocity of these materials, we obtained the linear relation of the sound velocity-density relation, and estimated the composition of the inner core, which can explain the velocity and density of the inner core.

(3) Circluation of water and carbon: Mantle transition zone is a place of accumulation of the subducting plates, and various type of heterogeneities are expected to exist. We have clarified the effect of carbon and hydrogen on melting and magma properties at high pressure. We also clarified the phase and melting relation of peridotite-CO_2 system at high pressure, the density of the CO_2 bearing magmas at high pressure, and applied for the origin of kimberlite magmas. We clarified the phase relations of the carbonated eclogite in the system CaO-Al_2O_3-MgO-SiO_2-Na_2O-CO_2 to 32 GPa and discussed the nature of carbonatite liquid expected to be formed in the deep mantle.

(4) Collision and high pressure polymorphs in shocked meteorites: We have studied the high pressure polymorphs of minerals formed by the shock events in the meteorites. We discovered coesite and stishivite and also discovered seifertitlte (α-PbO_2 structured SiO_2) in lunar meteorite for the first time. These high pressure polymorphs of silica can be used to estimate the inteisity of the collision in the early lunar surface such as Lunar Catacysm. We also studied the eveidence of shock events in Martian meteorites, and discovered the decompsotion texture of olivine to magnesiowusitute and perovskite.

International activity:

1) **Collaboation and Exchange with UC Davis:** Ohtani, E. made an invited lecture at Department of Geological Sciences, UC Davis and Advanced Light Source of UC Berkeley "In situ X-ray measurements of density of silicate and metallic melts at high pressure", February, 2010. We are considering further collaboration and exchange of graduate students between Tohoku and UC Davis.

2) **Global Network sysmposium:** Ohtani, E. made an invited talk, Iron-Silicate reaction and silicon as a light element in the core. Ohtani origanized the Global-Network symposium on Earth's Dynamics, Akiu, Sendai, Japan, March, 2010. This symposium is orignized by the international program committee composed of five major organizations, Tohoku, Lyon, Sobolev, Carnegie Institution, and Academia Sinica.
3) **Deep Carbon Cycle Research:** Ohtani worked as a member of the founding committee of Deep Carbon Observatory program funded by Sloan Foundation. Ohtani organized several symposium related to Deep Carbon Cycle, such as a Deep Carbon Cycle session at 2010 JpGU international symposium, 8th Water dynamics/Deep Carbon cycle workshop in March 8-10, 2011. Ohtani also organized a DCC session at 2011 Deep Carbon Cycle in the international symposium at 2011 JpGU international symposium.
4) **Lecture at Chinese academy of Science.** Ohtani, E., Invited lecture at Chinese Academy of Science, Beijing, China. Iron-Silicate Reactions and Light Elements in the Core, April, 2010.
5) **Invited lecture at Goldschmidt Conference (Knoxville):** Ohtani, E., Application of in situ X-ray observations to melting anf melt properteies at high pressure, June, 2010.
6) **Invited lecture at GCOE Solid Earth symposium:** Ohtani, E., Deep volatile cycle and Light Elements in the Core., July, 2010.
7) **Invited talk at SEDI (Study of the Earth Deep Interior) at UC Santa babara, July, 2010.** Ohtani, E., Physical and Chemical properties and thermal state of the core and lower mantle.
8) **Invited lecture at International Mineralogical Association:** Ohtani, E., Iron-Silicate reaction and Silicon in the Core., September, 2010.
9) **CECAM (Centre Européen de Calcul Atomique et Moléculaire), Invited lecture.** Ohtani, E., Composition, Physical Properties, and Thermal State of the Core., October, 2010.
10) **Invited lecture at LMU Munchen, October, 2010.** Ohtani, E., Material properties of Earth's materials, and structure, evolution, and dynamics of the mantle and core.
11) **Invited lecture at the Deep Carbon workshop at Altai, Russia, August 25-30, 2011.** Ohtani E., Carbon and light elements in planetary cores.
12) **Invited lecture at INSA,-Lyon for the ELyT laboratory, summer school at Lyon, September 4-13, 2011. E. Ohtani, Special Lecture for Origin and Evolution of the Earth and Planets**
13) **Invited talk at 2011 GSA meeting at Minneapolis, USA, October, 9-12, 2011.** Ohtani E., Sakai T., Kamada S., Fukui H., Shibazaki Y., Baron Alfred Q.R., Tsutsui S., Asanuma H., Phase relations density and sound velocity of Fe-Ni-Si alloys and composition of the inner core.

Award and Honor:

The medal with Purple Ribbon, November 3rd, 2010.

Published Journal Papers:

1. Sakamaki, T., **E. Ohtani**, S. Urakawa, A. Suzuki and Y. Katayama (2010). Density of dry peridotite magma at high pressure using an X-ray absorption method., American Mineralogist, 95, 144-147
2. Tatsuya, S., **E. Ohtani**, S. Urakawa, A. Suzuki, Y. Katayama and D. Zhao (2010). Earth and Planetary Science Letters, Density of high-Ti basalt magma at high pressure and origin of heterogeneities in the lunar mantle., Earth and Planetary Science Letters, 294, 94-100

3. Kamada, S., H. Terasaki, **E. Ohtani**, T. Sakai, T. Kikegawa, Y. Ohishi, N. Hirao, N. Sata and T. Kondo (2010). Phase relationship of the Fe-FeS system in conditions up to the Earth's outer core., Earth and Planetary Science Letters, 294, 94-100
4. Terasaki, H., K. Nishida, Y. Shibazaki, T. Sakamaki, A. Suzuki, **E. Ohtani**, T. Kikegawa (2010). Density measurement of Fe_3C liquid using X-ray absorption image up to 10 GPa and effect of light elements on compressibility of liquid iron., Journal of Geophysical Research-Solid Earth, 115, B02202
5. Frost, D. J., Y. Asahara, D. C. Rubie, N. Miyajima, L. S. Dubrovinsky, C. Holzapfel, **E. Ohtani**, M. Miyahara and T. Sakai (2010). Partitioning of oxygen between the Earth's mantle and core., Journal of geophysical research-solid Earth, 115, B02202
6. Ju, J., K. Huynh, J. Tang, Z. F. Li, M. Watahiki, K. Sato, H. Terasaki, **E. Ohtani**, H. Takizawa, K. Tanigaki (2010). Superconducting properties of $SmFeAsO_1$-x prepared under high-pressure condition., Journal of Physics and Chemistry of Solids, 71, 4, Sp. Iss. SI, 491-494
7. Miyahara, M., **E. Ohtani**, M. Kimura, A. El Goresy, S. Ozawa, T. Nagase, M. Nishijima and K. Hiraga (2010). Coherent and subsequent incoherent ringwoodite growth in olivine of shocked L6 chondrites., Earth and Planetary Science Letters, 295, 321-327, doi: 10.1016/j.epsl.2010.04.023
8. Asanuma, H., **E. Ohtani**, T. Sakai, H. Terasaki, S. Kamada, T. Kondo and T. Kikegawa (2010). Melting of Iron-silicon alloy up to the core-mantle boundary pressure: implications to the thermal structure of the Earth's core., Physics and Chemistry of Minerals, 37, 6, 353-359
9. Shimojuku, A., T. Kudo, **E. Ohtani**, T. Nakamura and R. Okazaki. (2010). Effects of hydrogen and iron on the silicon diffusivity of wadsleyite., Physics of the Earth and Planetary Interiors, 183, 1-2, 175-182
10. Sakai, T., **E. Ohtani**, H. Terasaki, M. Miyahara, M. Nishijima, N. Hirao, Y. Ohishi and N. Sata (2010). Fe-Mg partitioning between post-perovskite and ferropericlase in the lowermost mantle., Physics and Chemistry of Minerals, 37, 7, 487-496
11. Litasov, K. and **E. Ohtani** (2010). The solidus carbonated eclogite in the system CaO-Al_2O_3-MgO-SiO_2-Na_2O-CO_2 to 32 GPa and carbonatite liquid in the deep mantle., Earth and Planetary Science Letters, 295, 1-2, 115-126
12. Shatskiy, A., L. Konstantin, H. Terasaki, T. Katsura and **E. Ohtani** (2010). Performance of semi-sintered ceramics as pressure-transmitting media up to 30 GPa., High Pressure Research, 30, 3, 443-450, doi: 10.1080/08957959.2010.515079
13. Litasov, K. D., A. Shatskiy, Y. Fei, A. Suzuki, **E. Ohtani** and K. Funakoshi (2010). Pressure-volume-temperature equation of state of tungsten carbide to 32 GPa and 1673 K., Journal of Applied Physics, 108, 5, 053513
14. Dymshits, A. M., A. V. Bobrov, K. D. Litasov, A. F. Shatskiy, **E. Ohtani** and Y. A. Litvin (2010). Experimental study of the pyroxene-garnet phase transition in the $Na_2MgSi_5O_{12}$ system at pressures of 13-20 GPa: First synthesis of sodium majorite., Doklady Earth Sciences, 434, 1, 1263-1266
15. Collerson, K. D., Q. Williams, B.S. Kamber, S. Omori, H. Arai and **E. Ohtani** (2010). Majoritic garnet: A new approach to pressure estimation of shock events in meteorites and the encapsulation of sub-lithospheric inclusions in diamond., Geochimica et Cosmochimica Acta, 74, 20, 5939-5957
16. Litasov, K., O. Safonov and **E. Ohtani** (2010). Origin of Cl-bearing silica-rich melt inclusions in diamonds: Experimental evidence for an eclogite connection., Geology, 38, 12, 1131-1134, doi: 10.1130/G31325.1
17. Miyahara, M., **E. Ohtani**, M. Kimura, S. Ozawa, T. Nagase, M. Nishijima and K. Hiraga (2010). Melting and subsequent decompression processes recorded in a shock vein of an L6 chondrite., Meteoritics & Planetary Science, 45 (Supplement), A140
18. El Goresy, A., M. Miyahara, S. Ozawa, **E. Ohtani**, P. Gillet, P. Beck, G. Montagnac, T. Nagase and K. Hiraga (2010). Liquidus high-pressure assemblages in shocked Martian shergottites: constrains

to equilibrium peak shock-pressures and consequences to radiometric ages., Meteoritics & Planetary Science, 45, A50, (Supplement)

19. Feng, L., M. Miyahara, Y. Lin, **E. Ohtani**, A, EL Goresy, T. Nagase and S. Hu (2010). First evidence for multi shock events on the L chondritic parent body., Meteoritics & Planetary Science, 45, A53, (Supplement)
20. **Ohtani, E** (2010), Application of in situ X-ray observations to melting and melt properties at high pressure, GEOCHIMICA ET COSMOCHIMICA ACTA, 74, 12, A775-A775
21. Sakamaki, T; **Ohtani, E**; Urakawa, S; Suzuki, A; Katayama, Y; Zhao, DP (2010), Density of high-Ti basalt magma at high pressure and origin of heterogeneities in the lunar mantle, EARTH AND PLANETARY SCIENCE LETTERS, 299, 3-4, 285-289
22. Suzuki, A., **E. Ohtani**, R. Ando, H. Terasaki, T. Sakamaki and K. Funakoshi (2010), Viscosity of basaltic magma at high pressure, Acta Mineralogica-Petrographica, 6
23. Ozawa, S., M. Miyahara, **E. Ohtani**, M. Kimura and Y. Ito (2011). Petrography of Yamato 984028 lherzolitic shergottite and its melt vein: implications for its shock metamorphism and origin of the vein., Polar Science, 4, 550-557
24. Terasaki, H., Y. Shibazaki, T. Sakamaki, R. Tateyama, **E. Ohtani**, K. Funakoshi and Y. Higo (2011). Hydrogenation of Fe Si under high pressure., American Mineralogist, 96, 93-99
25. Konstantin, D. L., A. Shatskiy, **E. Ohtani** and T. Katsura. (2011). Systematic study of hydrogen incorporation into Fe-free wadsleyite., Physics and Chemistry of Minerals, 38, 1, 75-84
26. Litasov, K. D., I. S. Sharygin, A. F. Shatskiy, **E. Ohtani** and N. P. Pokhilenko. (2011). Experimental constraints on the role of chloride in the origin and evolution of kimberlitic magma., Doklady Earth Sciences 435, 2, 1641-1646
27. Shibazaki, Y., **E. Ohtani**, H. Terasaki, R. Tateyama, T. Sakamaki, T. Tsuchiya and K. Funakoshi (2011). Effect of hydrogen on the melting temperature of FeS at high pressure: Implications for the core of Ganymede., Earth and Planetary Science Letters, 301, 1-2, 153-158
28. Sakamaki, T., **E. Ohtani**, S. Urakawa, H. Terasaki and Y. Katayama. (2011). Density of carbonated peridotite magma at high pressure using an X-ray absorption method., American Mineralogist, 96, 4, 553-557, doi: 10.2138/am.2011.3577
29. **Ohtani, E.**, S. Ozawa, M. Miyahara, Y. Ito, T. Mikouchi, M. Kimura, T. Arai, K. Sato, and K. Hiraga. (2011). Coesite and stishovite in a shocked lunar meteorite, Asuka-881757, and impact events in lunar surface., PNAS, 108, 2, 463–466, doi: 10.1073/pnas.1009338108
30. Nakamura R., **Ohtani E.,** (2011), The high-pressure phase relation of the $MgSO_4$-H_2O system and its implication for the internal structure of Ganymede. Icarus, 211(1), 648-654
31. Zhao DP., Yu S., **Ohtani E.,** (2011), East Asia: Seismotectonics, magmatism and mantle dynamics. Journal of Asian Earth Science, 40, 3, 689-709
32. Sakai T., **Ohtani E.,** Hirao N., Ohishi Y., (2011), Equation of state of the NaCl-B2 phase up to 304 GPa. Journal of Applied physics, 109, 8, doi:10.1063/1.3573393
33. Miyahara M., **Ohtani E.,** Ozawa S., Kimura M., El Goresy A., Sakai T., Nagase T., Hiraga K., Hirao N., Ohishi Y., (2011), Natural dissociation of olivine to (Mg, Fe)SiO3 perovskite and magnesiowustite in a shocked Martian meteorite. Proceedings of the Natural Academy of Sciences of the United States of America, 108, 15, 5999-6003
34. Shatskiy A., Borzdov YM., Litasov KD., **Ohtani E.**, Khokhryakov AF., Palyanov YN., Katsura T., (2011), Press less split-sphere apparatus equipped with scaled-up Kawai-cell for mineralogical studies at 10-20 GPa. American Mineralogist, 96, 4, 541-548
35. Sakai T., **Ohtani E.**, Hirao N., Ohishi Y., (2011), Stability field of the hcp-structure for Fe, Fe-Ni, and Fe-Ni-Si alloys up to 3 Mbar. Geophysical research letters, 38, L09302

36. Terasaki H., Kamada S., Sakai T., **Ohtani E.**, Hirao N., Ohishi Y., (2011), Liquidus and solidus temperatures of a Fe-O-S alloy up to the pressures of the outer core: Implication for the thermal structures of the Earth's core. Earth and Planetary Science Letters, 304, 3-4, 559-564
37. Suzuki A., **Ohtani E.**, Terasaki H., Nishida K., Hayashi H., Sakamaki Y., Shibazaki Y., Kikegawa T., (2011), Pressure and temperature dependence of the viscosity of a NaAlSi2O6 melt. Physics and Chemistry of Minerals, 38, 59-64
38. Nishida K., **Ohtani E.**, Urakawa S., Suzuki A,, Sakamaki T., Terasaki H., Katayama Y., (2011), Density measurement of liquid FeS at high pressures using synchrotron X-ray absorption. American Mineralogist, 96, 864-868
39. Miyahara M., **Ohtani E.**, Kimura M., Ozawa S., Nagase T., Nishijima M. and Hiraga K., (2011), Evidence for multiple dynamic events and subsequent decompression stage recorded in a shock vein. Earth and Planetary Science Letters, 307, 361-368
40. Asanuma H., **Ohtani E.**, Sakai T., Terasaki H., Kamada S., Hirao N., Ohishi Y., (2011), Static compression of Fe0.83Ni0.09Si0.08 alloy to 374 GPa and Fe0.93Si0.07 alloy to 252 GPa: Implications for the Earth's inner core. Earth and Planetary Science Letters, doi:10.1016/j.epsl.2011.06.034
41. Tateyama R., **Ohtani E.**, Terasaki H., Nishida K., Shibazaki Y., Suzuki A., Kikegawa T., (2011), Density measurements of liquid Fe-Si alloys at high pressure using the sink-float method. Physics and Chemistry of Minerals, doi:10.1007/s00269-011-0452-1
42. Sakai T., **Ohtani E.**, Terasaki H., Kamada S., Hirao N., Miyahara M., Nishijima M., (2011), Phase stability and compression study of (Fe0.89, Ni0.11)3S up to pressure of the Earth's core. American Mineralogist, 96, 10, 1490-1494, doi:10.2138/am.2011.3822
43. Kuritani T., **Ohtani E.**, Kimura J., (2011), Intensive hydration of the mantle transition zone beneath China caused by ancient slab stagnation. Nature Geoscience, doi:10.1038/NGEO1250.
44. Miyahara M., **Ohtani E.**, Ozawa S., Kimura M., El Goresy A., Sakai T. Nagase T., Hiraga K., Hirao N., Ohishi Y., (2011), First evidence for natural dissociation of olivine to silicate-perovskite and magnesiowustite in a shocked Martian meteorite DAG 735. Meteoritics & Planetary Science, 46, SI, 1, A164-A164
45. Bindi, L; Dymshits, AM; Bobrov, AV; Litasov, KD; Shatskiy, AF; **Ohtani, E**; Litvin, YA (2011), Crystal chemistry of sodium in the Earth's interior: The structure of Na(2)MgSi(5)O(12) synthesized at 17.5 GPa and 1700 degrees C, AMERICAN MINERALOGIST, 96, 2-3, 447-450
46. Shibazaki Y., **Ohtani E.**, Fukui H., Sakai T., Kamada S., Ishikawa D., Tsutsui S., Baron A. Q., Nishitani N., Hirao N., Takemura K., (2011), Sound velocity measurements in dhcp-FeH up to 70 GPa with inelastic X-ray scattering: Implications for the composition of the Earth's core. Earth and Planetary Science Letters, in press
47. Kamada, S; Terasaki, H; **Ohtani, E**; Sakai (2011), Phase and Melting Relationships in the Fe-S System under High Pressures:Application to the Temperature Profile in the Core, The Review of high pressure science and technology, 21, 2, 77-83

Symposium Participations:

1. **Ohtani, E.** (2010). Effect of carbon and hydrogen on phase and melting relations and melt properties at high pressure., Deep Carbon Cycle International Conference in Beijing
2. **Ohtani, E.**, Y. Shibazaki and H. Terasaki (2010). Transport of hydrogen into the deep Earth by slab penetration., JpGU International Symposium 2010, SIT039-12, Chiba, May 23-28, 2010
3. **Ohtani, E.**, T. Sakai, S. Kamada, M. Murakami, H. Fukui and A. Baron (2010). Sound velocity of $Fe_{0.83}Ni_{0.09}Si_{0.08}$ alloy to core pressures., JpGU International Symposium 2010, SIT042-21, Chiba, May 23-28, 2010
4. Ohtani, E., T. Sakamaki and K. Litasov (2010). Effect of carbon and hydrogen on melting and magma properties at high pressure., JpGU International Symposium 2010, MIS010-12, Chiba, May 23-28, 2010
5. Kuramoto, K., K. Kobayashi and **E. Ohtani** (2010). Toward the structure, origin, and dynamics of the moon and rocky planets., JpGU International Symposium 2010, PPA007-03, Chiba, May 23-28, 2010
6. Kobayashi, K., K. Kuramoto and **E. Ohtani** (2010). Coevolution of surface environments of planets and life., JpGU International Symposium 2010, PPS007-04, Chiba, May 23-28, 2010
7. Ishii, M., **E. Ohtani**, H. Terasaki and K. Litasov (2010). Phase relation of Mercury's interior., JpGU International Symposium 2010, PPS004-22, Chiba, May 23-28, 2010
8. Takahashi, S., **E. Ohtani** and H. Terasaki (2010). Phase relation into the C-rich Mg-Fe-Si-O-C system under various redox conditions: Implication for Carbon Planet., JpGU International Symposium 2010, PPS010-11, Chiba, May 23-28, 2010
9. Shibazaki, Y., **E. Ohtani**, H. Terasaki, R. Tateyama, T. Sakamaki., K. Nishida and K. Funakoshi (2010). Melting relations of FeS-H and Fe-Ni-H systems under high pressure., JpGU International Symposium 2010, SIT036-5, Chiba, May 23-28, 2010
10. Sakai, T., **E. Ohtani**, H. Terasaki, S. Kamada, N. Hirao, E. Sata and Y. Ohishi (2010). Phase stability of subsolidus phases in Fe-Ni-S system at the core pressure., JpGU International Symposium 2010, SIT036-06, Chiba, May 23-28, 2010
11. Shiraishi, R., **E. Ohtani**, T. Kuno, A. Suzuki, N. Doi, A. Shimojuku, T. Kato, K. Kanagawa and T. Kikegawa (2010). Deformation experiment on fayalite using deformation-Cubic Anvil Press with synchrotron X rays., JpGU International Symposium 2010, SIT037-05, Chiba, May 23-28, 2010
12. Nishida, K., **E. Ohtani**, A. Suzuki, H. Terasaki, Y. Shibazaki, R. Tateyama and T. Kikegawa (2010). Equation of state of liquid FeS at high pressure and high temperature., JpGU International Symposium 2010, SIT041-12, Chiba, May 23-28, 2010
13. Shatskiy, A., K. Litasov, D. Yamazaki, T. Katsura and **E. Ohtani** (2010). Incipient fluid migration through the deep mantle by dissolution-precipitation: crystal growth constraints., JpGU International Symposium 2010, SIT042-5, Chiba, May 23-28, 2010
14. Litasov, K., A. Shatskiy, H. Terasaki, **E. Ohtani**, F. Yingwei and K. Funakoshi (2010). Carbon-silicate-Fe metal reactions at high pressures: New experimental constraints on deep volatile cycles., JpGU International Symposium 2010, MIS010-14, Chiba, May 23-28, 2010
15. Fumiko, T., **E. Ohtani** and T. Nakagawa (2010). Seismic evidence of dehydration induced fluids near the 660 Km phase transformation depths beneath stagnant slabs., JpGU International Symposium 2010, SIT039-07, Chiba, May 23-28, 2010
16. Sakamaki, T., **E. Ohtani**, A. Suzuki, S. Urakawa, H. Terasaki, Y. Katayama and K. Funakoshi (2010). Density, viscosity and structure of basaltic magma at high pressure and high temperature., JpGU International Symposium 2010, SIT041-09, Chiba, May 23-28, 2010
17. Takata, N., M. Murakami and **E. Ohtani** (2010). Brillouin scattering and X-ray diffraction of NaCl: a construction of primary pressure scale., JpGU International Symposium 2010, SIT036-P04, Chiba, May 23-28, 2010

18. Suzuki, A., **E. Ohtani**, K. Nishida, R. Tateyama, Y. Shibazaki and T. Kikegawa (2010). Viscosity of $K_2TiSi_4O_9$ melt at high pressure and high temperature., JpGU International Symposium 2010, SIT041-P04, Chiba, May 23-28, 2010, (poster)
19. Terasaki, H., Y. Shibazaki, T. Sakamaki., R. Tateyama, **E. Ohtani** and K. Funakoshi (2010). Hydrogen solubility onto FeSi under high pressure., JpGU International Symposium 2010, SIT036-P09, Chiba, May 23-28, 2010
20. Nishitani N., **E. Ohtani**, T. Sakai and M. Murakami (2010). Study of melting phenomena under the deep mantle conditions., JpGU International Symposium 2010, SIT036-P05, Chiba, May 23-28, 2010
21. Nishimoto, T., M. Murakami and **E. Ohtani** (2010). Elasticity and equation of state of sodium silicate glass., JpGU International Symposium 2010, SIT041-P05, Chiba, May 23-28, 2010
22. Tateyama, R., **E. Ohtani**, A. Suzuki, H. Terasaki, K. Nishida, Y. Shibazaki and T. Kikegawa, (2010). Density measurement of liquid Fe-Si using sink/float method under high pressure., JpGU International Symposium 2010, SIT041-P09, Chiba, May 23-28, 2010
23. Urakawa, S., H. Terasaki, K. Funakoshi, K. Uesugi and **E. Ohtani** (2010). In situ X-ray tomography observation of connectivity of Ni-S melts in olivine under of high pressure and temperature., JpGU International Symposium 2010, SIT041-P08, Chiba, May 23-28, 2010
24. **Ohtani, E.** (2010). Application of in situ X-ray observation to melting and melt properties at high pressure., The Goldschmidt 2010 Conference, Tennessee, June 13-18, 2010
25. Suzuki, A., **E. Ohtani**, T. Sakamaki, S. Urakawa, Y. Katayama, K. Nishida, R. Tateyama and T. Kikegawa (2010). Density and viscosity of the lunar high-Ti magma at high pressure., Western Pacific Geophysics Meeting, Taipei, June 22-25, 2010
26. **Ohtani, E.**, T. Sakai, S. Kamada, Y. Shibazaki, K. Kobayashi, H. Asanuma and N. Hirao (2010). Melting and phase relations of Fe(Ni)-Si systems to the Earth's core conditions, and their applications to the core., Western Pacific Geophysics Meeting, Taipei, June 22-25, 2010
27. **Ohtani, E.** (2010). Deep volatile cycle and light elements in the core., Global COE Symposium 2010 "Dynamic Earth and Heterogeneous Structure", July 13-15, 2010, Sendai, Japan, (oral)
28. Litasov, K., A. Shatskiy, H. Terasaki and **E. Ohtani** (2010). Carbonate-silicate-Fe metal reactions and stability of C-O-H species in the Earth's mantle., Global COE Symposium 2011 "Dynamic Earth and Heterogeneous Structure", July 13-15, 2010, Sendai, Japan, (oral)
29. Terasaki, H., Y. Shibazaki, T. Sakamaki, R. Tateyama, **E. Ohtani**, K. Funakoshi and Y. Higo (2010). The effect of hydrogen on melting of FeSi under high pressure., Global COE Symposium 2012 "Dynamic Earth and Heterogeneous Structure", July 13-15, 2010, Sendai, Japan, (oral)
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126. Seiji Kamada, **Eiji Ohtani**, Hidenori Terasaki, Takeshi Sakai, Yasuo Ohishi, Naohisa Hirao, Masaaki Miyahara, (2011) Melting relationships in the Fe-Fe3S system based on X-ray diffraction up to 180 GPa. (invited)
127. Satoru Urakawa, Asumi Nakatsuka, Hidenori Terasaki, Keisuke Nishida, Yoshinori Katayama, Tohru Watanabe, Takumi Kikegawa, **Eiji Ohtani,** (2011) Structure of pure liquid Fe at high pressure based on in-situ X-ray observation. AGU Fall Meeting, San Francisco, December 5-9 (oral)
128. Seiji Kamada, Hiroshi Fukui, **Eiji Ohtani,** Takeshi Sakai, Hidenori Terasaki, Alfred Q. Baron, Yasuo Ohishi, Naohisa Hirao, (2011) Compressional velocities of Fe3S at room temperature and high pressures using inelastic X-ray scattering. AGU Fall Meeting, San Francisco, December 5-9. (oral)

Michihiko Nakamura

Title/Affiliation	Associate Professor / Department of Earth Sciences, Graduate School of Science, Tohoku University
Specialized Field	Petrology, Volcanology
Research Subject	Mechanism of Volcanic Eruptions; Microstructure of fluid-bearing rocks

The Purpose of Research and The Abstract of Accomplishments:

Volcanic eruptions are representative of the dynamic activity of the Earth. A striking feature of the volcanic activity is its wide variety of eruption styles. They are different among volcanoes and eruptions of a volcano, and even changes within an eruption event. An important issue of modern physical volcanology is to first find out and define the bifurcation points of eruption styles in the course of magma ascent and emplacement, and then clarify the mechanisms of bifurcations. Besides scienetific interests, it provides a basis for predicting transitions of activity in volcanic crises. Among some key processes, we have been focusing on the outgassing mechanism of highly viscous, silicic magmas that often cause violent explosive eruption as well as relatively quiet lava dome growth. In such magmas, shear induced fracturing is believed to be an important process for outgassing. We have carried out for the first time experimental studies on fracturing of a vesicular magma and healing of fractures under high temperature and a confining pressure, and clarified their mechanisms from a viewpoint of material science.

Growing number of evidences from melt inclusions in phenocrysts and obsidian pyroclasts indicate that shallow and H_2O-rich magmatic system is often flushed with relatively CO_2-rich deep-derived fluid. In order to understand the effect of this "CO_2-fluxing" on the volatile behavior in subvolcanic systems, we performed hydrothermal experiments on the reaction between H_2O-rich melt and CO_2-rich fluid. Other projects on the Sakurajima activity, and the microstructure of fluid bearing rocks have been on-going.

Results:

1. We performed torsional deformation experiments on columnar rhyolites that simulated flow of rhyolites in shallow volcanic conduits. We showed that the deformation was localized and finally resulted in brittle failure, followed by a slip at the fractured interface, which prevented further brittle failure and shear-induced bubble coalescence in the remaining parts of the sample. We infer that repeated fracturing and healing processes are necessary for effective degassing of the entire magma.
2. The healing of magmatic fractures is considered essential to repetitive seismicity and the closure of degassing paths during emplacement of lavas. To estimate the healing time of magmatic fractures, we performed healing experiments of the contact interface of rhyolitic melts at 850°−1000°C. The interface became coherent in atomic scale and finally disappeared, which was characterized by the homogenization of water content across the contact via diffusion. We defined this closure interval as healing time and determined this based on a diffusion model. The microscopic healing time was strongly dependent on temperature and roughness of the interface, being consistent with the period of actual seismicity. It is prolonged sufficiently to permit the formation of millimeter thick bubble-free obsidian layers along fractures in vesicular lavas through bubble resorption due to diffusive degassing.
3. We found chemically-driven bubble growth during the interaction, which has a potential to trigger volcanic eruptions.

Published Journal Papers:

1. Yoshimura, S. and **M. Nakamura** (2010). Fracture healing in a magma: An experimental approach and implications for volcanic seismicity and degassing., Jour. Geophys. Res., 115, B09209 doi: 10.1029/2009JB000834
2. Okumura, S., **M. Nakamura**, T. Nakano, K. Uesugi and A. Tsuchiyama (2010). Shear deformation experiments on vesicular rhyolite: Implications for brittle fracturing, degassing, and compaction of magmas in volcanic conduits., Jour. Geophys. Res., 115, B06201, doi: 10.1029/2009JB006904
3. Yoshimura, S. and **M. Nakamura** (2010). Chemically driven growth and resorption of bubbles in a multivolatile magmatic system., Chem. Geol., 276, 18-28
4. Ohuchi, T., **M. Nakamura** and K. Michibayashi (2010). Effect of grain growth on cation exchange between dunite and fluid: implications for chemical homogenization in the upper mantle., Contrib. Mineral. Petrol., 160, 339-357, doi: 10.1007/s00410-009-0481-7
5. **Nakamura, M.**, S. Tamura, Y. Ito, S. Okumura, M. Iguchi and D. Miki (2010). Incubation processes for the Taisho eruption of sakurajima volcano - Constraints from the mineral chemistry of magnetite -., Annuals of Disas. Prev. Res. Inst. Kyoto Univ., 53 B
   Yoshimura, S., **Nakamura, M.**, Carbon dioxide transport in crustal magmatic systems, Earth Planet. Sci. Lett., 307, 470?478, 2011.

Symposium Participations:

1. **Nakamura, M.**, S. Okumura and S. Takeuchi (2010). Permeability development of volcanic pyroclasts: experimental constraints., Japan Geoscience Union Meeting, Makuhari, Japan, May23-28, 2010.
2. **Nakamura, M.** (2010). Bifurcations of eruption processes: An overview with a case study of the Asama volcano., Global COE Symposium 2010 "Dynamic Earth and Heterogeneous Structure", July 13-15, 2010, Sendai, Japan
3. Okumura, S., **M. Nakamura** and T. Nakano (2010). Experimental constraints on the permeable gas transport in ascending magmas., Global COE Symposium 2010 "Dynamic Earth and Heterogeneous Structure", July 13-15, 2010, Sendai, Japan
4. Yoshimura, S. and **M. Nakamura** (2010). Bubble growth and resorption driven by chemical interaction in the H_2O-CO_2-rhyolite system., Global COE Symposium 2010 "Dynamic Earth and Heterogeneous Structure", July 13-15, 2010, Sendai, Japan
5. Okumura, H. and **M. Nakamura** (2010). Crystallization kinetics in the system Ab-Qtz-H_2O: Implications for the formation of pegmatitic texture., Global COE Symposium 2010 "Dynamic Earth and Heterogeneous Structure", July 13-15, 2010, Sendai, Japan
6. **Nakamura, M.**, T. Kichise, Y. Yasui and T. Nagahashi, (2010). Voluminous juvenile lithic fragments in the pumice-fall deposit of the 1108 eruption of Asama volcano: Evidence of repeated compaction and fragmentation in the shallow conduit., American Geophysical Union 2010 Fall meeting, MR41A-1977, San Francisco, December 13-17, 2010
7. Okumura, S., **M. Nakamura**, T. Fujioka, A. Tsuchiyama, S. Takeuchi, T. Nakano and K. Uesugi (2010). Evolution of microstructure of bubbles and gas permeability in sheared rhyolite., American Geophysical Union 2010 Fall meeting,MR41A-1977, San Francisco, December 13-17, 2010 (Invited)
8. **Nakamura, M.**, Otsuki, S., Miki, D., Iguchi, M., Nanolites in volcanic ash: a clue to understand gas pocket processes in the on-going Sakurajima eruption, Japan Geosciences Union Meeting 2011, May 22-27, 2011, Chiba, Japan (Invited)
9. Yoshimura, S., **Nakamura, M.**, Carbon isotope evolution in magmatic systems by CO2 fluxing, Goldschmidt Conference 2011, August 14-19, 2011, Prague, Czech Republic (Invited)

Akio Suzuki

Title/Affiliation	Associate Professor / Department of Earth Sciences, Graduate School of Science, Tohoku University
Specialized Field	Experimental Petrology, Mineral Physics
Research Subject	Physical properties of silicate and metallic liquid under high pressure

The Purpose of Research and Outline of Accomplishments:

Knowledge about viscosity of silicate melt is valuable for understanding the activity of magma in the Earth's interior. We have carried out series of experiments using an X-ray radiography system and a high pressure apparatus installed at the synchrotron radiation facilities. The viscosity was determined by the falling sphere method.

Main Results:

We constructed a new beamline (NE7A) at KEK, Tsukuba, for high pressure experiments. Using a large volume press equipped with an X-ray imaging and diffraction system, we carried out in situ falling sphere viscometry of silicate melts and in situ buoyancy test for density measurements of metallic liquids. For example, the viscosity of a silicate melt of composition $NaAlSi_2O_6$ was measured at pressures from 1.6 to 5.5 GPa and at temperatures from 1,350 to 1,880C. We found that the viscosity of the $NaAlSi_2O_6$ melt decreased with increasing pressure up to 2 GPa. The pressure dependence of viscosity is diminished above 2 GPa. By using the relationship between the logarithm of viscosity and the reciprocal temperature, the activation energies for viscous flow were calculated to be $(3.7 \pm 0.4) \times 10^2$ and $(3.7 \pm 0.5) \times 10^2$ kJ/mol at 2.2 and 2.9 GPa, respectively.

In addition to the viscosity measurement, we carried out 1) the density measurement of silicate and metallic liquid by X-ray absorption method and in situ sink/float method, 2) the development of the diamond/SiC composite as an X-ray transparent anvil material, and 3) the deformation experiment using the D-CAP deformation apparatus and X-ray radiography system.

Published Journal Papers:

1. Nishida, K; Ohtani, E; Urakawa, S; **Suzuki, A**; Sakamaki, T; Terasaki, H; Katayama, Y (2011) Density measurement of liquid FeS at high pressures using synchrotron X-ray absorption AMERICAN MINERALOGIST, 96, 5-6, 864-868
2. **Suzuki, A**; Ohtani, E; Terasaki, H; Nishida, K; Hayashi, H; Sakamaki, T; Shibazaki, Y; Kikegawa, T (2011), Pressure and temperature dependence of the viscosity of a NaAlSi(2)O(6) melt PHYSICS AND CHEMISTRY OF MINERALS, 38, 1, 59-64
3. Litasov, K. D., A. Shatskiy, Y. Fei, **A. Suzuki**, E. Ohtani and K. Funakoshi (2010). Pressure-volume-temperature equation of state of tungsten carbide to 32 GPa and 1673 K**.**, Journal of Applied Physics, 108 doi: 10.1063/1.3481667
4. Sakamaki, T., E. Ohtani, S. Urakawa, **A. Suzuki** and Y. Katayama (2010). Density of dry peridotite magma at high pressure using an X-ray absorption method., American Mineralogist, 95
5. **Suzuki, A.** (2010). High-pressure X-ray diffraction study of ε–FeOOH., Physics and Chemistry of Minerals, 37 (3)
6. Arima, H., T. Hattori, K. Komatsu, J. Abe, W. Utsumi, H. Kag, **A. Suzuki**, K. Suzuya, T.

Kamiyama, M. Arai and T. Yagi (2010). Designing PLANET: the neutron beamline for high-pressure material science at J-PARC., Journal of Physics: Conference Series, 215

7. Nishida, K., E. Ohtani, S. Urakawa, **A. Suzuki**, T. Sakamaki, H. Terasaki and Y. Katayama (2010). Density measurements of liquid FeS at high pressure using synchrotron X-ray absorption. American Mineralogist., American Mineralogist, 96; 5-6; 864-868; doi: 10.2138/am.2011.3616
8. Doi, N., T. Kato, T. Kubo, R. Shiraishi, **A. Suzuki**, A. Shimojuku, K. Nishida, E. Ohtani and T. Kikegawa (2010). An in-situ X-ray diffraction study on the high-pressure decomposition reaction of albite under differential stresses., Photon Factory Activity Report 2008 (KEK Progress Report 2009-3), 26, B
9. Tateyama, R., **A. Suzuki**, E. Ohtani, H. Terasaki, K. Nishida, Y. Shimazaki and T. Kikegawa (2010). Density measurements of liquid Fe-S at high pressure using sink-float method. , Photon Factory Activity Report 2008 (KEK Progress Report 2009-3), 26, B
10. Nishida, K., **A. Suzuki**, E. Ohtani, H. Terasaki, T. Sakamaki, Y. Shibazaki, H. Hayashi, M. Funayama and T. Kikegawa (2010). Density measurements of liquid FeS at high pressure using X-ray absorption image., Photon Factory Activity Report 2008 (KEK Progress Report 2009-3), 26, B
11. Shiraishi, R., E. Ohtani, T. Kubo, **A. Suzuki**, N. Doi, A. Shimojuku and T. Kikegawa (2010). High pressure deformation experiments using deformation-cubic anvil, D-CAP 700, with synchrotron X rays., Photon Factory Activity Report 2008 (KEK Progress Report 2009-3), 26, B
12. **Suzuki, A.**, E. Ohtani, K. Nishida, R. Tateyama, H. Terasaki, Y. Shibazaki, R. Shiraishi and T. Kikegawa (2010). Viscosity of lunar high-Ti magma at high pressure., Photon Factory Activity Report 2008 (KEK Progress Report 2009-3), 26, B
13. Shibazaki, Y., E. Ohtani, **A. Suzuki**, T. Sakamaki, K. Nishida and H. Hayashi (2010). Phase relation of the Fe-Ni-H system under high pressures and high temperatures: application to the thermal structure of the Earth's core., SPring-8 User Experimental Report No.24 (2009B)
14. Ohtani, E., S. Urakawa, **A. Suzuki**, H. Terasaki, Y. Katayama and T. Sakamaki (2010). Density measurement of silicate melts by X-ray absorption method under high pressures and high temperatures., SPring-8 User Experimental Report No.23 (2009B)
15. **Suzuki, A.**, E. Ohtani, R. Ando, H. Terasaki, T. Sakamaki and K. Funakoshi (2010). Viscosity of basaltic magma at high pressure., Acta Mineralogica-Petrographica, 6

Symposium Participations:

1. **Suzuki, A.**, E. Ohtani, K. Nishida, R. Tateyama, Y. Shibazaki and T. Kikegawa (2010). Viscosity of $K_2TiSi_4O_9$ melt at high pressure and high temperature., Japan Geoscience Union meeting 2010, SIT041-P04 (international session) May 23-28, 2010, Chiba, Japan
2. **Suzuki, A.**, E. Ohtani, T. Sakamaki, S. Urakawa, Y. Katayama, K. Nishida, R. Tateyama and T. Kikegawa (2010). Density and viscosity of lunar high-Ti magma at high pressure., 2010 Western Pacific Geophysics Meeting, V33C-05 June 22-25, 2010, Taipei
3. **Suzuki, A.**, E. Ohtani, K. Nishida, R. Tateyama, Y. Shibazaki and T. Kikegawa (2010). Viscosity of $K_2TiSi_4O_9$ melt at high pressure and high tempearture., Global COE Symposium 2010 "Dynamic Earth and Heterogeneous Structure", P1-20 July 13-15, 2010, Sendai, Japan
4. **Suzuki, A.**, E. Ohtani, R. Ando, H. Terasaki, T. Sakamaki and K. Funakoshi (2010). Funakoshi, K., Viscosity of basaltic magma at high pressure., IMA2010, 20th General Meeting of the International Mineralogical Association,5SE08] August 21-27, 2010, Budapest, Hungary
5. **Suzuki, A.** (2010). Compression behavior of InOOH-type oxyhydroxide., 5th Asian Conference on High Pressure Research Matsue, Japan, November 8-12, 2010

Dapeng Zhao

Title/Affiliation	Professor / Research Center for Prediction of Earthquakes and Volcanic Eruptions, Graduate School of Science, Tohoku University
Specialized Field	Global Seismology, Physical Volcanology
Research Subject	3-D Earth structure, dynamics, seismic and volcanic activity

The Purpose of Research and Outline of Accomplishments

Using seismological methods to study the seismotectonics, volcanism and mantle dynamics of the Western Pacific and East Asia regions

Main Results

We used advanced seismological methods to determine the detailed 3-D velocity structure of the crust and mantle under the Western Pacific and East Asia regions. Our results shed new light on the seismotectonics, magmatism, and mantle dynamics in the regions. High-resolution geophysical imaging revealed structural heterogeneities in the source areas of large earthquakes, which may reflect magma and fluids that affected the rupture nucleation of large crustal earthquakes and interplate megathrust earthquakes such as the *Great 2011 Tohoku-oki earthquake (Mw 9.0)*. In subduction zone regions, the crustal fluids originate from the dehydration of the subducting slab. Magmatism in arc and back-arc areas is caused by the corner flow in the mantle wedge and dehydration of the subducting slab. The continental volcanoes in Northeast Asia (such as Changbai and Wudalianchi) seem to be caused by the corner flow in the big mantle wedge (BMW) above the stagnant slab in the mantle transition zone and the deep dehydration of the stagnant slab as well. The Tengchong volcano in Southwest China is possibly caused by a similar process in BMW above the subducting Burma microplate (or Indian plate). The Hainan volcano in southernmost China seems to be a hotspot fed by a lower-mantle plume associated with the Pacific and Philippine Sea slabs' deep subduction in the east and the Indian slab's deep subduction in the west down to the lower mantle. The occurrence of deep earthquakes under the Japan Sea and the East Asia margin may be related to a metastable olivine wedge in the subducting Pacific slab. The stagnant slab finally collapses down to the bottom of the mantle, which may trigger upwelling of hot mantle materials from the lower mantle to the shallow mantle beneath the subducting slabs and cause the slab-plume interactions.

International activity

(1) Attended international conferences in Europe (Vienna), China (Guangzhou), Japan (Sendai, Tokyo), Korea (Daejung) and USA (San Francisco) to give keynote or invited lectures there. (2) Visited Guangzhou Institute of Geochemistry in China for research collaboration. (3) Invited 8 foreign researchers and internship students to Tohoku University for conducting research collaborations and international student educations.

Honors and Awards

Being selected by **ScienceWatch (Thomson-Reuters)** to be **One of the World Top 10 Seismologists**

among the 30,670 researchers during 2000-2010 according to the peer-reviewed publications and citations (http://sciencewatch.com/ana/st/earthquakes2/authors/).

Published Journal Papers:

1. **Zhao, D.**, Z. Huang, N. Umino, A. Hasegawa, H. Kanamori (2011) Structural heterogeneity in the megathrust zone and mechanism of the 2011 Tohoku-oki earthquake (Mw 9.0). *Geophys. Res. Lett.* **38**, L17308.
2. **Zhao, D**., S. Yu, E. Ohtani (2011) East Asia: Seismotectonics, magmatism and mantle dynamics. *J. Asian Earth Sci.* 40, 689-709.
3. **Zhao, D**., Z. Huang, N. Umino, A. Hasegawa, T. Yoshida (2011) Seismic imaging of the Amur-Okhotsk plate boundary zone in the Japan Sea. *Phys. Earth Planet. Inter*. 188, 82-95.
4. Shao, G., C. Ji, **D. Zhao** (2011) Rupture process of the 9 March, 2011 Mw 7.4 Sanriku-Oki, Japan earthquake constrained by jointly inverting teleseismic waveforms, strong motion data and GPS observations. *Geophys. Res. Lett.* 38, L00G20.
5. Huang, Z., **D. Zhao,** L. Wang (2011) Stress field in the 2008 Iwate-Miyagi earthquake (M 7.2) area. *Geochem. Geophys. Geosyst*. 12, Q06006.
6. Jiang, G., **D. Zhao** (2011) Metastable olivine wedge in the subducting Pacific slab and its relation to deep earthquakes. *J. Asian Earth Sci*. 42, 1411-1423.
7. Tong, P., **D. Zhao**, D. Yang (2011) Tomography of the 1995 Kobe earthquake area: Comparison of finite-frequency and ray approaches. *Geophys. J. Int*. 187, 278-302.
8. Huang, Z., L. Wang, **D. Zhao**, N. Mi, M. Xu (2011) Seismic anisotropy and mantle dynamics beneath China. *Earth Planet. Sci. Lett*. 306, 105-117.
9. Padhy, S., O.P. Mishra, **D. Zhao**, W. Wei (2011) Crustal heterogeneity in the 2007 Noto-Hanto earthquake area and its geodynamical implications. *Tectonophysics* 509, 55-68.
10. Tian, Y., **D. Zhao** (2011) Destruction mechanism of the North China Craton: Insight from P and S wave mantle tomography. *J. Asian Earth Sci*. 42, 1132-1145.
11. Huang, Z., **D. Zhao**, L. Wang (2011) Frequency-dependent shear-wave splitting and multilayer anisotropy in Northeast Japan. *Geophys. Res. Lett.* 38, L08302.
12. Cheng, B., **D. Zhao**, G. Zhang (2011) Seismic tomography and anisotropy in the source area of the 2008 Iwate-Miyagi earthquake (M 7.2). *Phys. Earth Planet. Inter*. 184, 172-185.
13. Huang, Z., **D. Zhao**, L. Wang (2011) Seismic heterogeneity and anisotropy of the Honshu arc from the Japan Trench to the Japan Sea. *Geophys. J. Int.* 184, 1428-1444.
14. Mishra, O.P., **D. Zhao,** C. Ghosh et al. (2011) Role of crustal heterogeneity beneath Andaman-Nicobar Islands and its implications for coastal hazard. *Natural Hazards* 57, 51-64.
15. Huang, Z., **D. Zhao,** L. Wang (2011) Shear-wave anisotropy in the crust, mantle wedge and the subducting Pacific slab under Northeast Japan. *Geochem. Geophys. Geosyst*. 12, Q01002.
16. Lei, J., **D. Zhao**, F. Xie, J. Liu (2011) An attempt to detect temporal variations of crustal structure in the source area of the 2006 Wen-An earthquake in North China. *J. Asian Earth Sci.* 40, 978-996.
17. **Zhao, D.**, M. Santosh, A. Yamada (2010) Dissecting large earthquakes in Japan: Role of arc magma and fluids. *Island Arc* 19, 4-16.

18. **Zhao, D.**, L. Liu (2010) Deep structure and origin of active volcanoes in China. *Geoscience Frontiers* 1, 31-44.
19. **Zhao, D**., F. Pirajno, N.L. Dobretsov, L. Liu (2010) Mantle structure and dynamics under East Russia and adjacent regions. *Russ. Geol. Geophys.* 51, 925-938.
20. Wang, Z., **D. Zhao**, J. Wang (2010) Deep structure and seismogenesis of the north-south seismic zone in Southwest China. *J. Geophys. Res.* 115, B12334.
21. Sakamaki, T., E. Ohtani, S. Urakawa, A. Suzuki, Y. Katayama, **D. Zhao** (2010) Density of high-Ti basalt magma at high pressure and origin of heterogeneities in the lunar mantle. *Earth Planet. Sci. Lett*. 299, 285-289.
22. Huang, Z., L. Wang, **D. Zhao**, M. Xu et al. (2010) Upper mantle structure and dynamics beneath Southeast China. *Phys. Earth Planet. Inter*. 182, 161-169.
23. Tian, X., **D. Zhao**, H. Zhang, Y. Tian, Z. Zhang (2010) Mantle transition zone topography and structure beneath the central Tien Shan orogenic belt. *J. Geophys. Res.* 115, B10308.
24. He, R., **D. Zhao**, R. Gao, H. Zheng (2010) Tracing the Indian lithospheric mantle beneath central Tibetan Plateau using teleseismic tomography. *Tectonophysics* 491, 230-243.
25. Wang, J., **D. Zhao** (2010) Mapping P-wave anisotropy of the Honshu arc from Japan Trench to the back-arc. *J. Asian Earth Sci.* 39, 396-407.
26. Huang, Z., **D. Zhao**, N. Umino, L. Wang, T. Matsuzawa, A. Hasegawa, T. Yoshida (2010) P-wave tomography, anisotropy and seismotectonics in the eastern margin of Japan Sea. *Tectonophysics* 489, 177-188.
27. Santosh, M., **D. Zhao**, T. Kusky (2010) Mantle dynamics of the Paleoproterozoic North China Craton: A perspective based on seismic tomography. *J. Geodyn.* 49, 39-53.
28. Kiyosugi, K., C. Connor, **D. Zhao**, L. Connor, K. Tanaka (2010) Relationships between volcano distribution, crustal structure, and P-wave tomography: An example from the Abu monogenetic volcano group, SW Japan. *Bull. Volcanol.* 72, 331-340.

Books

1. **Zhao, D.**, S. Ueki, Y. Nishizono and A. Yamada (2010), New seismic evidence for the origin of arc and back-arc magmas., In: J. Ray, G. Sen, B. Ghosh (Eds.) Topics in Igneous Petrology, pp. 117-132, Springer Press.

Symposium Participations

1. **Zhao, D.** (2011). Structural heterogeneity and anisotropy in the mantle and core. *Global-COE Symposium "Dynamics of the Earth's Interior"*, February 15-16, 2011, Sendai, Japan
2. **Zhao, D.** (2011). On the origin of intraplate volcanoes in the polar regions. *Polar Research Symposium "Seismology of Blue Earth and White Continent"*, February 24, 2011, Tokyo, Japan
3. **Zhao, D.** (2011). Multiscale seismic tomography and mantle dynamics. *Global Dynamics Symposium,* March 10-11, 2011, University of Tokyo, Japan
4. **Zhao, D.** (2011). East Asia: Seismotectonics, volcanism and mantle dynamics. *Joint Meeting of Japan Earth and Planetary Sciences,* May 22-27, 2011, Chiba, Japan
5. **Zhao, D.** (2011). Mapping seismic heterogeneity and anisotropy in the mantle. *Joint Meeting of*

Japan Earth and Planetary Sciences, May 22-27, 2011, Chiba, Japan

6. **Zhao, D.,** T. Yanada, Y. Yamamoto (2011). On the influence of whole-mantle heterogeneity on teleseismic tomography. *Joint Meeting of Japan Earth and Planetary Sciences,* May 22-27, 2011, Chiba, Japan
7. **Zhao, D.**, Z. Huang, N. Umino, A. Hasegawa, T. Yoshida (2011). P and S wave tomography of the eastern margin of Japan Sea. *Joint Meeting of Japan Earth and Planetary Sciences,* May 22-27, 2011, Chiba, Japan
8. **Zhao, D.** (2011). On the earthquake-volcano interactions. *Annual Meeting of Volcanological Society of Japan*, October 2-4, 2011, Asahikawa, Japan
9. **Zhao, D.** (2011). Seismic imaging of the Western-Pacific subduction zone. *International Workshop "Ocean Mantle Dynamics: From Spreading Center to Subduction Zone"*, October 4-6, 2011, Kashiwa, Japan
10. **Zhao, D.,** Z. Huang, N. Umino, A. Hasegawa, H. Kanamori (2011). Tomography and mechanism of the 2011 Tohoku-oki earthquake (Mw 9.0). *Annual Meeting of Seismological Society of Japan*, October 12-15, 2011, Shizuoka, Japan
11. **Zhao, D.** (2011). Seismotectonics, volcanism and mantle dynamics of East Asia. *10th International Seminar on Seismology-related Works in Far-East Asia*, October 31-November 1, 2011, Daejung, Korea
12. **Zhao, D.** (2011). Multiscale seismic imaging of the Western-Pacific subduction zone. *Fall AGU Meeting*, December 5-9, 2011, San Francisco, USA (Invited lecture)
13. **Zhao, D.** (2011). Tomography of the megathrust zone and mechanism of the Tohoku-oki earthquake (Mw 9.0). *Fall AGU Meeting*, December 5-9, 2011, San Francisco, USA
14. **Zhao, D.** (2010). Multiscale seismic tomography and mantle dynamics. *Annual Meeting of European Geosciences Union (EGU)* (Keynote lecture), May 2-7, 2010, Vienna, Austria
15. **Zhao, D.** (2010). Tomographic imaging of the lithosphere and underlying mantle beneath China. *International Symposium on Solid-Earth Sciences*, Guangzhou (Invited lecture), May 14-16, 2010, Chiba, Japan
16. **Zhao, D.** (2010). Seismic evidence for deep slab dehydration and big mantle wedge in East Asia. *Joint Meeting of Japan Earth and Planetary Sciences*, May 23-28, 2010, Chiba, Japan
17. **Zhao, D.** and Y. Yamamoto. (2010). Seismic structure and mantle dynamics in the Western Pacific region. *Joint Meeting of Japan Earth and Planetary Sciences*, May 23-28, 2010, Chiba, Japan
18. **Zhao, D.** (2010). Tomographic imaging of Earth and Moon. *Global-COE Symposium 2010 "Dynamic Earth and Heterogeneous Structure"*, July 13-15, 2010, Sendai, Japan
19. **Zhao, D.** (2010). Dissecting the seismogenic zones in Japan, China and India. *China-Japan Joint Workshop on Inland Earthquakes* (Invited lecture), November 24-25, 2010, Tokyo, Japan
20. **Zhao, D.** (2010). Mantle structure and dynamics under the Japan Islands and East Asia: Big Mantle Wedge (BMW) model. *Workshop on Northeast Japan Arc and Back-Arc System* (Keynote lecture), November 26-27, 2010, Tokyo, Japan

Haruo Sato

Title/Affiliation	Professor / Department of Geophysics, Graduate School of Science, Tohoku University
Specialized Field	Seismology, Solid Earth physics
Research Subject	Study of the inhomogeneous structure of the solid earth

The Purpose of Research and The Abstract of Accomplishments:

The structure of the lithosphere is inhomogeneous reflecting the dynamic evolution of the solid earth. The objective of our research is to study the lithospheric inhomogeneity by using seismological methods. We develop wave scattering theory in random media having rich short wavelength spectra to establish the mathematical foundation for the interpretation of short period seismograms. We also develop a practical method to measure the spectrum of random inhomogeneity from the envelope broadening of short-period seismic waves with travel distance increasing and the coda wave excitation. Information about scattering and absorption is useful for understanding the geodynamic process but also for the quantitative prediction of strong earthquake motion.

Main Results:

(1) Development of wave scattering theory

1. Sato coauthored a textbook on seismic wave scattering entitled *"Seismic wave Propagation and Scattering in the Heterogeneous Earth (Second edition)"* with M. Fehler and T. Maeda (Springer, 2011, in press).
2. Sato succeeded in theoretically deriving Green's function having coda in a scattering medium from noise correlation, which gives the mathematical foundation for interpreting the coda of observed noise cross-correlation as a measure of crustal velocity structure [Sato, 2010].
3. Margerin and Sato [2011a,b] proved the retrieval of Green's function having coda in a scattering medium from noise correlation is equivalent to the general optial theorem.
4. Emoto et al. [2010, 2011] succeeded in the envelope synthesis in layereed random media having a free surface based on the Markov approximation for vector waves.

(2) Measurements of the lithospheric heterogeneity

1. From the whole S-seismogram analysis of Hi-net data by using the radiative transfer theory, we made a map of scattering strength and intrinsic absorption for short periods in Japan, which clearly shows regional variation of these quantities reflecting tectonic settings [Carcole and Sato, 2010].
2. Regional difference of crustal heterogeneity is revealed from the S wave envelope analysis of crustal earthquakes [Tripathi et al., 2010].
3. Applying the isotropic scattering model with PS conversion to explosion data at Asama volcano, Yamamoto and Sato [2010] found a small mean free path for S waves of the order of 1 km.

International activity:

1. Sato served as the leader of the cooperative resarch based on the Japan-France bilateral program of JSPS (2009-2010) on "Study on the space-time variation of the earth medium heterogeneity by using mu ltiple scattered seismic waves", where the leader of French side is Prf. M. Campillo.
2. Sato served as a co-convenor (Ludovic Margerin, Carene S. Larmat, Haruo Sato, Roel Snieder) and

a chair of a session “The Role of Scattering in Seismic Interferometry and Time Reversal” at 2010 AGU fall meeting (12/13-17, 2010) in San Francisco, California, USA.

3. Sato served as a member of Executive Organizing Committee for the GCOE symposium on “Dynamic Earth and Heterogeneous Structure” (Sendai City War Reconstruction Memorial Hall, 7/13-15, 2010).
4. Sato had seminars on seismic wave scattering at Colorado School of Mines (Prof. R. Snider) and Boise University (Prof. K. VanWijk) in Sep. 2011.

Published Journal Papers:

1. Campillo, M; Sato, H; Shapiro, NM; van der Hilst, RD (2011). New developments on imaging and monitoring with seismic noise Foreword,COMPTES RENDUS GEOSCIENCE,343,487-495
2. **Sato, H.**, M. Fehler and T. Maeda (2011b) *"Seismic wave Propagation and Scattering in the Heterogeneous Earth"*, Springer, in press.
3. Margerin, L. and **H. Sato** (2011) Generalized optical theorems for the reconstruction of Green’s function of an inhomogeneous elastic medium, J. Acous. Soc. Amer., DOI: 10.1121/1.3652856, in press.
4. Emoto, K., **H. Sato** and T. Nishimura (2011) Synthesis and Applicable Condition of VectorWave Envelopes in Layered Random Elastic Media with 2Anisotropic Autocorrelation Function Based on the Markov Approximation, Geophys. J. Int., in press.
5. Margerin, L. and **H. Sato** (2011a) Reconstruction of multiply-scattered arrivals from the cross-correlation of waves excited by random noise sources in a heterogeneous dissipative medium, *Wave Motion,* 48, 146-160.
6. Sawazaki, S., K., **H. Sato** and T. Nishimura (2011) Envelope synthesis of short-period seismograms in 3-D random media for a point shear-dislocation source based on the forward scattering approximation: Application to small strike-slip earthquakes in southwestern Japan, *J. Geophys. Res.*, 116, B08305, doi:10.1029/2010JB008182,.
7. Carcole, E. and **H. Sato** (2010). Spatial distribution of scattering loss and intrinsic absorption of short- period S-waves in the lithosphere of Japan on the basis of the Multiple Lapse Time Window Analysis of Hi-net data., Geophys. J. Int. 180, doi: 10.1111/j.1365-246X.2009.04394.x
8. Yamamoto, M. and **H. Sato** (2010). Multiple scattering and mode conversion revealed by an active seismic experiment at Asama volcano, Japan., Journal of Geophysical Research - Solid Earth, 115, doi: 10.1029/2009JB007109
9. Emoto, K., **H. Sato** and T. Nishimura (2010). Synthesis of vector wave envelopes on the free surface of a random medium for the vertical incidence of a plane wavelet based on the Markov approximation., Journal of Geophysical Research - Solid Earth, 115, doi: 10.1029/2009JB006955.
10. **Sato, H.** (2010). Retrieval of Green's function having coda waves from the cross-correlation function in a scattering medium illuminated by a randomly homogeneous distribution of noise sources on the basis of the first-order Born approximation., Geophys. J. Int., 180, doi: 10.1111/j.1365-246X.2009.04432.x
11. Tripathi, J. N., **H. Sato** and M. Yamamoto (2010). Envelope broadening characteristics of crustal earthquakes in northeastern Honshu, Japan., Geophys. J. Int. 182, doi: 10.1111/j.1365-246X.2010.04657.x
12. Margerin, L. and **H. Sato** (2010). Reconstruction of multiply-scattered arrivals from the cross-correlation of waves excited by random noise sources in a heterogeneous dissipative medium., Wave Motion, doi: 10.1016/j.wavemoti.2010.10.001

Books:

1. Campillo, M; **Sato, H**; Shapiro, NM; van der Hilst, RD(eds) (2011), New developments on imaging and monitoring with seismic noise**,** COMPTES RENDUS GEOSCIENCE, 343, 487-652
2. **Sato, H**., M. Fehler and T. Maeda (2011), Seismic wave Propagation and Scattering in the Heterogeneous Earth (2nd Edition), Springer, in press

Symposium Participations:

1. **Sato, H.** (2010). Retrieval of Green's function from the cross-correlation function in a scattering medium illuminated by noise sources., Japan Geoscience Union meeting 2010, May 23-28, 2010, Chiba, Japan
2. Anggono, T., T. Nishimura, **H. Sato**, H. Ueda and M. Ukawa (2010). Temporal changes of seismic velocity at Miyakejima associated with 2000 activity based on ambient seismic noise analyses., Japan Geoscience Union meeting 2010, May 23-28, 2010, Chiba, Japan
3. Emoto, K., **H. Sato** and T. Nishimura (2010). Synthesis of vector-wave envelopes in a layered random medium with velocity discontinuities., The Seismological Society Japan 2010 Fall Meeting, October, 2010, Hiroshima, Japan
4. **Sato, H.** and K. Emoto (2010). Envelope Synthesis of Vector Waves in Nonisotropic Random Elastic Media on the Basis of the Markov Approximation., Wokshop on "Seismic Waves In Laterally Inhomogeneous Media VII", Teplá Premonstratensian Monastery, June 21-26, 2010, Czech Republic (in Proceeding)
5. **Sato, H.** (2010). Lithospheric Heterogeneity Revealed from the Envelope Analysis of Short‐Period Seismograms., Global COE Symposium 2010 "Dynamic Earth and Heterogeneous Structure", July 13-15, 2010, Sendai, Japan (in Proceeding)
6. **Sato, H.** (2010). Retrieval of Green's Function Having a Coda Tail from the Cross-Correlation Function in a Scattering Medium on the Basis of the First Order Born Approximation., American Geophysical Union 2010 Fall meeting, San Francisco, December 13-17, 2010

Noriyoshi Tsuchiya

Title/Affiliation	Professor / Graduate School of Environmental Studies, Tohoku University
Specialized Field	Geofluid Science
Research Subject	Water - Rock Interaction

The Purpose of Research and Outline of Accomplishments:

I have been to Antarctica from Nov 2009 to Feb 2010 as an expedition leader of Earth Science Research Expedition in the Sør Rondane Mountains, which is part of 51st Japanese Antarctic Research Expedition (JARE-51). Earth Science Research Expedition in the Sør Rondane Mountains involved geology, geomorphology and meteorite search parties. I have performed geological survey in the entire area of the Sør Rondane Mountains, East Antarctica. Geology party collected more than 1.5 ton rock samples which were metamorphic and igneous rocks. Expedition was successfully completed, and we could come back to Japan safety. I studied the role of geofluid for high grade metamorphics and collected many types of ignepus rocks to identify geochemical characteristics of magma process in the Sør Rondane Mountains.

After Great East Japan Earthquake, I and our research group have studied on Tsunami Deposit and Soil. We investigated arsenic and other heavy metal concentration in the Tsumani deposit, and we already published contamination map of arsenic and meavey metals in Tsunami disaster area.

Published Journal Papers:

1. Zhang, S., Jin, F., Zeng, X., Hu, J., Huo, Z., Wang, Y., Watanabe, N., Hirano, N., and **Tsuchiya, N**. (2011), Effects of general zero-valent metals power of Co/W/Ni/Fe on hydrogen production with H2S as a reductant under hydrothermal conditions. , International Journal of Hydrogen Energy, 36, 8878-8884.
2. Watanabe,N., T. Ishibashi, N. Hirano, Y, Ohsaki, Y. Tsuchiya, T.Tamagawa, H. Okabe,and **N. Tsuchiya** (2011), Precise 3D Numerical Modeling of Fracture Flow Coupled With X-Ray Computed Tomography for Reservoir Core Samples. [SPE (Society of Petroleum Engineers) Journal, 16 (3), 683-691.
3. Setiani, P., J. Vilca ´ ez, N. Watanabe, A. Kishita, **N. Tsuchiya** (2011). Enhanced hydrogen production from biomass via the sulfur redox cycle under hydrothermal conditions., International Journal of Hydrogen Energy, 36, 10674-10682.
4. Takeda, A; Yamasaki, S; Tsukada, H; Takaku, Y; Hisamatsu, S; **Tsuchiya, N** (2011). Determination of total contents of bromine, iodine and several trace elements in soil by polarizing enerby-dispersive X-ray fluorescence spectrometry, SOIL SCIENCE AND PLANT NUTRITION, 57, 1, 19-28
5. Yamasaki, S; Matsunami, H; Takeda, A; Kimura, K; Yamaji, I; Ogawa, Y; **Tsuchiya, N** (2011). Simultaneous Determination of Trace Elements in Soils and Sediments by Polarizing Energy Dispersive X-ray Fluorescence Spectrometry, BUNSEKI KAGAKU, 60, 4, 315-323
6. Batkhishig, B., **N. Tsuchiya** and B. Greg (2010). Magmatism of the Shuteen Complex and Carboniferous subduction of the Gurvansaikhan terrane, South Mongolia., Journal of Asian Earth Science, 37

7. Okamoto, A., H. Saishu, N. Hirano and **N. Tsuchiya** (2010). Mineralogical and textural variation of silica minerals in hydrothermal AEow-through experiments: Implications for quartz vein formation., Geochimica Cosmochimica Acta, 74
8. Abe, J., **N. Tsuchiya**, S. Furukawa and N. Hirano (2010). Properties of H_2O and CO_2 AEuids in contact with quartz under supercritical conditions revealed by IR spectroscopy., Water-Rock Interaction, 13
9. Hirano, N., K. Ymamoto, A. Okamoto and **N. Tsuchiya** (2010). Observation of quartz fracturing under the hydrothermal condition using visible type autoclave., Water-Rock Interaction, 13
10. Saisyu, H., A. Okamoto and **N. Tsuchiya** (2010). Precipitation of silica minerals in hydrothermal AEow-through experiments., Water-Rock Interaction, 13
11. **Tsuchiya, N.**, Y. Ogawa, R. Yamada, S. Yamasaki, C. Inoue, T. Komai. J. Hara, Y. Kawabe, T. Shiratori and S. Kano (2010). Geosphere environmental informatic universal system for evaluation of geological pollution on heavy metals., Water-Rock Interaction, 13
12. Ogawa, Y., S. Yamasaki and **N. Tsuchiya** (2010). Application of a Dynamic Reaction Cell (DRC) ICP-MS in Chromium and Iron Determinations in Rock, Soil and Terrestrial Water Samples., Analytical Sciences, 26
13. Tagami, K., S. Uchida, A. Takeda, S. Yamasaki and **N. Tsuchiya** (2010). Estimation of Plant-Unavailable Iodine Concentrations in Agricultural Fields., Soil Chemistry, 74 (5)
14. Matsunami, H; Matsuda, K; Yamasaki, S; Kimura, K; Ogawa, Y; Miura, Y; Yamaji, I; **Tsuchiya, N** (2010). Rapid simultaneous multi-element determination of soils and environmental samples with polarizing energy dispersive X-ray fluorescence (EDXRF) spectrometry using pressed powder pellets, SOIL SCIENCE AND PLANT NUTRITION, 56, 4, 530-540

Motohiko Murakami

Title/Affiliation	Associate Professor/ Graduate School of Science and Faculty of Science Tohoku UniversityDepartment of Earth Sciences
Specialized Field	High-Pressure Mineral Physics
Research Subject	Dynamics of deep magma ocean in early Earth

Purpose of research and recent achievement:

(1) Spectroscopic evidence for ultrahigh-pressure polymorphism in SiO_2 glass

We have investigated the structural changes of SiO_2 glass in the previously unexplored pressure range from 60-207GPa by Brillouin scattering. Our results reveal of the onset of a new densification mechanism for SiO_2 glass at a pressure 140 GPa. High-pressure (P>10 GPa) polyamorphic transitions involving coordination changes in Si are characterized by three distinct pressure regimes: a low-pressure regime up to 40 GPa, with a gradual transition from fourfold to sixfold coordination; a high-pressure regime from 40-140 GPa dominated by sixfold coordinated silicon; and a newly discovered ultrahigh-pressure regime above 140 GPa in which there is a transition from sixfold to a higher coordination state of Si. The identification of a new densification mechanism above 140 GPa strongly suggests that glasses are probably far denser under ultrahigh-pressure conditions than previously envisioned. These results should provide a basis for evaluating the structural states of more compositionally complex silicate glasses and melts. The existence of highly densified SiO_2 glass with Si-O coordination numbers higher than 6 suggests the possible occurrence of gravitationally stable dense magmas deep within the Earth, and may have profound consequences for the compression mechanisms of network-structured glasses at ultrahigh pressure conditions.

(2) Remnants of ultradense $MgSiO_3$ melt from a deep terrestrial magma ocean

Ultra-low velocity zones (ULVZ's) are the largest seismic anomalies in the mantle, with 10-30% seismic velocity reduction observed in thin layers less than 20-40 km just above the Earth's core-mantle boundary (CMB). The presence of silicate melts, possibly a remnant of a deep magma ocean in early Earth, have been proposed to explain ULVZ's. It is, however, still an open question as to whether such silicate melts are gravitationally stable at the pressure conditions above the CMB. Fe enrichment is usually invoked to explain why melts would remain at CMB, but this has not been substantiated experimentally. Here we report the experimental identification of a new transformation to a denser structure of $MgSiO_3$ glass at pressures close to those of the CMB by *in-situ* high-pressure acoustic velocity measurements. The result suggests that $MgSiO_3$ melt is likely to become denser than crystalline $MgSiO_3$ above the CMB. Such silicate melts would be negatively buoyant and gravitationally stable at the bottom of the mantle, thus providing a mechanism for ultra-low seismic velocities above the CMB without enrichment in Fe in the melt. Identification of the neutral buoyancy depth near the CMB region may provide an explanation for the distinctive thinness of the ULVZ's. An ultradense melt phase and its geochemical inventory would be isolated from overlying convective flow over geologic time.

Publications:

Journals:

1. **M. Murakami**, J. D. Bass, Evidence of denser MgSiO3 glass above 133 GPa and implications for remnants of ultradense silicate melt from a deep magma ocean, Proceedings of the National Academy of Sciences of the United States of America, 108 (42) 17286-17289 (2011)
2. Y. Asahara, K. Hirose, Y. Ohishi, N. Hirao, **M. Murakami**, Thermoelastic properties of ice VII and its high-pressure polymorphs: implications for dynamics of cold slab subduction in the lower mantle, Earth and Planetary Science Letters, 299, 474-482 (2010)
3. **M. Murakami**, In-situ sound velocity measurements at high pressure and high temperature using Brillouin spectroscopy with synchrotron radiation and infrared laser heating system: Application to the deep earth science, Journal of the Japanese Society for Synchrotron Radiation Research, 26, 370-381 (2010)
4. **M. Murakam**, Elasticity of MgO to 130 GPa: Implications for lower mantle mineralogy, SRing-8 Research Frontiers 2009, 112-113, (2010)
5. **M. Murakami**, Densification of SiO2 glass under ultrahigh pressure: Implicatioins for the internal evolution of the Earth, NEW GLASS, 25, 31-35 (2010)
6. **M. Murakami**, Tactics and strategy toward a construction of primary pressure scale, The Review of High Pressure Science and Technology, 20, 252-261 (2010)
7. **M. Murakami,** J. D. Bass, Spectroscopic evidence for ultrahigh-presssure polymorphism in SiO_2 glass, Physical Review Letters, 104, 025504 (2010)
8. Y. Asahara, **M. Murakami**, Y. Ohishi, N. Hirao, K. Hirose, Sound velocity measurement in liquid water up to 25 GPa and 900 K: Implications for densities of water at lower mantle conditions, Earth and Planetary Science Letters, 289, 479-485 (2010)

Takahiro Kuribayashi

Title/Affiliation	Assistant Professor/ Graduate School of Science and Faculty of Science Tohoku UniversityDepartment of Earth Sciences
Specialized Field	Mineralogy and Crystallography (Earth Sciences)
Research Subject	Structural studies on hydrous minerals under high-pressure conditions using single crystal X-ray diffraction and spectroscopic methods

The purpose of research and the abstracts of accomplishments:

The main purpose of this research is to obtain the information on the behavior of hydrogen bonding under high-pressure conditions using single crystal X-ray diffraction and spectroscopic observation methods. Hydrogen bonding has three categories as follows: the weak, the intermediate and the strong. Under extreme high-pressure and high-temperature conditions, it is believed that the stable hydrous minerals would have the hydrogen bonding in their structures. We, therefore, tried to obtain the information on the behavior of hydrogen under high-PT conditions.

In 2009-2011, single crystal X-ray diffraction intensity data sets of phase E and super hydrous phase B (sup B) were collected under several high-pressure conditions (at ambient for phase E, and at ambient, 0.7, 3.5, 5.7 and 7.2 GPa for sup B). Although in the case of phase E, which has more H content than super hydrous phase B, the refinement of H positions was failure at ambient conditions, it was successful for the refinement of sup B. Therefore, we tried to refine the hydrogen positions of sup B under high-pressure conditions. The conditions of data collect were slightly changed to optimaize the refinement and ME analysis. As the results from X-ray measurements (D-Fourier method), the refinements of hydrogen position were failure at 3.5 and 7.2 GPa, but at 0.7 and 5.7 GPa, hydrogen positions were refined. OH distances were obtained as 0.91(3)Å at ambient, 0.89(7)Å at 0.7 GPa and 0.93(7)Å at 5.7 GPa. These are reasonable values. In this pressure range, OH distances remained unchanged in sup B structure. Moreover as the results from ME analysis, we can find the position of hydrogen (Fig 2). Now we are trying the other specimens.

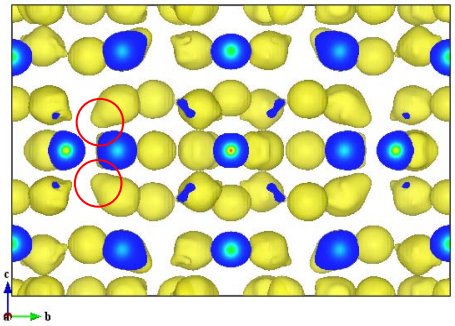

Figure 1. The electron density distribution in super hydrous phase B structure at ambient condition (analyzed by MEM). Red circle areas corresponded to Hydrogen positions.

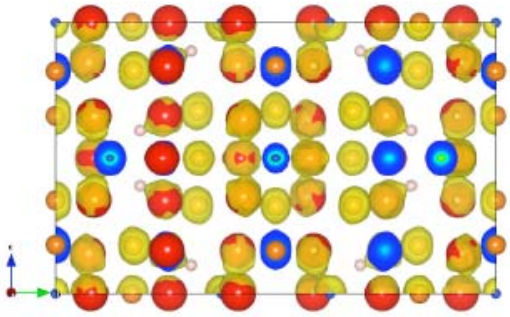

Figure 2. The electron density distribution map of super hydrous phase B structure at 5.7 GPa (analyzed by MEM). Pink sphare corresponded to hydrogen positions, where were consitent with the electron distribution.

Publications:

Journals:

1. **T.Kuribayashi** (2011) Behaviour of hydrogen in crystal strutures of the slab and mantle minerals, Journal of the Crystallographic Society of Japan, vol. 53-1, 19-24. (in Japanese)
2. Sano, A., **Kuribayashi, T.**, Komatsu, K., Ohtani, E. and Yagi, T. (2011) Investigation of hydrogen sites of wadsleyite: A neutron diffraction study, Physics of the Earth and Planetary Interiors, in press.
3. Momma, K., Nagase, T., Kudoh, Y. and **Kuribayashi, T.** (2009) Computational simulations of the structure of Japanese twin boundaries in quartz, European Journal of Mineralogy, 21, 373-383, DOI: 10.1127/0935-1221/2009/0021-1893.
4. Itoh, H., Nishi F., **Kuribayashi, T.** and Kudoh Y. (2009), Orientational ordering of three SiO_4 tetrahedra in □'-$Ca_{1.5}Sr_{0.5}SiO_4$ that satisfies bond-valence requirements and avoids O-O repulsion. Journal of Mineralogical Petrological Sciences, 104, 234-240.

Experimental Reports:

1. H. Uchiyama, **T. Kuribayashi** and Y. Kudoh (2011) Estimation of hydrogen position in (Fe, Al)-bearing phase E structure using single-crystal diffraction data, Photon Factory Activity Reports, #28, in press.
2. **T. Kuribayashi** (2011) Refinement of hydrogen position in super hydrous phase B, $Mg_{10}Si_3H_4O_{18}$, under high-pressure condition using single-crystal diffraction data, Photon Factory Activity Reports #28, in press
3. **T. Kuribayashi** and Y. Kudoh (2010) Estimation of hydrogen position in super hydrous phase B, $Mg_{10}Si_3H_4O_{18}$, at 1.0 GPa using single-crystal diffraction data, Photon Factory Activity Reports #27, p192.

Takeshi Sakai

Title/Affiliation	Assistant Professor / Department of Earth and Planetary Materials Science
Specialized Field	High pressure mineralogy
Research Subject	Earth and planetary interior structure

The Purpose of Research and Outline of Accomplishments:

My study's aim is to reveal the Earth's inner core structure and composition. I investigated about Fe-Ni-S system and Fe-Ni-Si system at ultra-high pressure and high temperature conditions. I also constructed new NaCl-B2 pressure scale which calibrated up to 304 GPa. It enabled to discuss about the Earth's inner core structure and composition accurately(for detail, see Main Results).

Main Results:

We compressed NaCl-B2 to 304 GPa and presented a pressure scale based on the Birch–Murnaghan and Vinet equations of state for this phase. The phase relations of Fe, $Fe_{90}Ni_{10}$ and $Fe_{87.9}Ni_{4.4}Si_{7.7}$ were investigated up to 273(6) GPa and 4490(560) K, 250(19) GPa and 2730(110) K and 304(3) GPa and 2780(210) K, respectively, and the hexagonal close-packed structure was found to be stable in all of these compounds under the pressure and temperature conditions studied. The weak temperature dependency of the axial ratio of hcp-Fe-Ni-Si alloy indicates that the c-axis is still harder than the a-axis at high temperature condition. Therefore the alignment of hcp-Fe–Ni–Si alloy with the c-axis parallel to the Earth's rotation axis could account for the observation of the seismic wave anisotropy of the inner core. On the other hand, $Fe_{88.1}Ni_{9.1}S_{2.8}$ alloy was compressed up to 335 GPa, and the hexagonal close-packed structure was found to be stable. Our results indicate that the hcp Fe-5 at.% Ni-7.9–10.3 at.% S alloy can account for the density of the inner core at 330 GPa, assuming a linear relationship exists between the density and the nickel and sulfur content.

Published Journal Papers:

1. **Sakai, T.**, E. Ohtani, S. Kamada, H. Terasaki, N. Hirao, Compression of $Fe_{88.1}Ni_{9.1}S_{2.8}$ alloy up to the pressure of Earth's inner core, J. Geophys. Res., under review.
2. Shibazaki, Y., E. Ohtani, H. Fukui, **T. Sakai**, S. Kamada, D. Ishikawa, S. Tsutsui, A.Q.R. Baron, N. Nishitani, N. Hirao, K. Takemura, Sound velocity measurements in dhcp-1 FeH up to 70 GPa with inelastic X-ray scattering: Implications for the composition of the Earth's core, Earth Planet. Sci. Lett., In press.
3. Terasaki, H., E. Ohtani, **T. Sakai**, S. Kamada, H. Asanuma, Y. Shibazaki, N. Hirao, N. Sata, Y. Ohishi, T. Sakamaki, A. Suzuki, K. Funakoshi, Stability of Fe-Ni hydride after the reaction between Fe-Ni alloy and hydrous phase (δ-AlOOH) up to 1.2 Mbar: Possibility of H contribution to the core density deficit, J. Geophys. Res., submitted.
4. **Sakai, T.**, E. Ohtani, H. Terasaki, S. Kamada, N. Hirao, M. Miyahara, M. Nishijima, Phase stability and compression study of $(Fe_{0.89},Ni_{0.11})_3S$ up to pressure of the Earth's core, Am. Mineral., 96, 1490-1494, 2011.
5. Asanuma, H., E. Ohtani, **T. Sakai**, H. Terasaki, S. Kamada, N. Hirao, Y. Ohishi, Static compression of $Fe_{0.83}Ni_{0.09}Si_{0.08}$ alloy to 374 GPa and $Fe_{0.93}Si_{0.07}$ alloy to 252 GPa: Implications for the Earth's inner core, Earth Planet. Sci. Lett., In press.

6. **Sakai, T.**, E. Ohtani, N. Hirao, Y. Ohishi, Stability field of the hcp-structure for Fe, Fe-Ni, and Fe-Ni-Si alloys up to 3 Mbar, Geophys. Res. Lett., 38, L09302, doi:10.1029/2011GL047178, 2011
7. Sakai, T., E. Ohtani, N. Hirao, Y. Ohishi, Equation of state of the NaCl-B2 phase up to 304 GPa, J. Appl. Phys., 109, 084912, doi:10.1063/1.3573393, 2011
8. Terasaki, H., Kamada, S., **Sakai, T.**, Ohtani, E., Hirao, N., Sata, N., Ohishi, Y., Liquidus and solidus temperatures of Fe-O-S alloy up to the outer core pressures: Implication to thermal structure of the Earth's core, Earth Planet. Sci. Lett., 304, 559-564, 2011.
9. Miyahara, M., E. Ohtani, S. Ozawa, M. Kimura, A. El Goresy, **T. Sakai**, T. Nagase, K. Hiraga, N. Hirao, Y. Ohishi, Natural dissociation of olivine to (Mg,Fe)SiO_3 perovskite and magnesiowüstite in a shocked Martian meteorite. Proc. Natl. Acad. Sci., 108, 5999-6003, doi/10.1073/pnas.1016921108, 2011.
10. **Sakai, T.**, Ohtani, E., Terasaki, H., Miyahara, M., Nishijima, M., Hirao, N., Ohishi, Sata, N., Fe-Mg partitioning between post-perovskite and ferropericlase at the lower mantle, Phys. Chem. Mineral., 37, 487-496, doi: 10.1007/s00269-009-0349-4, 2010.
11. Kamada, S., Terasaki, H., Ohtani, E., **Sakai, T.**, Kikegawa, T., Ohishi, Y., Hirao, N., Sata, N., Kondo, T., Phase relationships of the Fe-FeS system in conditions up to the Earth's outer core, Earth Planet. Sci. Lett., 294, 94-100, 2010
12. Frost, D. J., Asahara, Y., Rubie, D.C., Miyajima, N., Dubrovinsky, L.S., Holzapfel, C., Ohtani, E., Miyahara, M., and **Sakai, T.**, Partitioning of oxygen between the Earth's mantle and core, J. Geophys. Res., 115, doi:10.1029/2009JB006302, 2010.
13. Asanuma, H., Ohtani, E., **Sakai, T.**, Terasaki, H., Kamada, S., Kondo, T., Kikegawa, T., Melting of iron–silicon alloy up to the core–mantle boundary pressure: implications to the thermal structure of the Earth's core, Phys. Chem. Mineral., 37, 353-359, doi: 10.1007/s00269-009-0338-7, 2010.
14. Baron, Alfred Q. R. , Inui, Masanori , Ohtani, Ejii , Fukui, Hiroshi , Hosokawa, Shinya , Masaki, Tadahiko , Ishikawa, Daisuke , **Sakai, Takeshi** , Okada, Junpei T. , Tsutsui, Satoshi and Uchiyama, Hiroshi, Atomic Dynamics in Extreme Environments via Inelastic X-Ray Scattering at SPring-8, Synchrotron Radiation News, 23, 17-25(DOI:10.1080/08940886.2010.531678), 2010.
15. **Sakai, T.**, Ohtani, E., Terasaki, H., Sawada, N., Kobayashi, Y., Miyahara, M., Nishijima, M., Hirao, N., Ohishi, Y., Kikegawa, T., Fe-Mg partitioning between perovskite and ferropericlase at the lower mantle. Am. Mineral., 94, 921-925, 2009.

Symposium Participations:

1. **Sakai, T.**, E. Ohtani, N. Hirao, The compression study of MgO up to 3Mbar, AGU fall meeting 2011, MR41A-2098, USA, California, San Francisco, Moscone Convention Center, December 5-10, 2011.
2. Kamada, S., E.Ohtani, H.Terasaki, **T.Sakai**, Y.Ohishi, N.Hirao, M.Miyahara, Melting relationships in the Fe-Fe_3S system based on X-ray diffraction up to 180 GPa(Invited), AGU fall meeting 2011, MR42A-03, USA, California, San Francisco, Moscone Convention Center, December 5-10, 2011.
3. Kamada, S, H. Fukui, E. Ohtani, **T. Sakai**, H. Terasaki, Y. Shibazaki, S. Takahashi, A.Q.R. Baron, Y. Ohishi, N. Hirao, Compressional velocities of Fe3S at room temperature and high pressures using inelastic X-ray scattering, AGU fall meeting 2011, MR52A-08, USA, California, San Francisco, Moscone Convention Center, December 5-10, 2011.
4. Shibazaki, Y., E. Ohtani, H. Fukui, **T. Sakai**, S. Kamada, A.Q. Baron, N. Nishitani, N. Hirao, K. Takemura, Sound velocity measurements of dhcp-FeHx up to 70 GPa using inelastic X-ray scattering: Implications for

the abundance of hydrogen in the Earth's core, AGU fall meeting 2011, MR41A-2092, USA, California, San Francisco, Moscone Convention Center, December 5-10, 2011.

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6. Kamada, S, H. Fukui, E. Ohtani, **T. Sakai**, H. Terasaki, Y. Shibazaki, S. Takahashi, A.Q.R. Baron, Y. Ohishi, N. Hirao, Sound velocities of Fe3S up to 85 GPa at room temperature using inelastic X-ray scattering, GSA Annual meeting, 43, 5, Abstract No:191822, Minneapolis Convention Center, Minneapolis, Minnesota, October 9-12, 2011.
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8. **Sakai, T.**, E. Ohtani, N. Hirao, Y. Ohishi, Phase relation of Fe-Ni-Si alloy up to 3 Mbar, Japan Geoscience Union Meeting 2011, SIT003-12, May 22-27, Makuhari, Chiba, Japan, 2011.
9. Terasaki, H., S. Kamada, **T. Sakai**, E. Ohtani, N. Hirao, Y. Ohishi, Melting relation of Fe-O-S alloy at the outer core condition, Japan Geoscience Union Meeting 2011, SIT003-06, May 22-27, Makuhari, Chiba, Japan, 2011.
10. Shibazaki, Y., E. Ohtani, H. Fukui, **T. Sakai**, S. Kamada, N. Nishitani, K. Takemura, Y. Ohishi, Alfred Q.R. Baron, Sound velocity measurements of dhcp FeHx up to 70 GPa by inelastic X-ray scattering, Japan Geoscience Union Meeting 2011, SIT003-P02, May 22-27, Makuhari, Chiba, Japan, 2011.
11. Kamada, S., H. Fukui, E. Ohtani, **T. Sakai**, Y. Shibazaki, H. Terasaki, A.Q.R. Baron, Y. Ohishi, N. Hirao, Sound velocities of Fe_3S at high pressures using inelastic X-ray scattering, Japan Geoscience Union Meeting 2011, SIT003-P03, May 22-27, Makuhari, Chiba, Japan, 2011.
12. Sakairi, T., E. Ohtani, **T. Sakai**, Melting in the Fe-S-Si system at high pressure : Implication for the temperature in the outer core, Japan Geoscience Union Meeting 2011, SIT003-P04, May 22-27, Makuhari, Chiba, Japan, 2011.
13. Miyahara, M., E. Ohtani, S. Ozawa, M. Kimura, A. El Goresy, **T. Sakai**, T. Nagase, K. Hiraga, N. Hirao, Y. Ohishi, Dissociation of olivine to silicate-perovskite and magesiowustite in the shocked Martian meteorite DaG 735, Japan Geoscience Union Meeting 2011, PPS003-01, May 22-27, Makuhari, Chiba, Japan, 2011.
14. Kaneko, S., E. Ohtani, M. Miyahara, **T. Sakai**, M. Kayama, H. Nishido, Y. Ohishi, N. Hirao, Dynamic event recorded in a lunar meteorite NWA 4734, Japan Geoscience Union Meeting 2011, PPS003-P01, May 22-27, Makuhari, Chiba, Japan, 2011.
15. **Sakai, T.**, Ohtani, E., Terasaki, H., Kamada, S., Hirao, N., Sata, N., Ohishi, Y., Compression of Fe-Ni-S alloy up to the pressure of the center of the Earth, IMA2010, Budapest, August 21-27, 2010. (INVITED)
16. Ohtani, E., **Sakai, T.**, Kamada, S., Terasaki, H., Sata, N.,.Hirao, N., Ohishi, Y., Iron-Silicate Reaction and Silicon in the Core, IMA2010, Budapest, August 21-27, 2010.
17. **Sakai, T.**, Ohtani, E., Terasaki, H., Kamada, S., Hirao, N., Sata, N., Ohishi, Y., Density of Fe-Ni-S alloy at the pressure of the center of the Earth. Dynamic Earth and Heterogeneous Structure, July 13-15, 2010.

18. Kamada, S., Ohtani, E., Terasaki, H., **Sakai, T.**, Ohishi, Y., Hirao, N., Sata., N., Temperature profile of the outer core based on X-ray diffraction of Fe-Fe_3S and (Fe,Ni)-$(Fe,Ni)_3S$ system, AGU fall meeting 2010, USA, California, San Francisco, Moscone Convention Center, December 13-17, 2010.
19. **Sakai, T.**, E. Ohtani, H. Terasaki, S. Kamada, N. Hirao, N. Sata, Y. Ohishi, Compression study of S-bearing Fe-Ni alloy and $(Fe,Ni)_3S$ up to the core pressure conditions. Global-Network Symposium on Earth's Dynamics, Japan, Sendai、New Mitoya hotel、March 2-4, 2010.
20. Kamada, S., E. Ohtani, H. Terasaki, **T. Sakai**, T. Kikegawa, Y. Ohishi, N. Hirao, N. Sata, Melting Relationships of Fe-FeS System based on X-ray Diffraction. Global-Network Symposium on Earth's Dynamics, Japan, Sendai, New Mitoya hotel, March 2-4, 2010.
21. **Sakai, T.**, S. Kamada, H. Terasaki, E. Ohtani, N. Hirao, H. Asanuma, N. Sata, Y. Ohishi, Phase stability of $(Fe,Ni)_3S$ at ultra high pressure conditions. Joint AIRAPT-22 & HPCJ-50, Japan、Tokyo、July 26-31, 2009.
22. **Sakai, T.**, Micro sample preparation using Focused Ion Beam system for the experiment at multimegabar pressure. Laser Heating the DAC: Where we are and where we are going., America, California, Berkeley、Lawrence Berkeley National Laboratory、December 12-13, 2009.
23. **Sakai, T.**, H. Terasaki, E. Ohtani, S. Kamada, N. Hirao, N. Sata, Y. Ohishi, Phase stability of S-bearing Fe-Ni alloy and $(Fe,Ni)_3S$ at the core pressure conditions. American Geopyhsical Union 2009 Fall Meeting, America, California, San Francisco、Decenber 14-18, 2009.
24. Kamada, S., H.Terasaki, **T. Sakai**, E.Ohtani, M.Miyahara, H.Asanuma, H.Hayashi, T.Kikegawa, Y.Ohishi, N.Hirao, N.Sata, Stability of Fe_3S under the core conditions. Joint AIRAPT-22 & HPCJ-50, Japan、Tokyo、July 26-31, 2009.
25. Asanuma, H., E.Ohtani, **T.Sakai**, H.Terasaki, N.Hirao, N.Sata, Y.Ohishi, The Si content of the inner core based on the phase relations and compression. Joint AIRAPT-22 & HPCJ-50, Japan、Tokyo、July 26-31, 2009.
26. Nishitani, N., E. Ohtani, **T. Sakai**, M. Miyahara, N. Hirao, Y. Ohishi, M. Nishijima, M. Murakami, Study of melting phenomena under the deep mantle conditions, SIT040-07, May 22-27, Makuhari, Chiba, Japan, 2011.
27. Ohira, I., E. Ohtani, **T. Sakai**, M. Miyahara, N. Hirao, Y. Ohishi, M. Nishijima, Mg, Si-bearing delta-AlOOH as a reserver of water in the lower mantle, SIT040-P06, May 22-27, Makuhari, Chiba, Japan, 2011.
28. Ohtani, E., **T. Sakai**, S. Kamada, M. Murakami, H. Fukui and A. Baron (2010). Sound velocity of $Fe_{0.83}Ni_{0.09}Si_{0.08}$ alloy to core pressures., JpGU International Symposium 2010, SIT042-21, Chiba, May 23-28, 2010
29. **Sakai, T.**, E. Ohtani, H. Terasaki, S. Kamada, N. Hirao, E. Sata and Y. Ohishi (2010). Phase stability of subsolidus phases in Fe-Ni-S system at the core pressure., JpGU International Symposium 2010, SIT036-06, Chiba, May 23-28, 2010
30. Nishitani N., E. Ohtani, **T. Sakai** and M. Murakami (2010). Study of melting phenomena under the deep mantle conditions., JpGU International Symposium 2010, SIT036-P05, Chiba, May 23-28, 2010

Takahiro Watanabe

Title/Affiliation	COE Fellow / Department of Earth Science
Specialized Field	Geochemistry
Research Subject	Geochemistry of hot spring water, Tsunami sediments and lake sediments

The Purpose of Research and Outline of Accomplishments:

1) Geochemistry of hot springs (recovery of rare metals and rare earth elements from acidic hot spring water)

Acidic hot spring water in Japan contains natural resources, such as Indium, Gallium and Scandium. In this study, concentrations of inorganic elements in acidic hot spring water at Tohoku area, Japan, were measured, and chemical species were evaluated using X-ray Fluorescence (XRF) analysis, Atomic absobtion spectrometry (AAS), Inductively coupled plasma optical emission spectrometry (ICP-OES) and Inductively coupled plasma mass spectrometry (ICP-MS) system in order to recover rare metals and rare earth elements. Indium and Gallium cocentrations in the hot spring water at Tamagawa area were ca. 2-3 ppb and 40 ppb, respectively. Arsenic and Lead were also detected (ca. 3100 and 1200 ppb, respectively) in the hot spring water.

2) Geochemistry of Tsunami sediments

After the 2011 earthquake off the Pacific coast of Tohoku (3.11 Great East Japan earthquake), a part of coastal area in Tohoku, Japan (Miyagi, Fukushima and Iwate prefecture) was polluted by Arsenic and heavy metals. In this study, Arsenic and heavy metals pollution of soils and Tsunami sediments in the coastal area of Tohoku were evaluated using XRF, AAS, ICP-OES and ICP-MS measurements.

Bulk Arsenic and Lead contents in the Tsunami sediments from Kesennuma area (Miyagi prefecture) were relative high (up to 2560 ppm and 170 ppm, respectivery). Arsenic and Lead contents in water soluble fraction of the sediments were up to 390 ppb and 48 ppb, respectivery, which elevated above the Japanese standard of 10 ppb (Agricultural Land Soil Pollution Prevention Law, Ministry of the Environment).

Published Journal Papers:

1. Lu, X., L. Zhu, M. Nishimura, Y. Morita, **T. Watanabe**, T. Nakamura, Y. Wang (2011). Ahigh-resolution environmental change record since 19 cal ka BP in Pumoyum Co, southern Tibet. Chinese Science Bulletin, 56, 2931-2940.

Symposium Participtions:

1. Takahashi, S., K. Kaiho, S. Yamakita, M. Oba, T. Kakegawa, **T. Watanabe**, S. Yamasaki, Y. Ogawa, K. Kimura, N. Tsuchiya, T. Yoshida, S. Sakata, N. Suzuki, M. Ehiro, Reconstruction of palaeo-environmental variations during the end-Permian mass extinction and its aftermath at the pelagic super-ocean. Annual meeting of the Geochemical Society of Japan, September 2011, Sapporo, Japan
2. Nara, F.W., **T. Watanabe**, T. Kakegawa, K. Minoura, A. Imai, N. Fagel, M. El Ouahabi, K. Horiuchi,T. Nakamura, T. Kawai, Last glacial / post glacial changes of nitrate utilization in Lake Baikal and Lake

Hovsgol inferred from high-time resolution d15N records. BICER symposium 2011, June 2011, Kanazawa, Japan

3. Takahashi, S., K. Kaiho, **T. Watanabe**, T. Kakegawa, M. Oba, Sulfur isotope of sulfate profiles in the pelagic Panthalassic deep sea at the end-Permian. JpGU Meeting, May 2011, Makuhari, Japan.

Takeshi Kuritani

Title/Affiliation	COE Associate Professor / Department of Earth Science
Specialized Field	Petrology, Geochemistry
Research Subject	Dynamics of magmatic processes

The Purpose of Research and Outline of Accomplishments:

1) Geochemical study on Cenozoic basaltic lavas from NE China

The mantle transition zone is considered to be an important water reservoir in the Earth's interior because of the high water capacity of the transition-zone minerals. Recent studies using electrical conductivity observations have suggested that water distribution in the mantle transition zone is not homogeneous on a global scale, and that the mantle transition zone beneath NE China in particular has a high water content. In this study, we used geochemical data from Cenozoic intraplate basaltic lavas in NE China to elucidate the origin of the remarkably hydrous nature of the mantle transition zone beneath NE China.

We found that lavas from the Changbaishan volcanic field show remarkably higher EM1-like signature and higher Ba/Th and Pb/U than lavas from the surrounding volcanic fields, and this concentric spatial variation in geochemistry is well correlated with a plume-like structure of the low-velocity anomaly in the upper mantle down to 410 km beneath the Changbaishan area. On the basis of the constraints derived from the lead isotopic compositions of the Changbaishan lavas, it is suggested that there have been at least two superimposed hydration events in the mantle transition zone under NE China: an ancient (>1 Ga ago) hydration probably caused by dehydration of an ancient stagnant slab, and a recent hydration due to dehydration of the stagnant Pacific slab. The record of the ancient hydration event in the mantle transition zone suggests that the hydrated transition zone has been a long-term (> 1 Ga) stable water reservoir in the Earth's interior.

2) Behaviour of Os in subsuction zones

The Re-Os system has been used as a powerful tool to understand the processes and timescales of the long-term chemical evolution of the Earth. However, behaviors of Re and Os in subduction zones have still been unclear, because arc magmas commonly lost the primary information about the Re-Os system by interaction with the crust en route to the surface. In this study, we examined the Re-Os systematics for a well-characterized suite of relatively primitive alkali basalt lavas from Rishiri Volcano, northern Japan, to elucidate the behabior of Os during arc magma generation.

Rhenium-osmium isotopic analysis of the lavas suggests that the $^{187}Os/^{188}Os$ ratios of the primary magmas decreased systematically with an increase in the degree of fluid-flux melting of the source mantle. This systematic variation is consistent with the variation expected from the disequilibrium partitioning of Os, rather than the equilibrium partitioning, among the depleted mantle, influxed fluid phases, and primary melts during magma generation. We estimated that the Os in the slab-derived fluids was radiogenic ($^{187}Os/^{188}Os$ > ~1.0), but the concentration was not high (< ~100 ppt). The low Os concentration of the fluid may be attributed to the low mobility of Os in the slab-derived supercritical fluid, rather than by the low Os content of the subducting slab from which the fluid was derived.

Published Journal Papers:

1. **Kuritani, T.**, Yokoyama, T., Kitagawa, H., Kobayashi, K. and Nakamura, E. (2010) Geochemical evolution of historical lavas from Askja Volcano, Iceland: implications for mechanisms and timescales of magmatic differentiation., Geochimica et Cosmochimica Acta 75, 570-587.
2. **Kuritani, T.**, Yoshida, T. and Nagahashi, Y. (2010) Internal differentiation of Kutsugata lava flow from Rishiri Volcano, Japan: processes and timescales of segregation structures' formation., Journal of Volcanology and Geothermal Research 195: 57-68.
3. **Kuritani T.**, Ohtani E., Kimura J., (2011), Intensive hydration of the mantle transition zone beneath China caused by ancient slab stagnation. Nature Geoscience, doi:10.1038/NGEO1250.

Symposium Participations:

1. **Kuritani, T.**, Senda, R., Suzuki, K., Yoshida, T. and Nagahashi, Y., Osmium transportation by slab-derived supercritical liquid: constraints from alkali basalt lavas from Rishiri Volcano., JPGU Meeting 2010, May 23-28, 2010, Makuhari, Japan.
2. **Kuritani, T.**, Yoshida, T. and Nagahashi, Y., Selective crystal fractionation in a bubble-bearing magma body: implications from Kutsugata lava flow, Rishiri Volcano., JPGU Meeting 2010, May 23-28, 2010, Makuhari, Japan.
3. **Kuritani, T.** and Ohtani, E. Transition zone-derived mantle plume above the stagnant Pacific slab and its consequence for intraplate magmatism in northeast China., G-COE symposium 2010 "Dynamic Earth and Heterogeneous Structure", July 13-15, 2010, Sendai, Japan.
4. Ohtani, E., Zhao, D., **Kuritani, T.** and Tajima, F., Deep dehydration and physical and chemical nature of the mantle above the stagnant slab., AGU Fall Meeting 2010, December 13-17, 2010, San Francisco, USA.

Anton Shatskiy

Title/Affiliation	COE Associate Professor / Department of Earth Science
Specialized Field	Crystal growth, HP mineral physics
Research Subject	1. Lattice diffusion of Si, O, H in mantle minerals 2. Single crystal growth of mantle minerals implication to silicon self-diffusion experiments.

The Purpose of Research and Outline of Accomplishments and results:

In 2010 year I mainly concentrated on two topics. The first is mechanism of H and C transport and segregation in the deep mantle.

Carbon and hydrogen play important role in the mantle processes related to subduction (deep earthquakes due to dehydration of hydrous silicates, arc magmatism) and upwelling (kimberlite, lamproite magmatism, depth > 250 km, metasomatism, and diamond formation). Although an average concentration of H and C in the mantle does not exceed 100 wt. ppm, local mantle regions were extremely enriched in these elements. These are suggested from composition of protokimberlite magma which corresponds to the carbonatitic magma, from CO_2-H_2O fluid inclusions in natural diamond, and mantle xenoliths metasomatically altered by carbonatitic melts. The mechanism of the H_2O and CO_2 transport and segregation at the greater depth is unknown.

Based on our current results on H diffusion in olivine at 13 GPa and literature data a hydrogen and carbon transport by means the solid state diffusion through solid silicate is unrealistic due to very slow diffusion rates ($< 5\times10^{-10}$ m^2/s allowing diffusion distance of < 6 km in 10^9 yr. at mantle conditions). Moreover, the diffusion is a kind of indirect migration process which leads rather element dissipation than segregation. The well known porous flow (fluid/melt percolation via interconnected pores) transport reliable for the shallow depth (< 50 km) can not be applied for average mantle since the average mantle is the non-porous solid silicate matrix.

Therefore, in 2010 we start to develop new model which enables us to explain transport and segregation of trace amount of H_2O and CO_2 in the mantle. At the mantle conditions water and carbonates are the excellent silicate solvents. Hence the migration of insulated portions of fluid through the solid matrix can proceed by means of the dissolution-precipitation mechanism. The major driving force for this process would be a concentration gradient of solid silicate in the fluid. This can be caused by pressure or temperature gradient, differences in stable and metastable phase solubility, and stress. The fluid chamber migration rate equals to the silicate components diffusive flux through the fluid. The later is product of diffusion coefficient and applied driving force.

The diffusion of $MgSiO_3$ perovskite in hydrous fluid and water-carbonate melt at 24 GPa and 1500°C and Mg_2SiO_4 wadsleyite in carbonate melt at 17.5 GPa and 1700°C were measured to be 2×10^{-7}, 5×10^{-9}, and 2×10^{-9} m^2/s, respectively. The measurements were made using scaled-up Kawai-system which we previously developed. The general experimental procedure was the same as we used for the single crystal growth of $MgSiO_3$ perovskite by means of the thermal gradient growth technique. Obtained diffusion coefficients suggest that the dissolution-precipitation mechanism up to 3 order of magnitude faster than solid state diffusion of H_2O. However, in our present study the thermal gradient has been employed as a driving force,

whereas in the nature, stress would be more reliable. In this connection in this year we start development of the deformation HPHT experiments using D-DIA press installed in PFAR Tsukuba. Simultaneously from the last December we began study of phase relations and P-V-T EOS of alkali and alkali earth carbonates using *in situ* experiments at PFAR and Spring-8. These data are essential to know stability field of carbonatitic melt in the deep mantle.

The second topic was the regularities of pressure and temperature generation in the Kawai-type multianvil apparatus. The study of the phase relations in the mantle under controlled redox conditions in presence of volatiles (H, C, N, S) is one of the hot topics. However, this study requires large sample volume and therefore it was conducted only at low pressures generally 2-6 GPa (shallow mantle). The diffusion studies of silicate components in fluid/melt and hydrogen in mantle minerals are also needs large sample volume. The choice of the best scaled-up assemblage for a particular experiment at 10-25 GPa is still somewhat arbitrary. Optimizing the high-pressure cell is both time consuming and costly, because each failed experiment destroys several anvils, and a statistically significant number of trials of a given design are required to obtain conclusive results. That largely limits wide application of a scaled-up version of the Kawai-cell for essential use in the field of planetary and material science. During past year we summarized all our data on performance of the Kawai-cell. The essential part obtained using *in-situ* X-Ray radiography and energy dispersive diffraction has been also included in this analysis. The results were presented as a large paper which is now under reviewing in the Physics of the Earth and Planetary Interior.

Published Journal Papers:

1. **Shatskiy, A.,** D. Yamazaki, Y. M. Borzdov, T. Matsuzaki, K. D. Litasov, T. Cooray, A. Ferot, E. Ito, T. Katsura, Stishovite single-crystal growth and application to silicon self-diffusion measurements, American Mineralogist 95 (2010) 135-143.
2. **Shatskiy, A.,** K. D. Litasov, H. Terasaki, T. Katsura, E. Ohtani, Performance of semi-sintered ceramics as pressure-transmitting media up to 30 GPa, High Pressure Research 30 (2010) 443-450.
3. **Shatskiy, A.,** Y. M. Borzdov, D. Yamazaki, K. D. Litasov, T. Katsura, Y. N. Palyanov, Aluminum Nitride Crystal Growth from an Al-N System at 6.0 GPa and 1800 degrees C, Crystal Growth & Design 10 (2010) 2563-2570.
4. E. Ito, D. Yamazaki, T. Yoshino, H. Fukui, S. M. Zhai, **Shatskiy, A.,**, T. Katsura, Y. Tange, K. Funakoshi, Pressure generation and investigation of the post-perovskite transformation in $MgGeO_3$ by squeezing the Kawai-cell equipped with sintered diamond anvils, Earth and Planetary Science Letters 293 (2010) 84-89.
5. X. P. Wu, B. H. Zhang, J. S. Xu, T. Katsura, S. M. Zhai, T. Yoshino, G. Manthilake, **Shatskiy, A.,** Electrical conductivity measurements of periclase under high pressure and high temperature, Physica B-Condensed Matter 405 (2010) 53-56.
6. K. D. Litasov, **Shatskiy, A.,**, Y. W. Fei, A. Suzuki, E. Ohtani, K. Funakoshi, Pressure-volume-temperature equation of state of tungsten carbide to 32 GPa and 1673 K, Journal of Applied Physics 108 (2010)
7. A. M. Dymshits, A. V. Bobrov, K. D. Litasov, **Shatskiy, A.,** E. Ohtani, Y. A. Litvin, Experimental study of the pyroxene-garnet phase transition in the $Na_2MgSi_5O_{12}$ system at pressures of 13-20 GPa: First synthesis of sodium majorite, Doklady Earth Sciences 434 (2010) 1263-1266.

Konstantin Litasov

Title/Affiliation	COE Associate Professor / Department of Earth Science
Specialized Field	Earth Sciences
Research Subject	Phase equilibria of peridotite and eclogite with various fluids and deep understanding of spatial-temporal evolution of volatiles in the Earth's mantle

The Purpose of Research and Outline of Accomplishments and main results:

Most important achievement of 2010 stage include experimental modeling of mantle lithologies (peridotite and eclogite) coexisting with reduced C-O-H fluid at pressures of 3-15 GPa. In these experiments we used double-capsule method and controlled fO_2 using oxygen buffers MMO (Mo-MoO_2) and IW (Fe-FeO). The solidus temperatures were 300-400^{o}C higher than that in the systems with H_2O and CO_2. In turn these solidi were 300-400^{o}C lower than volatile-free ones for peridotite and eclogite systems at 15-20 GPa. The melt compositions in the peridotite and eclogite systems coexisting with reduced C-O-H fluid are characterized by the high SiO_2 contents (44-50 wt.%).

Study of the reactionary interaction between Fe and its compounds with carbonates leaded to following conclusions: 1) Interaction of Fe with carbonates cause formation of Fe_3C. Accordingly diamond formation in the mantle cannot occur in equilibrium with metallic Fe. 2) We observed low solubility of carbon in FeS melt and low solubility of hydrogen in Fe_3C. In addition we observed negligible reactions between carbonate and FeS. 3) According to experiments we suggested Fe-affinity range for light elements at high pressures as FeS > FeC > FeH > Fe.

Phase relations in model carbonate-chloride-bearing eclogite were studied at 7.0-10.5 GPa and 1200–1675°C. In this system melt composition because Si-rich at 1500-1700°C and contain up to 53 wt.% SiO_2. These compositions correspond to Si-rich endmemebr of the fluid/melt inclsions in fibrous diamonds. Therefore, we outlined experimentally affinity of these inclusions to eclogite paragenesis. We completed experimental study of model Cl-bearing Udahnaya kimberlite at 2.1-6.5 GPa and 900-1500^{o}C. The obtained phase relations indicate that kimberlite was not in equilibrium with mantle peridotite in the region of magma generation. Primary melt had carbonatite composition and Si-enrichment occurred during reaction of carbonatite melt with surroundaing mantle rocks during transport to the surface.

International activity:

In 2010 I presented the results in several international conferences including European Uinion of Geoscience, General Meeting of International Mineralogical Association, and American Geoscience Union. Two plenary lectures were presented at XVI All-Russian Conference on Experimental Mineralogy (Chernogolovka, Moscow). During October, 2010, I visited Novosibirsk and performed high-pressure experiments in the laboratory of Prof. Y. Palyanov, where we were able to measure composition of C-O-H fluid after experiments using gas chromatography. I had a presentation on current progress in collaboration between Tohoku University and Sobolev Institute of Geology and Mineralogy and a lecture on using high pressure techniques in synchrotron radiation facility "SPring-8" during Seminar for Young Scientists on using of Synchrotron Radiation in Earth Science in the Institute of Nuclear Physics SB RAS (Novosibirsk). I also supervised G-COE intern student Mr. Igor Sharygin (Novosibirsk, Russia). His internship project

includes study of mineral dissolution in carbonatite melt with implication to origin of kimberlite and diamond.

Published Journal Papers:

1. Shatskiy, A., Yamazaki, D., Borzdov, Y. M., Matsuzaki, T., **Litasov, K. D**., Cooray, T., Ferot, A., Ito, E., Katsura, T., 2010, Stishovite crystal growth - application to silicon self-diffusion measurements, American Mineralogist, 95, 135-143.
2. Shatskiy, A., Borzdov, Y. M., Yamazaki, D., **Litasov, K. D.**, Katsura, T., Palyanov, Y., 2010, Aluminum nitride crystal growth from Al-N system at 6.0 GPa and 1800°C, Crystal Growth and Design, 10 (6), 2563-2570.
3. **Litasov, K. D.**, 2010, Effect of Al_2O_3 on water solubility in periclase and ferropericlase at 25 GPa, Russian Geology and Geophysics, 51 (6), 644-649.
4. **Litasov, K. D.**, Ohtani, E., 2010, The solidus of carbonated eclogite in the system CaO-Al_2O_3-MgO-SiO_2-Na_2O-CO_2 to 32 GPa and carbonatite liquid in the deep mantle, Earth and Planetary Science Letters, 295, 115-126.
5. Gibsher A. A., Malkovets, V. G., **Litasov, K. D.**, Litasov, Yu. D., Pokhilenko, N. P., 2010, Composition of the Ordovician lithospheric upper mantle: evidence from the study of peridotite xenoliths from camptonite of the Sangilen Highland, Central Asian fold belt, Doklady Earth Science, 433 (1) 957-961.
6. Sokol, A. G., Palyanov, Y. N., Kupriyanov, I. N., **Litasov, K. D.**, Polovinka, M. P., 2010, Effect of oxygen fugacity on the H_2O storage capacity of forsterite in the carbon-saturated systems, Geochimica et Cosmochimica Acta, 74, 4793–4806.
7. Shatskiy, A., **Litasov, K. D.**, Terasaki, H., Katsura, T., Ohtani, E., 2010, Performance of semi-sintered ceramics as pressure transmitting media up to 30 GPa, High Pressure Research, 30 (3), 443-450.
8. **Litasov, K. D.**, Shatskiy, A., Fei, Y., Suzuki, A., Ohtani, E., Funakoshi, K., 2010, Pressure-volume-temperature equation of state of tungsten carbide to 32 GPa and 1673 K, Journal of Applied Physics, 108, 053513, doi:10.1063/1.3481667.
9. Dymshits A. M., Bobrov, A. V., **Litasov, K. D.**, Shatskiy, A. F., Ohtani, E., Litvin, Yu. A., 2010, Experimental study of the pyroxene-garnet phase transition in the $Na_2MgSi_5O_{12}$ system at pressures of 13−20 GPa: first synthesis of sodium majorite, Doklady Earth Science, 434, 1263-1266.
10. **Litasov, K. D.**, Sharygin, I. S., Shatskiy, A. F., Ohtani, E., Pokhilenko, N. P., 2010, Experimental constraints on the role of chloride in the origin and evolution of kimberlitic magma, Doklady Earth Science, 435, 1648−1653.
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1. **Litasov, K. D.**, Shatskiy, A., Fei, Y., Ohtani, E. (2010) Carbonate-silicate-metal equilibria at high pressures: New insights into deep volatile cycles. Global-Network Symposium on Earth's Dynamics, Tohoku University, Akiu Resort, Sendai, Japan, 35-36.
2. **Litasov, K. D.**, Shatskiy, A., Fei, Y., Ohtani, E. (2010) Experimental study of carbonate-silicate-metal equilibria at pressures to 30 GPa: New insights into deep volatile cycles, EGU General Assembly 2010, Geophysical Research Abstracts, 12, EGU2010-7483 (invited).
3. Shatskiy, A., **Litasov, K. D.**, Borzdov, Y. M., Katsura, T., Ohtani, E. (2010) Incipient fluid migration through the deep mantle by dissolution-precipitation: crystal growth constraints, EGU General Assembly 2010, Geophysical Research Abstracts, 12, EGU2010-7534.
4. Ohtani, E., Sakamaki, T., **Litasov, K. D.** (2010) Effect of carbon and hydrogen on melting and magma properties at high pressure, 2010 Japan Geoscience Union Meeting, Makuhari Messe, Chiba, Japan, MIS010-12 (invited).
5. Kiseeva, E. S., **Litasov, K. D.**, Yaxley, G. M., Ohtani, E., Kamenetsky, V. S. (2010) High-pressure experiments on anhydrous carbonated eclogite at 9-20 GPa - implications for the recycling of

carbonate into the mantle, 20th General Meeting of International Mineralogical Association, Budapest, Hungary.

6. Safonov, O. G., **Litasov, K. D.** (2010) The influence of chloride components on mantle melting: a review of the experimental data and future perspectives, XVI All-Russian Conference on Experimental Mineralogy, Chernogolovka, Russia, September 20-24 (plenary).
7. **Litasov, K. D.** (2010) Reactions between Mg- and Ca-carbonates with SiO_2 and iron at high pressures, XVI All-Russian Conference on Experimental Mineralogy, Chernogolovka, Russia, September 20-24 (plenary).
8. **Litasov, K. D.**, Shatskiy, A., Ohtani, E. (2010) Melting phase relations of model alkali carbonatite systems at 3-21 GPa and implication to mantle metasomatism, 51th High-Pressure Conference of Japan, Sendai, October 20-23, 3P44.
9. Fei, Y., **Litasov, K. D.** (2010) Carbon cycle in the subduction zone and deep mantle: Constraints from equilibrium experiments at high pressure and temperature. American Geophysical Union, Fall Meeting, San-Francisco, USA (invited).
10. **Litasov, K. D.**, Shatskiy, A., Ohtani, E. (2010) Melting phase relations of K- and Na-bearing carbonatite at 3-21 GPa with implication to deep carbon cycle. American Geophysical Union, Fall Meeting, San-Francisco, USA.

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Title/Affiliation	COE Assistant Professor / Department of Earth Science
Specialized Field	High-pressure planetary science
Research Subject	Transformation mechanism of high-pressure polymorphs in shocked-meteorites

The Purpose of Research and Outline of Accomplishments:

Olivine dissociates to (Mg,Fe) SiO_3-perovskite (Pv) + magnesiowüstite (Mw) around and below the transition zone of the Earth. However, the dissociation mechanism of olivine is still debated. The high-pressure and -temperature conditions of the dynamic event recorded in Martian meteorites have been estimated by several previous works, and the estimated conditions given in some reports are beyond the stability filed of ringwoodite. It is likely that olivine in shocked Martian meteorites dissociated to (Mg,Fe) SiO_3-Pv + Mw but overlooked. Accordingly, we scanned olivine grains in the Martian meteorite. We report the first evidence for the dissociation of olivine at high-pressure and -temperature condition induced by a dynamic event on Mars.

The existence of a high-pressure polymorph in a meteorite is suggestive of its parent body having gone through a dynamic event. Several previous studies proposed that only a very few high-pressure polymorphs are contained in a lunar meteorite although the moon's many craters and thick regoliths imply that it has experienced heavy meteorite bombardments. However we reveal that some lunar meteorites contain high-pressure polymorphs of silica, coesite, stishovite and α-PbO_2-type silica (seifertite) in shocked lunar meteorites.

Main Results:

Natural dissociation of olivine: TEM observations reveal that micro-texture of olivine dissociation evolves from lamellar to equigranular with increasing temperature at same pressure condition (Fig. 1), agreeing with the observations of synthetic samples recovered from high-pressure and temperature experiments. Equigranular (Mg,Fe) SiO_3-Pv and Mw have 50-100 nm in diameter. Lamellar (Mg,Fe)SiO_3-Pv and Mw have ~20 and ~10 nm in thickness, respectively. Partitioning coefficient, $K^{Pv/Mw} = [FeO/MgO]_{Pv}/[FeO/MgO]_{Mw}$, between (Mg,Fe) SiO_3-Pv and Mw in equigranular and lamellar textures are ~0.15 and ~0.78, respectively. The dissociation of olivine implies that the pressure and temperature conditions recorded in the shock vein and melt pockets during the dynamic event were ~25 GPa but 700 °C at least. We report this novel result in PNAS [2].

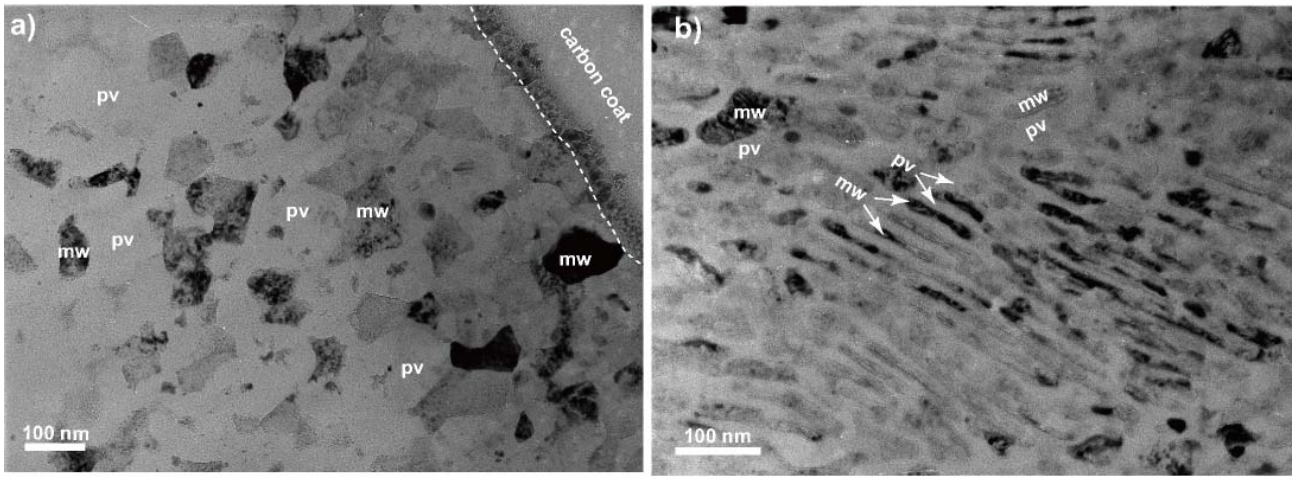

Fig. 1. TEM images of a) equigranular (Mg,Fe)SiO_3-Pv and Mw and b) lamellar (Mg,Fe)SiO_3-Pv and Mw.

High-pressure polymorph of silica in lunar meteorite: Microcrystals of coesite and stishovite were discovered as inclusionsin in shocked melt pockets of a lunar meteorite Asuka-881757. These high-pressure polymorphs of SiO_2 in amorphous silica indicate that the meteorite experienced an equilibrium shock-pressure of at least 8–30 GPa. Observation of coesite and stishovite formed in the lunar breccias suggests that high-pressure impact metamorphism and formation of high-pressure minerals are common phenomena in brecciated lunar surface altered by the heavy meteoritic bombardment [5]. We also identified α-PbO_2 type silica (seifertite) from another lunar meteorite, NWA 4734 by syncrotoron XRD analysis and TEM observation (Miyahara et al, under review). Seifertite was discovered only from Martina meteorites so far. The seifertite in NWA 4734 formed from cristobalite. We also clarified the transformation mechanism from cristobalite to seifertite.

Published Journal Papers:

1. **Miyahara M.**, Ohtani E., Kimura M., Ozawa S., Nagase T., Nishijima M. and Hiraga K. Evidence for multiple dynamic events and subsequent decompression stage recorded in a shock vein. *Earth and Planetary Science Letters,* 307, 361-368, 2011.
2. **Miyahara M,** Ozawa S., Ohtani E. Modification of olivine due to collision of planetesimals, yuseijin, 20, 147-153, 2011.(in Japanese)
3. **Miyahara M**., Ohtani E., Ozawa S., Kimura M., El Goresy A., Sakai T., Nagase T., Hiraga K., Hirao N. and Ohishi Y. Natural dissociation of olivine to (Mg,Fe)SiO_3 perovskite and magnesiowüstite in a shocked Martian meteorite. *Proceedings of the National Academy of Sciences U.S.A.,* 108, 5999-6003, 2011.
4. Ozawa S., **Miyahara M.**, Ohtani E., Kimura M. and Ito Y. Petrography of Yamato 984028 lherzolitic shergottite and its melt vein: implications for its shock metamorphism and origin of the vein., *Polar Science*, 4, 550-557, 2011.
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7. **Miyahara M.**, Ohtani E., Kimura M., El Goresy A. Ozawa S., Nagase T., Nishijima M. and Hiraga K. Coherent and subsequent incoherent ringwoodite growth in olivine of shocked L6 chondrites. *Earth and Planetary Science Letter*, 295, 321-327, 2010.
8. Hirauchi K., Katayama I., Uehara S., **Miyahara M.** and Takai Y. Inhibition of subduction thrust

earthquakes by low-temperature plastic flow in serpentine. *Earth and Planetary Science Letter*, 295, 349-357, 2010.

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2. El Goresy A., Boyet M., **Miyahara M**. Almahata Sitta MS-17 EL-3 chondrite fragment: contrasting oldhamite assemblages in chondrules and matrix and significant oldhamite REE-patterns. *Meteoritics & Planetary Science*, 46 (Supplement), A63, 2011.
3. **Miyahara M.**, Ohtani E., Ozawa S., Kimura M., El Goresy A., Sakai T., Nagase T., Hiraga K., Hirao N., Ohishi Y. First evidence for natural dissociation of olivine to silicate-perovskite and magnesiowüstite in a shocked Martian meteorite DaG 735. *Meteoritics & Planetary Science*, 46 (Supplement), A164, 2011.
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6. El Goresy A., **Miyahara M.**, Ozawa S., Ohtani E., Gillet Ph., Beck P. Montagnac G., Nagase T. and Hiraga K. Liquidus high-pressure assemblages in shocked Martian shergottites: constrains to equilibrium peak shock-pressures and consequences to radiometric ages., *Meteoritics & Planetary Science*, 45 (Supplement), A50, 2010.
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