

Earth Probe Newsletter



An NSF funded Consortium for Materials Properties Research in Earth Sciences

<http://www.compres.us>

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COMPRES Fourth Annual Meeting

COMPRES celebrated its third anniversary (on May 1, 2005). On June 16-19, the 4th COMPRES Annual Meeting was held at the Mohonk Mountain House in New Paltz. As COMPRES has gained significant experience in developing and operating community facilities, new scientific emphasis is added to the annual meeting. There were three sessions focusing on the latest progress in Earth's geochemical evolution, mantle and core,

in addition to the reports from the community facilities and infrastructure projects. The geochemical evolution focus session included two keynote talks: "*The One-layer vs Two-layer dilemma: the Tolstikhin-Hofmann solution for a two-layer mantle (Where is the second layer?)*" by Albrecht Hoffman from Max Planck Institut für Chemie, and "*Chemical evolution of the lowermost mantle: Slab accumulation and*



Total of 108 registered participants attended the annual meeting

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reaction with the core" by Kei Hirose of Tokyo Institute of Technology. The keynote lectures in Earth's mantle session were given by Barbara Romanowicz of UC Berkeley on "*Superplumes at the base of the mantle: the cutting edge*" and by Guillaume Fiquet of Institut de Physique du Globe de Paris on "*Mineral physics perspectives for the Earth's mantle*". The core focus session included two keynote talks: "*The Earth's Core: Seismological View*" by Miaki Ishii from UC San Diego and "*Mineral physics of the core: origins and recent progress*" by Lars Stixrude from University of Michigan. A special lecture "*The mantle transition zone: Seismic properties, deep subduction, earthquakes, and petrology*" was delivered by Wang-Ping Chen from University of Illinois at Urbana-Champaign. ■

President's Message

Bob Liebermann

COMPRES has reached mid-life in its first collaborative agreement [May 2002 to April 2007]. Planning has now commenced for submission of a renewal proposal on August 1, 2006 for the period May 2007 to April 2012; an open session of the COMPRES community on the last day of the recent Annual Meeting kicked off this process—keep turned to these pages and the monthly and other messages from the President for updates and calls for input from the community.

Following are some of the highlights of activities of the COMPRES and related scientific communities during the period March 2004 to July 2005.

A Workshop on Multi-Anvil Techniques was held at GSECARS/APS of the Argonne National Laboratory on March 1-3, 2005. Conveners were Kurt Leinenweber (Arizona State University), Charles Leshar (University of California at Davis), and Yanbin Wang (GSECARS and University of Chicago). A detailed report may be accessed from the COMPRES website or directly at: http://gsecars.org/LVP/LVP_workshop_05/Main_index.htm See additional details in this issue of the newsletter.

On March 4-6, I attended a COE-21 Symposium on “Origin, Evolution and Dynamics of the Earth: Present and Future Research.” This symposium was held at the Institute for the Study of the Earth's Interior of Okayama University in Misasa, Japan. Among the keynote and invited speakers were the following members of the COMPRES community: Raymond Jeanloz (University of California at

Berkeley), Eiji Ito (Okayama University) Shun Karato (Yale University), Hugh O'Neill (Australian National University), and me.

New institutional member of COMPRES

The application of the University of Western Ontario was unanimously approved by the Executive Committee, with Rick Secco as the non-voting representative. Thus, UWO becomes the first institution in Canada to become a member of COMPRES and brings the number of foreign affiliates to 15.

In late June, two new U. S. institutions became member of COMPRES:

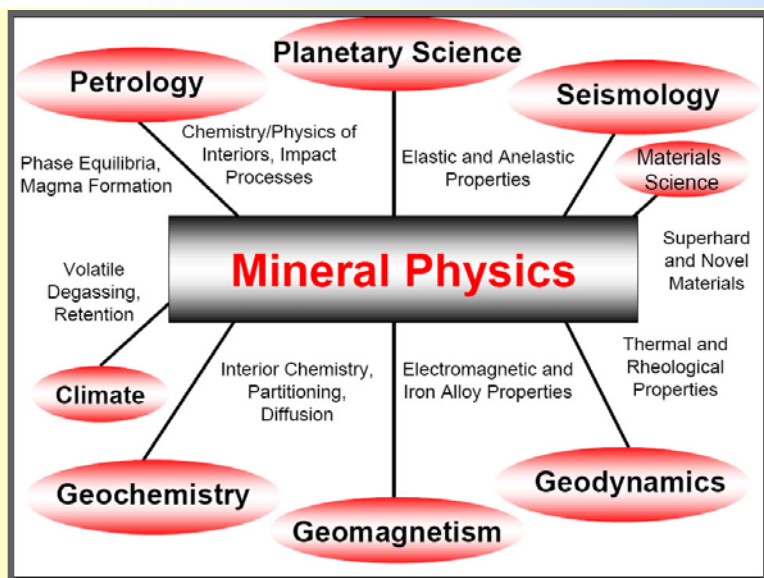
Lawrence Berkeley National Laboratory: Elector: Simon Clark; Alternate: Corwin Booth.

University of Missouri at Kansas City: Elector: Michael Kruger; Alternate: Raymond Coveney.

This brings the number of U. S. institutions to 44.

On March 24-25, I represented COMPRES and Stony Brook University at a meeting of the Science and Technology Steering Committee of the Brookhaven Science Associates at the Brookhaven National Laboratory. Of particular interest to the COMPRES community was that the proposal for NSLS II, a plan to construct a new generation of the National Synchrotron Light Source [the NSLS] is moving through administrative channels at the Department of Energy, with the hope that it will soon achieve the status of Critical Decision-O [or CD-O, “Approve Mission Need”].

(continued on page 3)



Future of High-Pressure Mineral Physics/ Role of COMPRES

Article for EOS by Robert C. Liebermann

Research in mineral physics is essential in interpreting observational data from many other disciplines in the earth sciences, from geodynamics to seismology to geochemistry to petrology to geomagnetism to planetary science and also to materials science and climate studies, as illustrated in the left Figure. Thus, the field of high-pressure mineral physics is highly interdisciplinary and fundamentally multidisciplinary. Mineral physicists do not always study minerals nor use only physics; they study the science of materials which comprise the Earth and other planets and employ the full range of concepts and techniques from chemistry, physics, materials science, and biology. See EOS for full text.

President's message *(cont'd)*

The Center for the Study of Matter at Extreme Conditions [CeSMEC] hosted their third biennial conference at Hotel Deauville, Miami Beach from April 17-21. More than 160 scientists from 20 countries attended, with a heavy emphasis on non-U. S. participants. The principle themes of the conference were high-pressure physics, solid state physics, and materials science. Additional details may be found at the meeting website: <http://www.cesmec.fiu.edu/SMEC2005/>.

Congratulations to Surendra Saxena and his fine team for this very successful meeting, for which COMPRES was one of the sponsors and more than 29 members of the COMPRES community attended.

I attended the European Geosciences Union General Assembly in Vienna, Austria from April 24-29. Special features included a Union symposium on "Neutrons at the Frontier of Earth Sciences and Environment" convened by H. Schober, J. Parise and H. Kagi. I gave a paper in the symposium on "High-pressure and high-temperature mineral physics: Contributions towards the understanding of planetary interiors" convened by D. Frost. At the EGU, special awards were given to two members of the COMPRES community: David Dobson received the Outstanding Scientist Award from the European Mineralogical Union; David Kohlstedt received the Louis Neel Medal and delivered a lecture entitled: "Mantle Flow, Melt Migration, and Seismic Anisotropy: Aligned Against the Flow." During the first week of May, I visited the Bayreuth Geoinstitut in Germany [hosted by Dan Frost and David Rubie] and the Geophysical Institute of the Czech Academy of Sciences in The Czech Republic [hosted by Jaroslava Plomerova and Vladislav Babuska].

On May 10, the Facilities Committee [M. Rivers-Chair, Y. Fei, A. Kavner, C. Prewitt] paid a Site Visit to the high-pressure beamlines at the National Synchrotron Light Source of the Brookhaven National Laboratory. The purpose of this visit was to learn the current status of the diamond-anvil and multi-anvil facilities operated for COMPRES by the Carnegie Institution of Washington [H. Mao and R. Hemley] and Stony Brook University [D. Weidner and M. Vaughan], respectively, and to discuss future plans for enhancing these facilities to serve the COMPRES community.

The U. S. National Academy of Sciences announced the election of 72 new members, including three from the mineral and rock physics community: Marcia McNutt from the Monterey Bay Aquarium, Barbara Romanowicz from the University of California at Berkeley, and Paul Tappanier [Foreign Associate] from the Institut de Physique du Globe in Paris.

On May 17, Harry Green, Mark Rivers and I visited the Advanced Light Source at the Lawrence Berkeley National Laboratory to see the new facilities for high-pressure mineral physics operated for COMPRES by the University of California [R. Jeanloz]. We were hosted by Raymond and Simon Clark and their team of associates including Martin Kunz, Sander Caldwell and Arianna Gleason [COMPRES Beamline Intern].

As part of a western trip in mid-May, I also visited the Lawrence Livermore National Laboratory [hosted by William Durham, Dan Farber, Jeff Roberts, and Brian Bonner] to see their high-pressure facilities. On the way home, I stopped for a day to visit Ivan Getting at the University of Colorado to get an update on the Johnson noise

(continued on page 4)



President's message *(cont'd)*

thermometry project that he is conducting part of the COMPRES infrastructure development program.

The 15th Goldschmidt Conference was held in Moscow, Idaho from May 20-25, with many special symposia of interest to the COMPRES mineral physics community, including "Geochemical, Rheological, and Geophysical Aspects of Deep Mantle Phase Changes" [convened by J. Bass and I. Daniel] and "Mantle Heterogeneity, Past and Present" [convened by F. Albarede and P. Tackley]. Additional details of the meeting may be found at: <http://www.the-conference.com/2005/gold2005/index.php>.

At the Goldschmidt Conference, Alexandra Navrotsky received the 2005 Harold Urey Medal of the European Association of Geochemistry and James van Orman received the 2005 Clarke Medal of the Geochemical Society.

On May 27, Harry Green and I visited the Division of Earth Sciences of the National Science Foundation to meet with David Lambert, Herman Zimmerman, Russell Kelz, Kaye Shedlock, James Whitcomb and David Fountain. Among the topics discussed were:

- a. Planning for submission of a renewal proposal for COMPRES in July 2006.
- b. Eligibility of COMPRES for the MRI program competition at the NSF.
- c. Grand Challenge collaborative research projects.

Additional details may be found on the minutes for the Executive Committee meeting of May 31, 2005 on the COMPRES website.

In collaboration with the Executive Committee, I have written an article entitled: "Future of High-Pressure Mineral Physics/Role of COMPRES" for EOS. It is expected to appear soon and will

contain this figure illustrating the central role that mineral physics plays in the geosciences.

In early June, the Royal Academy of Sciences awarded the Gregori Aminoff Prize for 2005 to Ho-kwang (Dave) Mao of the Carnegie Institution of Washington. Several mineral physicists from the U. S. participated in a symposium in Dave's honor in Stockholm.

I attended the Gordon Conference on Earth's Interior at Mt Holyoke College in South Hadley, MA from June 12-16. The Conference was chaired by Lars Stixrude and included many fine invited talks: those from mineral physics were by Paul Asimow, Guillaume Fiquet, Daniel Frost, Kei Hirose and Jie Li.

Guy Masters, one of the members of the COMPRES Advisory Committee, has recently been elected Fellow of the Royal Society of London.

The 4th Annual Meeting of COMPRES was held at the Mohonk Mountain House in New Paltz from June 16-19. There were 108 registered participants and many accompanying persons to enjoy this splendid site. One of the new features was a set of keynote talks focused on the mantle, geochemical evolution and the core, with speakers for each topic from both within and outside the mineral physics community. The social events of the meeting were underwritten by 11 industrial sponsors: Almax, Blake Industries, D'Anvils, Delaware Diamond Knives, Diacell, HKL, MAR-USA, Rigaku MSC, Rockland Research, Scimed, and Technodiamant. Additional details of the Annual Meeting appear elsewhere in this newsletter. ■



We note with sadness the passing of a giant in the field of geosciences, Volkmar Trommsdorff on June 17. Born in Darmstadt in 1936, Trommsdorff held many distinguished positions in his 40+ year career, the longest for 30 years as Professor of Petrography at the ETH and University of Zurich, Switzerland. The chief focus of his research concerned metamorphism and fluid-rock interaction in the earth crust and upper mantle and the application of this research on geodynamic processes but also on the mobility of substances. The work was a cooperative effort involving various institutes in the USA, Australia, and Europe. The combination of investigation in the field with high pressure experimentation and theoretical considerations stood in the foreground of his research interests. A moment of silence was observed at the Annual Meeting of COMPRES in memory of a person remembered as an outstanding and provocative scientist and a wonderful gentleman.

COMPRES Sponsored Workshop

Multi-Anvil Techniques

Kurt Leinenweber

The COMPRES Workshop on Multi-Anvil Techniques was hosted by the COMPRES Multi-anvil Cell Assembly Development project and was held at GSECARS at Argonne National Laboratories. The conveners were Kurt Leinenweber, Yanbin Wang, and Charles Lesher. Nancy Lazarz provided much of the organization of the workshop, and Jennifer Kung was instrumental in the demonstrations. The purposes of the workshop were to teach multi-anvil techniques with emphasis on synchrotron applications, to encourage scientific research on the GSECARS beam line, to transfer technology to various laboratories, and to describe the cell assembly project of COMPRES and alert students and others to the resources available from that project.

The event was part workshop and part tutorial, with considerable input from the audience as well as the conveners. Senior members of the audience were recruited to give talks on the first day. Speakers were also selected from the staff at APS. An introduction to APS and GSECARS was given by Mark Rivers, followed by an outstanding historical introduction to multi-anvil techniques by Charles Lesher, and a description by Yanbin Wang of the state of the art in synchrotron applications for large-volume presses (LVP's). This was followed by lunch and a tour of the beam lines. After lunch, Kurt Leinenweber described the COMPRES cell

assembly development project and the materials that are available as a result of it, Kevin Righter gave an overview of control of oxygen fugacity in high-pressure experiments and proposed a COMPRES effort to control oxygen fugacity in COMPRES assemblies, Ray Jones gave a description of the Daresbury beam line and the science that is done there, and Jennifer Kung presented a talk on ultrasonics in the multi-anvil in combination with x-ray diffraction.

On the second and third days, live beam was available and the workshop participants were involved in experiments on the beam line. A sample prep area

was set up with demos of assemblies and also the actual assemblies that were put together for the experiments. The experiment floor formed a second locus of activity, with the operation of the large-volume press, radiography, and diffraction. The third area was the data

analysis area where the data was ported over to several computers and analyzed by workshop participants in real time as it was collected.

The first experiment (actually, two separate experiments were performed) was a falling-sphere experiment with two falling spheres of different densities in a silicate melt. The analysis involved measuring pressure and also calculating viscosities from the velocities of the falling sphere. The second experiment was a pressure measurement combined with resistivity, in which the pressures of the bismuth



Workshop on Multi-Anvil Techniques
Advance Photon Source, Argonne National Laboratory

March 1 - 3, 2005

SPONSORED BY
COMPRES MULTI-ANVIL PROJECT AND GSECARS

Multi-Anvil Techniques

(cont'd)

transitions were obtained from an MgO standard. The third experiment was the observation of the transition from coesite to stishovite.

On the second night, a well-lubricated dinner with a view of the distant skyline of Chicago was provided on-site by GSECARS. This dinner was a highlight of the workshop, as the conversation bubbled much like the beverages that were served.

The spotlight fell on the workshop participants as the workshop ended on the afternoon of the third day with presentations of the results by volunteers from the group. The falling sphere experiment was presented by Rachel Dwarski (University of New Mexico), who performed the viscosity calculations, and Julienne Hill (Argonne National Laboratories), who summarized the pressure/temperature measurements. The bismuth transition experiment was presented by Claire Runge (Princeton). The SiO₂

experiment was presented by Don Musselwhite (Lunar and Planetary Institute) with a post-mortem by Rachel Dwarski (University of New Mexico) on a blowout that happened after the transition was completed.

It is our feeling that the workshop was well-paced and well-received. There are indications that some new groups are submitting beam time proposals as a result of the workshop, and some of the participants have contacted Kurt Leinenweber about the COMPRES cell assemblies. Thus, the workshop served its broader purposes in addition to being a source of learning and entertainment. We thank all the participants for their efforts and their enthusiasm throughout the workshop.

The presentations, schedule, and photographs of the workshop are on the workshop web site at http://gsecars.org/LVP/LVP_workshop_05/Main_index.htm



The Royal Swedish Academy of Sciences, which awards the Nobel Prizes, has awarded Ho-kwang (Dave) Mao, a member of COMPRES community at Geophysical Laboratory of the Carnegie Institution of Washington, the 2005

Gregori Aminoff Prize in Crystallography for his pioneering research of materials at ultrahigh pressures and temperatures. Named after Gregori Aminoff, the pioneering Swedish crystallographer, the prize is given annually to recognize a scientist, or a group, of international distinction who has made a major contribution to crystallography.

The prize was presented at the Academy in Stockholm on June 8, 2005. A two-day Symposium, illuminating the latest developments and results in the field of

high pressure and high temperature Symposium, illuminating the latest developments and results in the field of high pressure and high temperature crystallography, was organized June 9-



10 to the honor of Dave Mao. The symposium was supported by the Academy through its Nobel Institute for Chemistry.

Above: Dave at the award ceremony delivering keynote lecture.



Dave joined by daughter Wendy, an invited speaker of the symposium.



Jennifer Mae Jackson, Ph.D. 2005

Department of Geology
University of Illinois at Urbana-Champaign

Dissertation: **The effect of minor elements on the physical and chemical properties of lower mantle minerals at high-pressure**

The sound velocities, elasticity, and crystal chemistry of minerals in Earth's lower mantle are of general importance for the interpretation of seismic wave observations, geochemical modeling, and geodynamic simulations. Aluminum-bearing (Mg,Fe)SiO₃ perovskite and (Mg,Fe)O ferropericlase are proposed to be the most abundant phases in Earth's lower mantle, with aluminum-bearing (Mg,Fe)SiO₃ perovskite occupying roughly half of Earth's volume. Despite their major roles in the deep Earth, our knowledge about the sound velocities and crystal chemistry of these chemically complex materials under the appropriate pressure-temperature conditions is still quite limited. In this study, Brillouin spectroscopy was applied to determine the sound velocities, as well as novel nuclear resonant scattering of synchrotron radiation to investigate the electronic state of iron (which is thought to influence material properties) in candidate lower mantle minerals.

Brillouin spectroscopy measurements were performed to determine the sound velocities and elasticity of polycrystalline aluminous MgSiO₃ perovskite (containing 5 wt.% Al₂O₃) to 45 GPa and single-crystal (Mg_{0.94}Fe_{0.06})O ferropericlase to 20 GPa. The measurements were made with diamond anvil cells using methanol-ethanol-water or neon as pressure-transmitting media. The results indicate that the shear sound velocities and elastic moduli of these chemically complex phases are significantly lower than their Mg end-members. In combination with a one-dimensional average Earth model (PREM), the results show that the average mineralogy of Earth's lower mantle should be enriched in Si compared to a peridotitic upper mantle. Furthermore, observed seismic lateral variations in Earth's lower mantle could be caused by a variation in the aluminum content of silicate

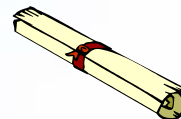


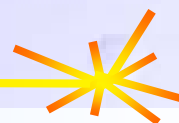
perovskite. In addition to sound velocity measurements, synchrotron Mössbauer spectroscopy measurements of (Mg,⁵⁷Fe)SiO₃ perovskite were carried out to 120 GPa at sector 3-ID of the Advanced Photon Source (Argonne National Laboratory). The electronic properties, including the charge and spin states, of iron in silicate perovskite were determined to 120 GPa at room temperature. A continuous spin crossover terminating at about 70 GPa was observed in the Fe³⁺ component of (Mg,Fe)SiO₃ perovskite.

Statement

I would like to thank my Ph.D. thesis advisor, Professor Jay Bass at the University of Illinois at Urbana-Champaign, as well as my colleagues and collaborators at UIUC and the Advanced Photon Source for many exciting times during my graduate studies. Presently, I am a Visiting Scientist with the high-resolution x-ray scattering group, led by Wolfgang Sturhahn, at the Advanced Photon Source. I am working on projects involving nuclear resonant spectroscopy under extreme pressures and temperatures in an effort to understand the deep interiors of planets. In the fall, I will be a Postdoctoral Fellow at the Geophysical Laboratory of the Carnegie Institution of Washington.

— Jennifer





Hello! My name is Husin Sitepu and I am a postdoctoral research associate employed by COMPRES to help broaden the earth science neutron scattering community and to stimulate and promote

the use of neutron scattering methods, especially at high pressures and temperatures. Nine recent examples of high P/T neutron applications in the earth sciences are described in my poster given at the 4th Annual COMPRES meeting and will be available on <http://www.compres.stonybrook.edu/>.

Recent neutron research in the earth and environmental sciences was also highlighted at the *Neutrons Frontier of the Earth Sciences and Environment* (NESE-2005) symposium in Vienna in April. A range of topics were covered including in-situ investigations of minerals and phase transitions at high P/T, the hydrous component of minerals, silicate melts, magmas and glasses, magnetism, rock textures and stress and strain analyses. The development of Kirkpatrick-Baez (K-B) mirrors by Gene Ice (ORNL) and co-workers for focusing neutrons was one of the noteworthy technical achievements presented. A summary of the symposium and presentations can be found at http://neutron.neutron-eu.net/n_nmi3/n_networking_activities/n_nese.

Neutron Meetings & Workshops

- National School on Neutron and X-ray Scattering (August 14-28, 2005, Argonne National Laboratory, USA). (<http://www.dep.anl.gov/nx/>)
- XX IUCr Congress (August, 23-31, 2005, Florence, Italy). (<http://www.iucr2005.it/>)
- Magnetism, Neutrons and High-Pressure (Sept. 1-2, 2005, Edinburgh, UK). (http://www.csec.ed.ac.uk/NSG_main.html/)
- NSE2005 : Spin-Echo workshop at the ILL (September 8-10, 2005, Grenoble, France). (<http://www.ill.fr/YellowBook/IN11/NSE2005/>)
- Theoretical Problems in Fundamental Neutron Physics (Oct14-15, 2005, Columbia, SC, USA). (<http://www.physics.sc.edu/TPFNP/>)
- International Conference on Neutron Scattering (Nov 27 - Dec 2, 2005, Sydney, Australia). (<http://www.icns2005.org/>)

In other news, Dr. Jianzhong Zhang and Dr. Yusheng Zhao of the Lujan Jr. Neutron Scattering Center, Los Alamos National Laboratory used a toroidal anvil press (right photo) and discovered the glass formation in pure zirconium metal



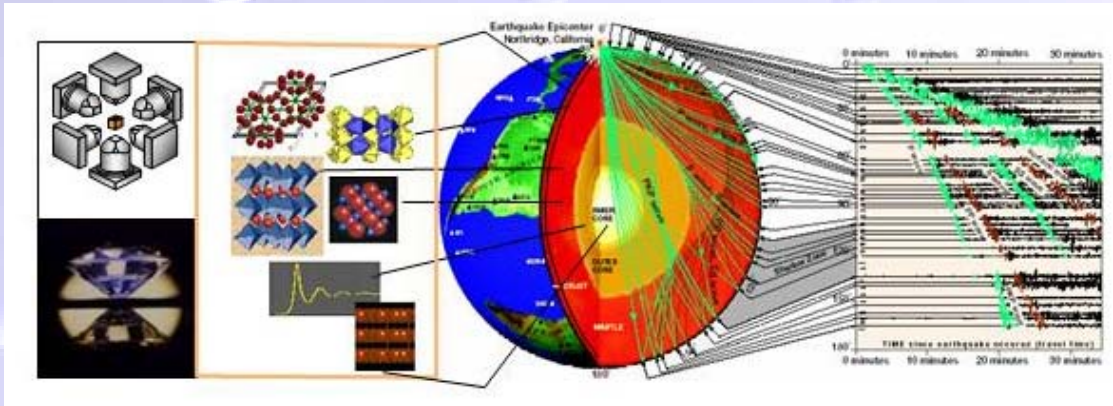
(<http://www.lanl.gov/worldview/news/releases/archive/04-068.shtml>). Dr Chris Benmore and colleagues of the Intense Pulsed Neutron Source (IPNS), Argonne observed the atomic structure of a dense, purely octahedral glass in GeO₂ at 5GPa (http://www.anl.gov/Media_Center/News/2004/IPNS_041210.html). Scientists working at the Institut Laue-Langevin, Grenoble discovered a crystal which – in open defiance of the accepted laws of physics – melts when it is cooled and "freezes" when it is heated! The team believes that hydrogen bonds are responsible for this intriguing behavior (http://www.ill.fr/pages/press/gb/press_releases/crystal.htm). The Spallation Neutron Source in Oak Ridge, TN (www.sns.gov) is only one year from completion. Chris Tulk is the instrument scientist in charge of the design and construction of the SNAP (Spallation Neutrons At Pressure) diffractometer for the SNS which will be used to study a variety of powdered and single crystal samples under extreme conditions of pressure and temperature. The increased neutron flux coupled with large volume pressure cells utilizing large synthetic single crystal opposed anvils will allow significant advances in the pressure range accessible to neutron diffraction. The pressure goal is 50-100 GPa on ~1 mm³ samples on a routine basis.

On a final note, we are modifying the COMPRES Neutron website (<http://www.crystal.vt.edu/compres/>). There will be a section where you can download (i) educational materials for teaching <Education Materials>, (ii) check deadlines for submission of proposals to neutron facilities <Neutrons Sites> and (iii) application information for financial aid for US-based earth scientists (especially Ph.D. students and postdoctoral research fellows) to carry out high P-T neutron scattering experiments and/or to participate in workshops and conferences on neutron scattering <Applying for Support>. Questions and requests should be submitted to me at sitepu@vt.edu.

— Husin Sitepu

Promoting communication between Mineral Physics and other Earth Science Disciplines

As we progress to refinement of the structure of Earth's interior, interdisciplinary approaches become essential to reveal fine structure of the planet. In view of the demand of integrated research in Earth science, COMPRES is playing a leading role in promoting the communication between mineral physics and other Earth science disciplines including geochemistry,



seismology, petrology and geodynamics. At its 4th annual meeting, COMPRES organized three research-oriented focus sessions; each of which paired off two keynote lectures from mineral physics and non mineral physics. Invited speakers from geochemistry and seismology delivered very strong message of the need for mineral physics input in their most challenging research. Geochemist Albrecht Hoffman clearly demonstrated in his talk that the evolution of the convection model of Earth's interior heavily depends on experimental data of physical properties of minerals at the pressure and temperature conditions of Earth's interior. Both seismologists, Barbara

Romanowicz and Miaki Ishii, presented puzzles in illustrating the seismic observations in the Earth's mantle and the core. Mineral physics input are demanded to reveal the nature of superplumes and inner core layers. On the Other hand, seismologist,

Wang-ping Chen, demonstrated the critical role of seismic observation in validating mineral

physics models of deep-focus earthquakes. Participants of the annual meeting from both within and outside the mineral physics community recognized the essential of interdisciplinary effort in solving critical issues in Earth science.

The COMPRES annual meeting has become a platform for such interdisciplinary discussion and nucleation of collaborative research. We have been pleased with the increasing number of participants from outside mineral physics at the annual meeting, among whom are past invited speakers, Richard O'Connell and Guy Masters (also member of the COMPRES Advisory Committee). ■

COMPRES ANNUAL MEETING

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