

³Geophysical Laboratory, Carnegie Institution of Washington, 5251 Broad Branch Road, NW, Washington, DC 20015, United States

⁴Laboratoire de minéralogie-cristallographie physique, Université Paris-6, case 115, Paris 75252, France

Knowing the physical properties of Fe-based liquids would greatly improve our understanding of the composition of planetary cores as well as their formation. A complementary approach is the experimental determination of ternary and quaternary phase diagrams. At ambient pressure, ternary diagrams of potential liquid core materials show a large gap of miscibility (Fe-Si, Fe-FeO and Fe-S-C systems). This would limit for instance the solubility of Si in a primary Fe-S melt percolating through the surrounding silicates during planetary differentiation.

Two issues will be addressed: 1) what are the equations of state of simple binary liquid Fe-alloys?, and 2) how the Fe-Si ternary diagram evolves with pressure in terms of im/miscibility? Density of liquid Fe-Si alloys was measured *in situ* at high pressure by an X-ray absorption technique using synchrotron radiation. We compare the equations of state of Fe, Fe-Si and Fe-S liquids to identify the effect of light elements, Si or S, on the compressibility, local order and P-waves velocity of these materials. These data give us a basis to apprehend more complicated though more realistic ternary systems. We report melting experiments in the Fe-S-Si system conducted in a multi-anvil apparatus up to 27 GPa. The chemical evolution of both liquids with pressure and temperature is followed by *in situ* x-ray diffraction experiments. The experiments document the change of melting relations with increasing pressure. The results have important implications for the differentiation processes of the planets and the composition of their cores.

P42A-02 1100h

Equation of State of Liquid Fe-17wt%Si: Si in the cores of planetary bodies?

Xueyang Yu¹ (xyu22@uwo.ca)

Richard A. Secco¹ (1-519-661-4079; secco@uwo.ca)

¹Department of Earth Sciences, Univ. of Western Ontario, London, ON N6A 5B7, Canada

It is widely accepted that 8-18wt% light elements in the Earth's outer core can explain the 10% density deficit compared to the pure Fe at the core pressure and temperature. Si is one of the most probable light elements in the outer core and is also a candidate for other planetary bodies (Mars, Ganymede, Io). In this study, equation of state (EOS) of liquid Fe-17wt%Si is being explored to investigate the possible existence of Si in the cores of planetary bodies. Sink-float static high pressure density measurement technique with composite spheres is used to bracket the liquid density by either sinking, floating or neutrally buoyant markers. The composite spheres consist of a Pt or WC core and a ruby mantle, with adjustable density by changing the radius ratio of the core and mantle material, thus increasing the range of density measurement and accuracy of bracket value. The chemically inert mantle efficiently protects the metal core from reacting with the sample. The high density of Pt/WC core ensures a composite sphere with high enough density and relative small volume to be accommodated within the pressure cell. Density of the probe spheres at high P, T was calculated from the post-experiment geometric analyses according to the areal ratio of the mantle and core materials. Compressibility and thermal expansion coefficients of these materials were used in the third-order Birch-Murnaghan EOS to calculate composite sphere density. The density of liquid Fe-17wt%Si at room pressure was estimated to be approximately 5.86 g/cm³, which is taken as a reference for constructing a reliable EOS. The results of experiments so far to 8GPa and at 1773K will be reported.

P42A-03 1115h

Alloying effects of Ni, Si, and S on the phase diagram and sound velocities of Fe under high pressures and high temperatures

Jung-Fu Lin¹ (202-4788911; j.lin@gl.ciw.edu);

Yingwei Fei¹ (fei@gl.ciw.edu); Wolfgang Sturhahn² (sturhahn@aps.anl.gov); Jiyong Zhao² (jzhao@aps.anl.gov); Ho-kwang Mao¹ (mao@gl.ciw.edu); Russell Hemley¹ (hemley@gl.ciw.edu)

¹Carnegie Institution of Washington, 5251 Broad Branch Road NW, Washington DC, DC 20015, United States

²Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL 60439, United States

Iron-nickel is the most abundant constituent of the Earth's core. The amount of Ni in the core is about

5.5 wt%. Geophysical and cosmochemical studies suggest that the Earth's outer core also contains approximately 10% of light element(s) and a certain amount of light element(s) may be present in the inner core. Si and S are believed to be alloying light elements in the iron-rich planetary cores such as the Earth and Mars. Therefore, understanding the alloying effects of Ni, Si, and S on the phase diagram and physical properties of Fe under core conditions is crucial for geophysical and geochemical models of planetary interiors.

The addition of Ni and Si does not appreciably change the compressibility of hcp-Fe under high pressures. Studies of the phase relations of Fe and Fe-Ni alloys indicate that Fe with up to 10 wt% Ni is likely to be in the hcp structure under inner core conditions. On the other hand, adding Si into Fe strongly stabilizes the bcc structure to much higher pressures and temperatures (Lin et al., 2002). We have also studied the sound velocities and magnetic properties of Fe_{0.92}Ni_{0.08}, Fe_{0.85}Si_{0.15}, and Fe₃S alloys with nuclear resonant inelastic x-ray scattering and nuclear forward scattering up to 106 GPa, 70 GPa, and 57 GPa, respectively. The sound velocities of the alloys are obtained from the measured partial phonon density of states for ⁵⁷Fe incorporated in the alloys. Addition of Ni slightly decreases the V_P and V_S of Fe under high pressures (Lin et al., 2003). Si or S alloyed with Fe increases the V_P and V_S under high pressures, which provides a better match to seismological data of the Earth's core. We note that the increase in the V_P and V_S of Fe_{0.85}Si_{0.15} and Fe₃S is mainly contributed from the density decrease of adding Si and S in iron. Time spectra of the nuclear forward scattering reveal that the most iron rich sulfide, Fe₃S, undergoes a magnetic to non-magnetic transition at approximately 18 GPa from a low-pressure magnetically ordered state to a high-pressure non-magnetic ordered state. The magnetic transition significantly affects the elastic, thermodynamic, and vibrational properties of Fe₃S. It is conceivable that the magnetic collapse of Fe₃S may also affect the binary phase diagram of the iron-sulfur system, changing the solubility of sulfur in iron under higher pressures. Study of the non-magnetic phase is more relevant to understand the properties of the Fe₃S under planetary core conditions where high pressures and high temperature ensure the non-magnetic ordering state, affecting the interpretation of the amount and properties of sulfur being in the planetary cores. If the Martian core is in the solid state containing 14.2 wt% sulfur, it is likely that the non-magnetic Fe₃S phase is a dominant component and that our measured sound velocities of Fe₃S can be used to understand the velocity profile in the Martian core.

P51A CC: 519 B Friday 0830h

Subsurface Radar Investigations of Terrestrial Martian Analogues I (joint with GP, H, V, NS)

Presiding: E Heggy, Lunar and Planetary Institute; S Arcone, Cold Regions Research and Engineering Laboratory (CRREL); S Clifford, Lunar and Planetary Institute

P51A-01 0835h

Subsurface Radar Investigations of Terrestrial Martian Analogues: Introduction to the Session

Clifford Stephen¹ (281 486 2146; clifford@lpi.usra.edu)

Essam Heggy¹ (heggy@lpi.usra.edu)

Steve Arcone² (Steven.A.Arcone@erdc.usace.army.mil)

¹Lunar and planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058, United States

²ERDC/ U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), 72 Lyme Road, Hanover, NH 03755-12, United States

The Mars Exploration Program has identified the search for subsurface water on Mars as a key investigation towards understanding the hydrologic and geologic history of the planet and for identifying potential environments for the survival of primitive life forms. During the coming decade, a variety of geophysical tools will be used to address this task in an effort to reduce the ambiguities concerning the state, distribution and total abundance of water within the Martian crust. Over the next decade, this search for water will involve as many as three different radar sounding instruments, operating over a combined frequency range of 0.5 MHz - 1 GHz. The ability of these radars to detect and identify the presence of liquid water will and further subsurface features strongly depend on the physical properties, mineralogy and thermal structure of

the Martian subsurface, especially by the way in which these properties influence the electrical and magnetic characteristics of the crust. Our understanding of the data returned by such investigations, will benefit from geophysical studies of terrestrial analog environments, such as the arctic, volcanic terrains and arid deserts. An important complement to these field investigations will be the electromagnetic characterization of rock and soil samples retrieved from these analog sites, mineralogical matches to the composition of the Martian regolith inferred from orbital and landed investigations, and the SNC meteorites.

P51A-02 0850h

Electromagnetic Subsurface Soundings at HF frequencies and Antenna Impedance Measurements on the Antarctic Continent

CIARLETTI Valeria¹ (33-1-3925-4866;

@cetp.ipl.fr); BERTHELIER Jean-Jacques²

(33-1-4511-4242;

jean-jacques.berthelier@cetp.ipl.fr); NEY

Richard² (33-1-4511-4248;

richard.ney@cetp.ipl.fr); HAMELIN Michel²

(33-1-4511-4279; michel.hamelin@cetp.ipl.fr);

BONAIME Sebastien² (33-1-4511-4267;

sebastien.bonaime@cetp.ipl.fr); Dolon Francois²

(33-1-4511-4266; francois.dolon@cetp.ipl.fr);

REINEIX Alain³ (33-5-5545-7354;

reineix@unilim.fr)

¹Centred'Etude des Environnements Terrestre et Planetaires, 10/12 avenue de l'Europe, Velizy 78140, France

²Centred'Etude des Environnements Terrestre et Planetaires, 4 avenue de Neptune, Saint Maur 94107, France

³IRCOM - Universite de Limoges, 123 avenue Albert Thomas, Limoges 87060, France

In the frame of the NETLANDER project, a ground penetrating radar (GPR) dedicated to the exploration of the Martian subsurface has been developed. This GPR is designed for deep sounding down to a depth which is sufficient to allow possible detection of liquid water and thus operates mainly at a frequency of 2 MHz. Contrary to the normal mode of operation of subsurface radars which can be moved over the soil to be explored, the GPR of NETLANDER aims at performing 3D imaging of the underground reflecting structures even if it operates in a fixed position. This is achieved by retrieving not only the distance of the reflectors but also the direction of the backscattered waves by measuring the 2 horizontal electric components and the 3 magnetic components of the reflected waves. Two perpendicular dipoles each consisting in two 35-meters electric monopoles are used for both transmission and reception, while the receiving magnetic antenna can be successively directed along 3 mutually orthogonal directions. In addition, the perfect stability of the environment allows a very large number of coherent integrations to be performed, which provide a satisfactory sensitivity. Ground tests were recently carried out on the Antarctic continent in 2004. Soundings at frequencies in the range 2-5 MHz have been performed with the NETLANDER monostatic GPR prototype and with the updated version of this instrument, which operates in a real bistatic mode. As expected the echoes due to interaction with the bedrock are detected and the magnetic component measurements provide information linked to the orientation of the reflecting structures. The first experimental results will be reported. We will present results on the electric antenna impedance measurements, which give information on the permittivity of the upper subsurface layer. We will also focus on the analysis of the backscattered signals using both electric and magnetic components of the received field. Comparisons with numerical simulations taking into account the actual environment of the GPR will also be presented.

P51A-03 0905h

The SORA experiment: a test of the penetrating radar SHARAD of the Mars Reconnaissance Orbiter mission

Gian Gabriele Ori¹ (39-085-453-7534; ggori@irsps.unich.it)

Enrico Flamini² (enrico.flamini@asi.it)

Roberto Seu³ (roberto.seu@uniroma1.it)

Lucia Marinangeli¹ (luciam@irsps.unich.it)

¹IRSPS, Univ. d'Annunzio Viale Pindaro 42, Pescara 65127, Italy

²ASI, Solar System Exploration Via di Villa Grazioli, Roma 00100, Italy

³INFCOM, Universita' La Sapienza Via Eudossiana, Roma 00100, Italy

SORA is part of a test programme of the Agenzia Spaziale Italiana (ASI) in order to test the two penetrating radars that ASI has prepared for the Mars exploration. The first instrument is MARSIS on board of Mars Express ESA mission; the other is SHARAD for the Mars Reconnaissance Orbiter NASA mission. The SORA experiment will be dedicated to testing SHARAD. MARSIS has a strong penetration power (a few kilometers) and lower vertical resolution, whereas SHARAD will penetrate only several 100s meters but its data will have high-resolution range. SORA will consist of a stratospheric balloon flaying at about 35 km above sea level will carry the experiment. The balloon will carry a model of SHARAD with the electronics scaled to the experiment parameters. The balloon will be launched from Svalbard where the facility of the Italian base will be used. Simulations of the balloon trajectory show a circular shape with a landing area within 100 km from the launch pad. During the flight the balloon will get data from northern Greenland the Canadian Archipelago and part of northern Siberia and adjoining islands. The experiment will be able to investigate thick ice sheets, permafrost areas, seasonally snow covered zones and sea ice. This experiment will support the analysis of the SHARAD data and will provide some clues on the use of a similar instrument on the icy satellites.

P51A-04 0920h

Ground Penetrating Radar Measurements of Ice and Frozen Ground in the Mackenzie Delta, NWT, Canada

Kevin K. Williams¹ (williamsk@nasm.si.edu)

John A. Grant¹ (grantj@nasm.si.edu)

Alan E. Schutz² (Alan.S@geophysical.com)

¹Center for Earth and Planetary Studies, National Air and Space Museum Smithsonian Institution, Washington, DC 20013-7012, United States

²Geophysical Survey Systems, Inc., 13 Klein Drive, North Salem, NH 03073, United States

Ground Penetrating Radar (GPR) is an efficient, non-invasive tool for subsurface investigations. Whereas low frequency orbital and airborne radar sounders can penetrate hundreds of meters or even a few kilometers, ground-coupled GPR operating between 100 and 1000 MHz can penetrate 10 to 20 m below the surface. GPR data from the top 10s of meters provide high-resolution information about the electrical properties and geologic structure of the shallow subsurface. On Earth, geologic GPR surveys have been used to study the third dimension (depth) of geologic relationships observed at the surface. Depth information is a significant addition to understanding the geologic setting and history of a field site. In recognition of the potential for a rover-deployed Mars GPR to help characterize future landing sites, fieldwork is being conducted at martian analog sites to demonstrate and assess the capabilities of GPR in those environments. Data are collected using commercial antennas at several frequencies as well as a prototype Mars GPR antenna currently under development. To complement past GPR measurements from arid environments in Arizona, California, and Egypt, fieldwork is planned to collect data in areas with ground ice and frozen ground. Data collection is planned in the Mackenzie Delta region of Northwest Territories, Canada, for late March when the average air temperature is -14°C and the ground has been constantly frozen for more than five months. The Mackenzie Delta offers analogs for various terrains and features that may exist at mid- to high-latitudes on Mars. This area has been the focus of previous studies of ground ice, and the GPR measurements will be coordinated with a study using resistivity measurements to map ice. In addition, shallow seismic data will be collected, and existing bore hole data will be used to tie geophysical measurements to the local geology. Data will be collected over ice wedges, a pingo, snow-covered gullies, the transition from ice-poor to ice-rich ground, and over ground ice overlain by sand and by gravel. If weather conditions permit, data will also be collected on frozen lake and sea ice.

P51A-05 0935h

The Potential of Low-Frequency (16-80 MHz) Ground Penetrating Radar to Investigate the Shallow Subsurface in the Arid, Volcanic, and Conductive Soils Near Yucca Mountain: Implications for MARSIS and SHARAD

Essam Heggy¹ (heggy@lpi.usra.edu)

Stephen Clifford¹ (clifford@lpi.usra.edu)

Robert Grimm² (grimm@boulder.swri.edu)

Cynthia L. Dinwiddie³ (cldinwiddie@cnwra.swri.edu)

¹Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058-1113, United States

²Southwest Research Institute, 1050 Walnut St, Suite 400, Boulder, CO 80302, United States

³CNWRA at Southwest Research Institute, 6220 Culebra Road, San Antonio, TX 78228-0510, United States

In March 2004, the MARSIS radar sounder aboard the Mars Express spacecraft will begin acquiring the first of what will eventually be a global data set of the radar properties of the Martian subsurface within the frequency range of 0.5-5 MHz. Because no MARSIS prototype was ever built, and only limited GPR investigations of the Earth have been made within this frequency range, we plan to conduct a comprehensive radar investigation of a number of well-characterized terrestrial analog sites over the range of frequencies that will be employed by MARSIS and future Mars radars. The ability of these radars to determine the subsurface stratigraphy, structure, and distribution and aqueous history of water on Mars will be strongly dependent on the physical properties, mineralogy, and thermal structure of the subsurface properties that will define the electrical and magnetic characteristics and ultimately determine the propagation, scattering and reflective properties of the crust. The arid volcanic environment around Yucca Mountain, Nevada has many similarities to the geologic environment of Mars. For example, the soil mineralogy is dominated by the presence of iron oxides, materials that can result in significant electrical and magnetic losses to the radar signal, thus affecting the maximum sounding depth and depth at which any subsurface feature can be identified. In order to evaluate and quantify the magnitude of these losses, we performed a 16 - 80 MHz GPR survey at several well-characterized areas in a region to the southwest of Yucca Mountain. A principal goal of this survey is to determine the extent to which these adverse soil properties influence the identification of subsurface stratigraphy, structure, and a water table at depths ranging from several tens to hundreds of meters. We will present a summary of the field and laboratory data acquired during this survey and discuss its implications for radar sounding investigations of Mars

P51A-06 0950h

Specular Reflection of Mars Odyssey's UHF Beacon from H2-Enriched Northern Martian Latitudes

John L Callas¹ (John.L.Callas@jpl.nasa.gov)

Michael D Cousins² (michael.cousins@sri.com)

Hrefna Marin Gunnarsdottir³ (hrefna@stanford.edu)

Ivan R Linscott³ (linscott@Stanford.edu)

G. Leonard Tyler³ (len@nova.stanford.edu)

¹Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109, United States

²SRI International, 333 Ravenswood Ave., Menlo Park, CA 94023, United States

³Stanford University, Packard Engineering 350 Serra Mall, Stanford, CA 94305, United States

On August 29th, 2003, the Mars Odyssey UHF beacon and its specular reflection off the Vastitas Borealis surface of Mars was detected with the SRI/Stanford 46-m dish antenna. The specular reflection at Doppler compensated frequencies near 437.1 MHz had an SNR of 6 dB/Hz, and the specular point traversed an arc from Martian latitudes and longitudes starting at [58,280], up to [68,272], and ending at [53,326]. Although weak, the signal incurred an abrupt transition in intensity and bandwidth near [66,300], which interestingly is where the Odyssey GRS H2 maps indicate the H2 concentration itself transitions from high to low. Because the UHF signal's wavelength is 0.686 m, the specular reflection's ability to sense subsurface conditions, particularly the regularity and depth of the scattering interface, may be evident in the intensity and bandwidth profile of the reflection.

P52A CC: 519 B Friday 1030h

Subsurface Radar Investigations of Terrestrial Martian Analogues II

(joint with GP, H, V, NS)

Presiding: E Heggy, Lunar and Planetary Institute; S Arcone, Cold Regions Research and Engineering Laboratory (CRREL); S Clifford, Lunar and Planetary Institute

P52A-01 1035h

Exploring Subsurface Geology Using Radar Techniques: Experiments in Sahara and Consequences for Mars Exploration

Philippe Paillou¹ (33-557776126; paillou@obs.u-bordeaux1.fr)

Gilles Grandjean² (g.grandjean@brgm.fr)

Essam Heggy³ (heggy@lpi.usra.edu)

Tom Farr⁴ (tom.farr@jpl.nasa.gov)

¹Observatoire de Bordeaux, 2 rue de l'Observatoire BP 89, Floirac 33270, France

²Bureau de Recherches Geologiques et Minieres, 3 avenue Claude Guillemin BP 6009, Orleans 45060, France

³Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston, TX 77058, United States

⁴Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109, United States

For several years, we have conducted a quantitative study of radar penetration performances in various desert arid environments. This study combines both SAR (Synthetic Aperture Radar) imaging from orbital and airborne platforms and in situ GPR (Ground Penetrating Radar) measurements. Laboratory characterization of various minerals and rocks are used as input to electromagnetic models such as IEM (Integral Equation Model) and FDTD (Finite Difference Time Domain) that describe the subsurface scattering process for inversion purposes. Several test sites were explored, mainly the Sahara. Our first experiment was realized in Republic of Djibouti, an arid volcanic area which is a good analog to Mars. We observed a very little radar penetration there because of the presence of iron oxides and salts in the subsurface that make the soil conductive [Paillou et al., GRL, 2001]. A more favorable site for radar penetration was then explored in southern Egypt: the Bir Safsaf area where buried river channels were discovered using orbital SAR images. We showed how to combine SAR and GPR in order to obtain a complete description of subsurface geology down to several meters [Paillou et al., IEEE TGRS, 2003]. Such field experiments were the basis for more systematic laboratory measurements of the electromagnetic properties of various rocks and minerals which were used in numerical models in order to simulate the performances of future Martian radars, e.g. MARSIS and NETLANDER low frequency radars [Heggy et al., Icarus, 2001; Berthelier et al., JGR, 2003; Heggy et al., JGR, 2003]. More recently, new explorations were conducted in Mauritania in order to demonstrate radar capacities for geologic mapping [Grandjean et al., Coll. Afr. Geol., 2004] and in Libya where radar discovered a double impact crater in the southern desert [Paillou et al., C.R. Geoscience, 2003]. More local radar experiments were also conducted on a test site located in France, the Pyla sand dune, where we observed and modeled a radar signature of subsurface water [Grandjean et al., IEEE TGRS, 2001; Paillou et al., IGARSS'03, 2003]. All of these results shall be used in the context of "terrestrial analogs to Mars" studies in order to prepare for future Mars exploration using radars [Farr et al., Planet. Dec. Study, 2002; Paillou et al., 35th LPSC, 2004]: it concerns both GPR instruments onboard rovers and landers devoted to the exploration of the deep subsurface [Berthelier et al., ESA Paster, 2003] and SAR imaging systems onboard orbital platforms for global mapping of the shallow subsurface geology [Paillou et al., Conf. Water Mars, 2001].

P52A-02 1050h

Mars Orbital SAR: Obtaining Geologic Information from Radar Polarimetry

Bruce Campbell¹ (202 633 2472; campbell@nasm.si.edu)

Ted Maxwell¹ (maxwell@nasm.si.edu)