of an electromagnetically probable thermal horizon on Europa would be one characterized by water (or brine) pockets lying along a eutectic at the base of cold brittle ice lying over warmer ductile ice (that is possibly convecting). Such an interface is hypothesized to lie within a few kilometers of Europa's surface. An analogous electromagnetic horizon on Earth is the boundary between polar ice and the temperate ice that lies beneath it on the glaciers of Svalbard. A compositional horizon on Europa that might be electromagnetically probed would be the ice-ocean interface beneath a simple (thermally conducting) shell that has been modified by tidal/tectonic processes. Another compositional horizon would be the boundary with accreted ice that is hypothesized to lie beneath inactive "chaotic" zones in these models. Many electromagnetic analogs for the compositional horizons in these tidal/tectonic models can be found in Antarctica's floating ice shelves and subglacial lakes. One also expects ubiquitous near-surface structural horizons associated with both transform and normal faulting in the tidally/tectonically modified models of Europa's icy mantle. The analogous electromagnetic horizons on Earth may be found in the shear margins and grounding zones of the Antarctic valley glaciers and ice streams. Our ultimate goal is to review the relevant radar studies of analogous polythermal glaciers and Antarctic ice shelves as well as to present new results from our most recent airborne radar studies of Antarctic ice stream, valley glacier and subglacial lake analogs.

P42B-08 1530h

The Surface of Titan: Arecibo Radar Observations

Donald B Campbell[1] (607-255-3735; campbell@astro.cornell.edu)

Gregory J Black[2] (434-243-8941; gblack@virginia.edu)

Lynn M Carter[3] (607-255-3317; lcarter@astro.cornell.edu)

Steven J Ostro[4] (818-354-3173; ostro@reason.jpl.nasa.gov)

[1]National Astronomy & Ionosphere Center, Cornell University 528 Space Sciences Bldg, Ithaca, NY 14853-6801, United States

[2]University of Virginia, Department of Astronomy PO Box 3818, Charlottesville, VA 22903, United States

[3]Cornell University, Department of Astronomy Space Sciences Bldg, Ithaca, NY 14853-6801, United States

[4]California Institute of Technology, Jet Propulsion Laboratory 4800 Oak Grove Dr., MS 300-233, Pasadena, CA 91109-8099, United States

The Arecibo 12.6 cm radar system was used to obtain echo spectra for Titan in late 2001 and late 2002. A circularly polarized signal was transmitted with the Arecibo 305 m antenna and the echo was received in both the OC (expected for a mirror like reflection) and SC senses of circular polarization. For most of the observations Arecibo was used to receive the echo but for one observation in 2001 and for most of the 2002 observations the new 100 m Green Bank Telescope (GBT) was also used. Arecibo's limited tracking time combined with the 2 hr 15 min round-trip-light time to the Saturn system meant that it could only receive the echo for about 30 min corresponding to 0.5 deg of Titan rotation. For echo reception with the GBT the signal-to-noise ratio is lower but the echo can be received for the full round-trip-time corresponding to over 2 deg of motion of the sub-earth point on Titan. Sixtenn spectra were obtained in 2001 at sub-earth points uniformly spaced over the full range of longitudes. The 9 Arecibo/Arecibo and 15 Arecibo/GBT observations in 2002 did not provide uniform coverage. The latitudes of the sub-earth tracks in 2001 and 2002 were 25.9S and 26.2S, respectively. Most of the echo power is contained in a broad diffuse component. However, about 70% of the spectra show a weak specular echo that varies in width and amplitude with sub-earth longitude. The disk averaged normalized radar backscatter cross section varies from about 0.12 near 270 deg to about 0.19 at 90 deg, the longitude of the high near-IR albedo feature. The errors on these values are dominated by systematic errors of about 30%. The circular polarization ratio varies from about 0.4 to 0.6. The OC cross sections as a function of sub-earth longitude correlate very strongly with the disk integrated 2 micron albedoes from Griffith et al (1998). Fits of combined diffuse and specular scattering laws to the 16 2001 spectra resulted in 12 statistically significant specular echoes with the normalized cross sections ranging from 0.007 to 0.04 and rms slopes from 0.5 deg to 3.5 deg. These values for the cross sections are generally consistent with those expected for reflections from liquid hydrocarbons. A mix of liquid ethane, methane and nitrogen at Titan's surface temperature has a dielectric constant in the range of 1.65 to 1.81 (Thompson and Squyres, 1990) corresponding to radar cross sections between 0.016 to 0.022. The measured cross sections are also consistent with reflections from a higher dielectric constant surface of which only a fraction is smooth enough to give a specular echo. References: Griffith, C.A., T. Owen, G.A. Miller and T. Geballe, Nature, 395, 575-578, 1998. Thompson, W.R. and S.W. Squyres, Icarus, 86, 336-354, 1990.

P42C MCC: 2000 Thursday 1600h

Life in the Martian Regolith, Present and Past *(joint with B, C)*

Presiding: **A P Zent,** NASA Ames Research Center**; I Friedmann,** Florida State University

P42C-01 1600h INVITED

Challenges to Life on Mars — Ecological Perspective

Henry Sun[1] (818 354 0600; henry.j.sun@jpl.nasa.gov)

Christopher McKay[2] (650 604 6864; cmckay@arc.nasa.gov)

Imre Friedmann[2] (650 604 1136; ifriedmann@mail.arc.nasa.gov)

Gene McDonald[1] (818 354 8014)

[1]Jet Propulsion Laboratory, 4800 Oak Grove Drive, MS 183-301, Pasadena, CA 91109, United States

[2]Ames Research Center, Space Science Division, 245-3, Moffett Field, CA 94035, United States

This talk will address the habitability of Mars by considering major environmental challenges against the tolerance limits of microorganisms from extreme terrestrial environments including the Antarctic desert and permafrost. At the planet surface, the combination of low atmospheric pressure (below the triple point of water), high fluxes of ultraviolet radiation, and one or more powerful oxidants are likely to create sterilizing conditions that will be a barrier to the colonization and dispersal of microorganisms. In the subsurface below, long-term survival is dependent upon the frequency and duration of warm, metabolically active periods that are needed to repair cellular damages. Low temperature itself does little harm to microorganisms, but a long dormant period will accrue lethal dosages of ionizing radiation and amino acid racemization. It is probable that within the depth range of current sampling technologies, there are no conditions for extant life, leaving organic or inorganic fossils as the only legitimate target in the search for life on Mars.

P42C-02 1615h INVITED

Water bearing halites: Oases of Mars?

Russell H Vreeland[1] (rvreeland@wcupa.edu); William D Rosenzweig[1]; Jennifer Jones[1]; Jessica Krammes[1]; Anne Monson[1]; Tim Lowenstein[2]; Cindy Satterfield[2]; Michael Timofeeff[2]

[1]West Chester University, Department of Biology, West Chester, PA 19383, United States

[2]Binghamton University, Department of Geological Sciences and Environmental Studies, Binghamton, NY 13902, United States

Without liquid water there can be no life as we know it. This tenet focuses our search for extraterrestrial life on celestial bodies that had, or may still have, this essential substance. Searching for extraterrestrial life means selecting samples likely to protect water this requires reaching water containing perma-frosts, underground aquifers, or evaporites. Assuming one finds life similar to that on Earth how can we know it is from another planet and not contamination? This paper focuses on recent isolations of living microbes from halite that is at least 250 million years old. The presentation traces the recent data and theoretical considerations providing evidence for the age of the microbe, differences between it and modern relatives and its survival within water-bearing minerals. The evidence that evaporites may be a natural mechanism for maintaining life under adverse conditions is compelling and suggests that similar materials may be targets on Mars and elsewhere.

P42C-03 1630h INVITED

Unfrozen Water in the Martian Regolith

Aaron Zent (650-604-5517; Aaron.P.Zent@nasa.gov)

NASA Ames Research Center, MS 245-3, Moffett Field, CA 94035

The martian high-latitude, volatile-rich mantle deposit, at least locally, contains more ice than can be accounted for in undisturbed pore volume. Excess ice cannot be cold-trapped from the atmosphere; hypotheses for how excess ice might occur include burying surface ice, or post-depositional in situ processing that causes the formation segregated ice. The terrestrial record indicates that segregated ground ice occurs in a limited number of ways: outright melting and flow, or temperature-dependent suction that develops in a porous freezing soil. Implicit in the post-depositional formation of segregated ice is significant H2O mobility, and consequently, the periodic presence of substantial unfrozen water in the mantle deposit. It is possible that the mantle represents the remnants of a dusty snowbank, or frozen body of surface water. Post-depositional processing would be limited to vapor-phase dessication of the upper tens of centimeters. The correspondence between vapor-phase transport models and the observed GRS distribution of ice suggests that vapor phase transport has operated to redistribute H2O in the deposit. Wedge ice would satisfy the GRS observations, but requires relatively saturated conditions to form in the same manner terrestrial wedges form. In unsaturated soils, water responds to potentials resulting from osmotic and interfacial (matric) forces. Only in near-saturated soils are gravitational potentials strong enough to drive flow. Cryosuction is a response to negative pressure potential in wet soils, and is the dominant redistribution mechanism in unsaturated soil. Cryosuction requires unfrozen water, and effective hydraulic conductivity that allows water to be transported to the freezing front. Accurate orbital tracking through the past few million years of Mars history indicates that substantial unfrozen water might have occurred in many instances, depending upon the meteorologic response to obliquity variations.

P42C-04 1645h

The Potential for Melting of Subsurface Ice at the Phoenix Lander Latitudes in Mars' Recent Past

Robert M Haberle[1] (650-604-5491; Robert.M.Haberle@nasa.gov)

Carol R Stoker[1] (650-604-6490; Carol.R.Stoker@nasa.gov)

[1]NASA/Ames Research Center, Space Sciences Division MS 245-3, Moffett Field, CA 94035, United States

The Phoenix Lander will set down on the surface of Mars in the northern plains between 65N and 75N. Odyssey's Gamma Ray Spectrometer and Neutron Spectrometer have detected large hydrogen abundances in this latitude band that are most likely due to the presence of ice within 50 cm of the surface. Here we report the results from the Ames general circulation model (GCM) on the ability of solar heating and subsurface conduction to melt these deposits. If melting did occur at some time in the past, it would make these latitudes particularly interesting for biological investigations. Melting is not possible in the present epoch because temperatures never get high enough even though surface pressures in this latitude band do exceed the triple point of water. However, about 25,000 years ago the longitude of perihelion was shifted 180 degrees such that perihelion occurred near northern summer solstice rather than northern winter solstice. Simulations of that epoch show broad regions where surface temperatures exceed 273 K enhancing the potential for melting. Indeed, surface temperatures and pressures exceed the triple point for water for as much as 90 sols of total time at some locations. A key question, of course, is whether the ice seen by Odyssey was actually present at those times and if so, at what depth below the surface. This will depend on the ability of the ice to diffuse through the soil and the water vapor content of the atmosphere. However, the short precessional time scale may limit the amount of water that can diffuse out of the soil. And the atmospheric water content will be higher with perihelion at northern summer solstice. We plan to explore these possibilities with the Ames GCM.

P42C-05 1700h

The Phoenix Scout Mission

Peter H Smith (520-621-2725; psmith@lpl.arizona.edu)

University of Arizona, Lunar and Planetary Lab 1629 E. University Ave, Tucson, AZ 85721, United States

Phoenix will restore the 2001 lander to flight condition and select a scientic payload from instruments flown on Mars Polar Lander and delivered for the 2001 lander. Landing in May 2008 at the beginning of northern Summer, Phoenix will explore the subsurface ice layers discovered by Odyssey scientists at about 70 N latitude. Descent and panoramic imaging will reveal the small scale geology of this ice-rich region and a robotic arm will dig layer by layer beneath the surface. A German-supplied camera on the arm will examine the trench walls for stratigraphic clues to the origin of the region. Two instruments on the deck will receive samples taken from various depths from the surface to an impermeable ice layer. A thermal evolved gas analyzer (TEGA) will accept samples in one of eight ovens, heating the samples to 1000C will performing differential scanning calorimetry on them. The gases are piped to a mass spectrometer and all species between 1 and 140 Da are identified. Altered minerals (clays, carbonates,etc.) and organics materials can be clearly identified by the multi-dimensional nature (mass, temperature, and depth) of this experiment. Isotopic ratios for hydrogen, neon, argon, carbon, and nitrogen will give clues to the history of the soils and ices. The MECA instrument performs microscopy, electro-chemistry, and conductivity measurments on samples. Bringing water from Earth and mixing it in a sealed cell with samples creates the same conditions as when the ice melts beneath the surface and allows us to determine the acqueous chemistry of the soils. Acidity, redox potential, and salt content are all acquired giving us the first idea of what the biological potential of this habitat might be. Microscopes examine the grain structures and the thermal and electrical conductivity of the soil is examined with a special probe on the scoop. A Canadian MET station uses a lidar to measure the depth of the boundary layer and also pressure and temperature throughout northern Summer and Fall. Phoenix provides insight into the biological potential of the near surface ice.

URL: http://phoenix.lpl.arizona.edu

P42C-06 1715h

Subsurface Halophilic Microbial Communities in the Hyperarid Core of the Atacama Desert: An Analog for Possible Subsurface Life in Regolith on Mars

Aharon Oren[1] (972-2-6584951; orena@c.huji.ac.il)

Kimberley Warren-Rhodes[2] (650-604-0489; kwarren-rhodes@mail.arc.nasa.gov)

Frederick T. Rainey[3] (frainey@lsu.edu)

Stephanie Ewing[4] (saewing@nature.berkeley.edu)

Christopher P. McKay[2] (cmckay@mail.arc.nasa.gov)

[1]Division of Microbial and Molecular Ecology, The Institute of Life Sciences The Hebrew University of Jerusalem, Jerusalem 91904, Israel

[2]NASA-Ames Research Center, Planetary Sciences Mail Stop 245-3, Moffett Field, CA 94035, United States

[3]Louisiana State University, Department of Biological Sciences 508 Life Sciences Building, Baton Rouge, LA 70803, United States

[4]University of California at Berkeley, Ecosystem Sciences Division Department of Environmental Science, Policy and Management, Berkeley, CA 94720, United States

The Atacama Desert in its driest portion provides an interesting analog for possible past or present life in the Martian regolith. In the hyperarid core of the Atacama, surface soils are virtually abiotic, with no plants and "near sterile" concentrations of heterotrophic bacteria (i.e., exceedingly low densities of approximately 100 colony forming units per gram soil). The dearth of microbial life at the surface is likely maintained through extremely low water availability, low organic content and the highly oxidizing nature of the soil. In marked contrast to the surface, however, extremely halophilic microorganisms exist in salt layers 1.2-1.5m below the surface. Mineralogical analyses indicate the layers are predominantly halite (70% NaCl) but also contain sodium nitrate (5% NaNO3). Culturing and polar lipid analyses suggest the halophiles are archaeal Halobacterium-like motile rods. Microclimate monitoring at 1m indicates a soil relative humidity of 20% which is stable year-round even during decadal rain events such as that experienced in July 2002. This suggests the layers are isolated from even significant moisture influxes at the surface. Although further research is necessary, important parallels exist between this Earthly desert analog and the possible existence and detection of subsurface life on Mars despite harsh abiotic conditions at the surface.

P42C-07 1730h

Sensitive Amino Acid Composition and Chirality Analysis in the Martian Regolith with a Microfabricated in situ Analyzer

Alison M Skelley[1] (alison@zinc.cchem.berkeley.edu)

Frank J Grunthaner[2]

Jeffrey L Bada[3]

Richard A Mathies[1] (1-510-642-3599; rich@zinc.cchem.berkeley.edu)

[1]Department of Chemistry, UC Berkeley, Berkeley, CA 94720, United States

[2]Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109, United States

[3]Scripps Institution of Oceanography, UC San Diego, La Jolla, CA 92093, United States

Recent advances in microfabricated "lab-on-a-chip" technologies have dramatically enhanced the capabilities of chemical and biochemical analyzers. The portability and sensitivity of these devices makes them ideal instruments for in situ chemical analysis on other planets. We have focused our initial studies on amino acid analysis because amino acids are more chemically resistant to decomposition than other biomolecules, and because amino acid chirality is a well-defined biomarker [1]. Previously, we developed a prototype electrophoresis chip, detection system and analysis method where the amino acids were labeled with fluorescein using FITC and then electrophoretically analyzed using g-cyclodextrin as the chiral resolution agent [2]. Extracts of the Murchison meteorite were analyzed, and the D/L ratios determined by microchip CE closely matched those from HPLC and GCMS and exhibited greater precision. Our microchip analyzer has now been further improved by establishing the capability of performing amino acid composition and chirality analyses using fluorescamine rather than FITC [3]. Fluorescamine is advantageous because it reacts more rapidly than FITC, and because excess reagent is hydrolyzed to a non-fluorescent product. Furthermore, the use of fluorescamine facilitates interfacing with the Mars Organic Detector (MOD) [4]. Fluorescamine-amino acids are separated using similar conditions as the FITC-aa, resulting in similar separation times and identical elution orders. Fluorescamine-aa are chirally resolved in the presence of hydroxy-propyl-b-cyclodextrin, and typical limits of detection are $\sim$ 50 nM. This work establishes the feasibility of combining fluorescamine labeling of amino acids with microfabricated CE devices to develop low-volume, high-sensitivity apparatus for extraterrestrial exploration. The stage is now set for the development of the Mars Organic Analyzer (MOA), a portable analysis system for amino acid extraction and chiral analysis that will combine the capabilities of microchip CE with the previously developed extraction capabilities of MOD [4]. Amino acids are first extracted from soil by sublimation to a cold finger coated with fluorescamine for solid phase labeling. Sample transfer between MOD and the CE device is achieved through a capillary sipper driven by microfabricated valves and pumps [5]. The construction of a portable MOA instrument will facilitate in situ studies of amino acids in Mars analog sites such as the Atacama Desert in Chile. Preliminary chiral analyses of Atacama soil extracts on the microfabricated CE device have shown amino acid detection down to low ppb concentrations. Future field tests in the Atacama Desert will explore the feasibility of the portable CE device for performing in situ amino acid analysis. This work will provide the technology base for the development the Mars Organic Laboratory (MOL), a portable device that will analyze a broad suite of biomolecules, including nucleobases, sugars, and organic acids and bases [6]. [1]J.L. Bada, G.D. McDonald, Icarus 114 (1995) 139. [2]L.D. Hutt, D.P. Glavin, J.L. Bada, R.A. Mathies, Anal. Chem. 71 (1999) 4000. [3]A.M. Skelley, R.A. Mathies, J. Chromatogr. A (2003) in press. [4]G. Kminek, J.L. Bada, O. Botta, D.P. Glavin, F. Grunthaner, Planet. Space Sci. 48 (2000) 1087. [5]W.H. Grover, A.M. Skelley, C.N. Liu, E.T. Lagally, R.A. Mathies, Sens. Actuators B 89 (2003) 325. [6]A.M. Skelley, F.J. Grunthaner, J.F. Bada, R.A. Mathies, in SPIE: Proceedings of the In-Situ Instrument Technologies Meeting, Pasadena, CA, 2002.

P42C-08 1745h

What are the best ways to look for extinct or extant life on mars? Thinking outside the box

Jeffrey L. Bada[1] (858 534-4258; jbada@ucsd.edu)

Frank Grunthaner[2] (Frank.J.Grunthaner@jpl.nasa.gov)

Richard Mathies[3] (Rich@zinc.cchem.berkeley.edu)

[1]Scripps Institution of Oceanograph, Univ. Calif. at San Diego, La Jolla, CA 92093

[2]Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109

[3]Dept. Chem., UC Berkeley, Berkeley, CA 94720

Although the Viking missions a quarter century ago performed a series of life detection experiments, the question of whether life ever existed or even still exists on Mars remains unanswered. The finding that the Martian surface is highly oxidizing seemed to preclude the presence of a robust surface biology, but the subsurface may be more compatible with respect to the survival of both viable organisms (1) and organic compounds. Moreover, it is now also known that the Viking GCMS would not have detected refractory organic compounds (2) or amino acids associated with over a million bacterial cells in a gram of soil (3). The entire Mars community now faces a major challenge as to what we should do next in our search for evidence of life on Mars. The option that is presently favored is to fly "safe" missions focused on characterizing the mineral and elemental makeup of the surface with little emphasis on state-of-the-art analyses for important biomarkers. A second, or perhaps parallel, bolder approach would be to fly payloads made up of highly sensitive instruments designed to search for a wide variety of key organic compounds. Instrumentation available to detect trace levels of key biological compounds have improved dramatically since the Viking missions and many of these methods can be miniaturized so they can be accommodated into a spacecraft. The critical issue is what suite of instruments would provide the most definitive results in answering the life on Mars question. To rigorously address this question, we propose that various organic detection systems be extensively tested in situ using a common and well controlled set of samples in an environment that is known to have low levels of both microbes and organic compounds. One locality that would be a strong candidate is the Yungay Station site in the Atacama desert of Chile, one of the driest and harshest places on Earth. Only those instruments that are able to detect at high sensitivity organic biomarkers in a natural field situation such as this should be considered for components for a future Mars mission payload package. If an instrument can not detect the presence of life's organic signature here on Earth, there is no justification for flying this instrument in a payload to Mars! NIH and DOE embarked upon a similar critical competition to development the best methodology to sequence the human genome and this process was dramically successful. NASA's search for possible signs of life on Mars deserves at the same level of critical and competitive decision-making where scientific capability rather than other factors determine what is included in payloads. 1. B. P. Weiss et al, Proc. Natl Acad. Sci USA 97, 1395 (2000). 2. S. A. Benner et al, Proc. Natl Acad. Sci USA 97, 2425 (2000). 3. D. P. Glavin et al, Earth Planet. Sci. Lettrs. 185, 1 (2001).

P51A MCC: 2002-2004 Friday 0800h

Sagan Lecture

P51A-01 0810h INVITED

Extrasolar Planets

Paul Butler (paul@dtm.ciw.edu)

Carnegie Institution, Department of Terrestrial Magnetism 5241 Broad Branch Road, NW, Washington, DC 20015, United States

None of the roughly one hundred hundred extrasolar planets found to date closely resembles the Solar System. Unlike the Solar System, most extrasolar planets are in eccentric orbits. The giant planets in the Solar System all orbit beyond 5 AU, while the known extrasolar planets (with one exception) all orbit within 4 AU, with several in extraordinarily small orbits with periods of days to weeks. Current state-of-the-art technology can only detect giant planets, with the most massive planets being the easiest to detect. Nonetheless the planet mass function rises toward lower masses down to the limit of detection incompleteness, below a jupiter-mass. There are almost no planets more massive than 5 jupiter-masses though these would be the easiest to detect. The planet bearing stars are significantly enriched in elements heavier than hydrogen and helium relative to both the Sun and nearby stars. NASA, the European Space Agency, NSF, and the European Southern Observatory are all focused on "next generation" planet detection technologies including giant ground-based 30 and 100 meter telescopes capable of directly imaging giant planets, space-based interferometers apable of detecting terrestrial-size planets in earth-like orbits, and space-based telescopes capable of directly imaging earth-like planets and taking their spectra. The first of these next generation instruments should be operating by the end of the decade, with first results coming in around 2015. The goal of our group is to survey all Sun-like stars out to 50 parsecs, a total of about 2,000 stars. At the time of this writing (September 2003) we are surveying 1,700 of these stars using the Lick 3-m (California), Keck 10-m (Hawaii), 3.9-m AAT (Australia) and 6.5-m Magellan (Chile) telescopes. Recent discoveries from our group include several systems of multiple planets, the only known transit planet, and the first sub-saturn mass companions, as well as two-thirds of all known extrasolar planets. Solar System analogs, Jupiter and Saturn–like planets orbiting beyond 4 AU, have not yet been discovered. These elusive planets will begin emerging from our existing surveys before the end of this decade. By 2010 our surveys will provide a first planetary census of nearby stars, allowing us to estimate the ubiquity of planetary systems and of "Solar System" analogs, and thus put the Solar System in a Galatic perspective for the first time.

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