Available spacecraft observations of seasonal water will be discussed with the aid of GCM model simulations, and examined in the context of water distributions and phases.

P72C-07 1535h

Seasonal Migration of Water Frost on Mars

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The annual recession of the north polar cap of Mars has been studied with Viking IRTM and MAWD instruments and, more recently, with MOC, TES, and MOLA instruments on the Mars Global Surveyor spacecraft. Discrepancies between certain of these measurements have been attributed to a band of water ice that accompanies and lags behind the retreat of the CO2 seasonal cap. This "migration" would transport heat by transfer of latent heat of sublimation and condensation – a far more efficient process for achieving local thermal equilibrium than atmospheric convection under martian conditions. Related considerations suggest that the form of this migrating water will be low density hoarfrost, which could average centimeters in thickness at the highest latitudes. Local coldtrapping in sheltered locations could further concentrate these seasonal deposits into drifts where, with sufficient heating, localized melting may be possible.

P72C-08 1550h INVITED

Middle- and Polar-latitude Gullies Through the Second Mars Year of MGS MOC Observations

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Middle- and polar-latitude gullies, first observed in Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) 1.5 to 12 m/pixel images [Malin and Edgett, *Science, 288,* 2330-2335, 2000], provide compelling evidence that Mars may have contemporary groundwater at shallow depths (< 500 m). Through July 2002, ∼1200 of the ∼53,000 high resolution images show these landforms. Gullies occur most often, but not exclusively, on poleward-facing slopes of troughs and craters at middle and high latitudes. Northern hemisphere gullies are more likely than those in the south to be on equator-facing slopes. Except for gullies in Nirgal Vallis, few occur equatorward of 30° latitude. The spatial relations suggest gully genesis is sensitive to solar insolation. Banked, leveed, and anastomosing channels suggest transport involved a fluid with all the properties of liquid water; multi-lobed aprons indicate multiple depositional phases or events. Most gullies appear to be geologically young; most are uncratered, not mantled by dust, and have channels that cut and aprons that superpose surrounding landforms. The channels are free of debris; this observation suggests they experience events of sufficient energy to flush material through the channels, and that these events occurred relatively recently because the channels have not become choked with detritus shed from their walls. Although alternative materials such as CO_2, shallowly-emplaced ground ice, or snowmelt have been proposed, the most likely source of fluid is groundwater (fresh, brine, or frozen), suggested not only by morphology but by the occurrence of regional clusters and associations with specific layer(s), both attributes of aquifers. In the past Mars year, MOC has focused on change monitoring of known gullies (no changes have been observed), imaging at higher resolution and in stereo, and a continued global search for additional gullies. Previously identified subclasses of gullies are now distinguished on size, morphology, geography, and topography. For example, gullies on dune slip faces differ in marked ways from other forms; contrary to some predictions, new examples of these have not formed in the past two Mars years.

P72C-09 1610h

Martian aquicludes required for gully formation

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We continue to study the apparently recent Martian gullies in Nirgal Vallis, Dao Vallis, Hale Crater and Gorgonum Chaos using Mars Orbiting Camera (MOC) images. All gullies analyzed here are found on poleward-facing slopes. Every observed gully emanates from within a single competent subsurface rock layer or from a specific competent layer among multilayered strata. The gullies emanate from the layer, even when the layer is faulted, suggesting a causal relationship. We have measured the elevation of gully heads using Mars Orbiter Laser Altimeter (MOLA) data and found the depth of the gully heads measured ranges from approx. 10 to 800 m (average: 280 m; n=70) below the local surface and 2 km above to 5 km below the MOLA datum. To test the hypothesis that the subsurface depth is related to subsurface geology, we calculated average depths below the local surface of the gully heads as a function of mapped surficial geologic unit. Our data show that the average depth of gully heads is more variable in strata beneath geologic units predicted to have greater primary or secondary permeability. We posit that gully heads with a more regular range of depths within a geologic unit indicate a regionally continuous impermeable layer (e.g., ash or clays) approximately parallel to the local surface. Gully heads that show a greater variability in depths within a geologic unit may indicate the occurrence of faulted and/or semipermeable layers (strata with abundant unconformities or disrupted units at craters and chaos). The average elevations of gully heads show no correlation with latitude, suggesting the layer associated with the gully heads is not permafrost.

We advocate a model in which gullies are produced in areas where 1) ground ice is present and 2) is melted in the near-surface within a climate that can sustain liquid water which 3) percolates through any permeable materials down the hydraulic gradient until encountering an impermeable layer (aquiclude). If the impermeable layer dips toward an exposed wall, this groundwater may flow along the layer and discharge at the surface, forming a gully. Implicit in this model is that regions without impermeable layers would lack gullies. At Dao Vallis (approx. 33S to 38S), exiting groundwater contributes to both gullies and deposits of smooth, positive-relief material we interpret to be ice-rich regolith, likely indicative of cooler local surface temperatures than the other gullies examined. The average gully alcove depth of 280 m below the Martian surface probably reflects the relatively high permeability of the upper hundreds of meters due to various weathering processes. The presence of gullies may mark the distribution of subsurface impermeable layers globally. As some of these geologic units are mapped as Noachian, the aquicludes marked by gullies may have controlled the flow of groundwater throughout much of Martian history.

P72C-10 1625h

Mars Polar Gully Modification and Possible Formation from Condensed Volatiles

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The apparently young age of Martian gullies, a morphology indicative of groundwater seepage and surface runoff, and conditions of the near-surface that preclude long-term storage and flow of liquid water has presented a challenge to geologists and theoreticians trying to explain the origin of these enigmatic features. Various hypotheses have been presented and published, including those that invoke obliquity changes and enhanced volatile concentration in the past. Here we present results from MOC image analysis, together with theoretical arguments, showing that water ice is preferentially concentrated in polar gullies by progressive cold trapping in the presence of CO2 frost. Thermal buffering by the CO2 maintains the high concentrations of water within pole-facing gullies until near the summer equinox, when midnight sun incident on steep slopes causes sublimation of the CO2. Water ice may melt under ideal conditions in this scenario or, at the very least, play a role with the CO2 in lubricating surface materials. This process is possible in the present day and is consistent with other observations from surface and orbital Mars platforms showing enhanced volatile concentration over and above atmospheric column abundances. This process likely plays a role in the modification and possibly in the formation of gullies, especially in polar regions of Mars where sufficient volatiles can be concentrated.

P72C-11 1640h

Morphologic, Topographic, and Thermal Analysis of Slope Streaks on Mars

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Surfaces containing features known as slope streaks are common on Mars in regions where thermal-inertia is low and steep slopes are frequent. We have recently compiled a catalog of slope streak images and identified previously unrecognized correlations with surface properties. Building on this work, we analyze data from Mars Orbiter Camera, from Mars Orbiter Laser Altimeter, and from the Thermal Emission Imaging System instrument on board Mars Odyssey, to constrain the physical properties and thermal conditions at the specific sites where slope streaks are forming. A number of proposed theories explaining the formation mechanism of slope streaks can be tested using new data, including an exciting possibility of the potential role of a water phase-transition.

P11A MCC: Hall D Monday 0830h

Small Bodies, Moons, and Earth's Moon Posters *(joint with SM, V)*

Presiding: **R M Nelson,** Jet Propulsion Laboratory**; W D Smythe,** Jet Propulsion Laboratory

P11A-0343 0830h POSTER

Dust Levitation and Transport Near Surfaces

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There are many examples of active dust transport near surfaces in the solar system: dust grains suspended above the lunar surface, spokes observed in Saturn's rings, and recent images of infilled craters from the NEAR spacecraft at Eros. Electrostatic dust levitation and transport have also been theorized to occur on Mercury, asteroids, and comets. Dusty regoliths are produced by the interplanetary micrometeoroid flux on nearly all airless bodies in the solar system. Therefore, understanding dust charging, levitation, and dynamics above surfaces is important for interpreting remote sensing data and analyzing the evolution of most planetary surfaces.

Objects in a plasma, such as planetary bodies in the solar wind, charge to a floating potential determined by the balance between charging currents in the local plasma environment. The primary charging currents are due to collection of electrons and ions from the plasma, photoemission, and secondary electron emission. When photoemission is the dominant charging process, a photoelectron sheath forms near the surface of the object. Positively charged particles released from the surface can levitate above the surface at a height where the gravitational force is balanced by the electric force. In cases where secondary electron emission and photoemission are weak, objects will become negatively charged due to electron collection and will be surrounded by a plasma sheath. Negatively charged dust grains from these surfaces can levitate in the electric field created by the plasma sheath. Dust levitation and transport near surfaces in the solar system is thought to be primarily due to the interaction between charged dust particles and a photoelectron or plasma sheath on the surface.

We report the results of experiments on the levitation and transport of dust particles in an argon

plasma sheath above a flat, conducting surface. Levitation experiments are performed using monodisperse polystyrene DVB microbeads. Transport experiments are performed using JSC-1, a lunar regolith simulant, and JSC-Mars-1, a martian regolith simulant. Plasma characteristics are determined using a Langmuir probe, while the sheath potential profiles are measured by an emissive probe. Dust particles levitating above the surface of the plate are illuminated by an Ar laser and observed by a video camera. Various types and sizes of particles can levitate above the plate, and particle dynamics in the plasma sheath can be quite complex. We find that particle levitation height and corresponding charge are comparable to the values calculated from orbital motion limited (OML) theory. We also derive an equation to describe the evolution of the dust distribution on the plate as a result of transport in the plasma sheath. In addition, we present results from a numerical model that simulates dust transport in a sheath above a planetary surface.

This work is supported by NASA's Microgravity Fluid Physics Program and NASA's Office of Space Sciences GSRP.

P11A-0344 0830h POSTER

Are Small Asteroids Magnetic?

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The possible presence of significant magnetic remanence on asteroids is important because a significant magnetic moment would both shield the surface from the solar wind flux and cause a disturbance in the solar wind flow. This possibility has been raised for the two small (approx. 30 km) asteroids Gaspra and Ida. Galileo data showed magnetic perturbations near these S-type asteroids that have been interpreted as signatures of the solar wind interaction with an asteroidal magnetic field. The size of the observed disturbance suggested that both Gaspra and Ida could have a strong magnetic field. Interplanetary magnetic perturbations are common in the solar wind. To determine if the signatures observed by Galileo are asteroid related or if simply solar wind in origin we compare Galileo observations with the signature generated near a magnetized asteroid using 2-D hybrid simulations (fluid electrons, kinetic ions). We find that when the IMF is perpendicular to the flow, the interaction of the plasma with a magnetized asteroid generates a perturbation downstream of the asteroid that is formed by whistler and magnetosonic waves. This perturbation resembles in some ways the signature observed near Gaspra. However, sufficient discrepancies are found between observations and simulated signatures so that we conclude that the perturbation near Gaspra was not generated by the interaction of the solar wind with a magnetized asteroid. For Ida, the IMF is at 45^o to the flow, and our simulations differ even more from observations. The wave wake forms upstream of the asteroid at a distance that is small compared with observations, and has a small size. Therefore, we conclude that the signature observed near Ida was not generated by the solar wind interaction with the asteroid. Furthermore, in both cases, the observed signatures are linearly polarized, resembling the magnetic discontinuities that are commonly found in the solar wind, and in contrast to the nearly circularly polarized whistler-mode signatures of the simulations. Our results suggest that it is unlikely that Gaspra and Ida have a magnetic field able to shield them from the space environment.

P11A-0345 0830h POSTER

Are the Circular, Dark Features on Comet Borrelly Albedo Variations or Craters?

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The highest resolution images of Comet P/19 Borrelly taken by the Miniature Integrated Camera and Spectrometer (MICAS) on Deep Space 1 show several dark circular features which upon first inspection might be construed as craters (Soderblom et al., 2002). However, it is also reasonable to suggest that these are localized albedo differences and not the product of shadowing variations from a depression in the local topography. To distinguish this we conducted a photometric analysis of the three most prominent of these features using six of the highest quality MICAS images from the DS1 flyby. The phase angle variation in this data set is from 51 to 75 degrees. The lower spatial resolution images were re-scaled at resolution equivalent to the highest resolution image. The integrated flux in each of the three circular features was measured. We find that the integrated I/F increased as phase angle exhibiting a photometric behavior similar to the higher albedo surrounding terrain. This is inconsistent with the behavior or a shadowed region where increases in spatial resolution should cause a decrease in I/F. Two control regions that were just beyond the terminator (and hence in permanent shadow but still exhibiting flux from the coma) were also measured in each image. The control regions showed no increase in I/F with decreasing phase angle as expected for a region in permanent shadow. We also made photometric scans through the center of each circular feature from the terminator direction toward the limb direction. These were searched for changes in symmetry of the transect with phase variation as might be expected if these features were craters. The scans showed no pronounced asymmetry and no changes in symmetry were found with change in phase angle. In summary we find that: 1) The dark circular features follow the photometric behavior of the rest of the object and not that of shadowed areas 2) The darkest parts of the circular features have an integrated reflectance that is well above the coma 3) The brightness of the dark circular features increases with increasing spatial resolution (if they were craters then they should decrease) 4) The contrast does not fade with decreasing angle of incidence 5) Profiles through craters do not show bright lips or pronounced asymmetry from terminator to limb We conclude from these measurements that the dark circular features seen on comet Borrelly are not craters but are low albedo regions on an otherwise topographically uniform localized area. This work carried out at JPL and USGS under contract with NASA.

Soderblom et al., 2002. Science, 296, 1087-1091

P11A-0346 0830h POSTER

Comet ISSI as seen by MUPUS

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In only a few weeks form now the Rosetta Spacecraft will begin its long voyage towards comet p/Wirtanen. One of the instruments (MUPUS) on the Rosetta Lander will measure the temperature profile and the thermal diffusivity of the uppermost 32 cm as a function of time.

At the same time while we were designing and building our instrument, major progress was achieved in the field of thermophysical comet modelling: hosted by ISSI (Bern, Switzerland), a group of experienced modellers worked out a set of comet reference models (computer code and a set of physical input parameters). We employ results from one of the ISSI comet models (Benkhoffs model No. 4B) to assess the performance of our instrument, as it would see the ISSI comet. Based on test results and the calibration of the Flight Model, we process the data delivered by the model code, as if it would have been measured with the actual instrument (reduction of spacial and temporal resulution to a few cm and 5 minutes, reduction of rel. accuracy to 0.05 K, noise added). Simulated temperature, thermal diffusivity, heat flow and energy balance results will be presented.

We conclude that the design requirements that have been set up well before the ISSI group started their work still hold, and the achieved performance of the instrument is well suited to meet the science goals on an ISSI-type target comet.

P11A-0347 0830h POSTER

Commanding Cassini Radar for the Imaging of Titan's Surface

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We have investigated the dependence of Cassini radar performance on pulse repetition frequency (PRF) and incidence angle for Synthetic Aperture Radar (SAR) imaging of Titan's surface. The Cassini radar has 5 beams which are used sequentially and whose 3dB beam widths are about 0.35 deg x 1.5 deg, except for the central beam of 0.38 deg x 0.38 deg. To make imaged areas of Titan's surface usable, it is necessary for each image pixel to have signal-to-noise ambiguity ratio higher than +14 dB and a thermal noise equivalent backscatter cross-section lower than -10 dB. Using the Doppler sharpening technique, we expect the Cassini radar to achieve an imaging resolution of 300 x 500 m^2 in the along track and cross track dimensions at low altitudes (< 2000 km) and 600 x 1000 m^2 at high altitudes (> 2000 km). For a typical Titan flyby pass for SAR imaging, the orbit of the Cassini spacecraft is hyperbolic with its lowest altitude of 950 km at the closest approach. As a result, the range from the Cassini radar to Titan's surface varies widely and continuously with time. This in turn requires PRF and incidence angle to be adjusted with time in order to maximize the usable area. We have simulated the performance of the Cassini radar by examining the contiguity of usable image area and by measuring the number of looks. Our preliminary studies show that at low altitudes incidence angle can be increased up to 30 deg and PRF up to 5-6 KHz while low incidence angles of less than 20 deg and low PRF of 3-4 KHz are preferred at high altitudes. The number of looks is 3-4 at low altitudes and approaches 10 at high altitudes. We will show the results of parameter studies and the resulting performance variation.

P11A-0348 0830h POSTER

First Ground-Based Look at Compositional Differences in the Uranian Satellites

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Observations of four of the five inner Uranian satellites, Ariel, Umbriel, Titania, and Oberon, have been obtained in the U, B, V, and R filters. The construction of rotational lightcurves has begun for each satellite in order to determine surface components and to gain an understanding of the exogenous alteration processes that caused them. The lightcurves will also be used to compare the colors and albedos of the leading and trailing sides of each moon. Images collected previously by Voyager were analyzed by Buratti and Mosher in 1991 and revealed the leading sides of the outer four satellites to be redder than the trailing sides. The magnitude of the color dichotomy increased with distance from Uranus. A false aperture technique was used to create the lightcurve for each satellite by accounting for the scattered light from Uranus. These observations are the first of their kind because of the moons previous poleward orientation with Earth. The results for the satellite Oberon agree with the data collected by Voyager and thus reveal the hemispherical color differences.

P11A-0349 0830h POSTER

Techniques for Distant Scatterometry of Saturn Satellites using the Cassini RADAR

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From July 2004 through July 2008, the Cassini spacecraft will be conducting an extensive survey of the Saturn system with many instruments. The primary focus of the Cassini RADAR will be on imaging Titan through the optically thick hazy atmosphere. However, several other types of radar observations are also being planned. When the spacecraft swings past various icy satellites there will be a number of unique opportunities to collect Ku-band backscatter data using the Cassini RADAR in scatterometer mode. These data collections are distinct from the normal Titan observations because the range will be much larger (around 100,000 km) and the target bodies are much smaller. Generally, the angular size of the target body will be comparable to the beam-width (0.35 deg). To acquire enough signal in these circumstances, the radar will be

operated in a narrow bandwidth tone mode during an extended integration. Integration times around half an hour or more will be typical. Passive radiometric measurements will simultaneously be obtained to aid in interpreting the backscatter results. This presentation will summarize the special technical issues involved in planning for these observations.

P11A-0350 0830h POSTER

Multiple scattering in a dark material - an anomaly

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For remote sensing observations of planetary regoliths it is well known that as phase angle becomes small, the reflectance of a particulate material will increase non-linearly and exhibit the 'opposition effect' [1]. The phase curve, the size of the opposition surge and the width of the phase curve near zero degrees, have been attributed to two processes commonly called 'shadow hiding' (SHOE) and 'coherent backscattering' (CBOE)[2,3,4] Understanding the relative contribution of the SHOE and CBOE components to the integrated phase curve is a prerequisite for developing models that can confidently determine fundamental regolith textural properties such as particle size and packing density from remote sensing data. Laboratory experiments have attempted to distinguish the contribution of SHOE and CBOE by illuminating samples with circularly polarized monochromatic light and measuring the ratio of circular polarization to linear polarization in the returned signal. If the returned signal is singly scattered then this ratio should decrease as phase angle decreases. If the returned signal is multiply scattered then the circular polarization ratio should strongly increase as phase angle decreases. We have observed this increased ratio with decreasing phase angle in many highly reflective particulate media [5,6,7]. For materials with low reflectance, the expectation is that most of the returned signal is singly scattered because of the high probability absorption at each scattering event. Hence, for absorbing media the circular polarization ratio is not expected to sharply increase as phase angle decreases. In general we have found this to be true [5]. However, we have encountered recently an interesting exception. Measurements on a suite of boron carbide samples (reflectance = 5%) have shown a significant increase in circular polarization ratio with decreasing phase angle, a result that is not consistent with our interpretation of the process. This result suggests that albedo is not only parameter determining the amount of multiple scattering in the medium. This unusual behavior is as yet unexplained; one conjecture is that a unique particle shape may create a very unusual single scattering phase function in boron carbide. It is important to understand this unusual behavior and its implications for models that retrieve surface textural properties from remote sensing data.

This work performed at JPL under a contract from NASA's Planetary Geology and Geophysics Program.

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P11A-0351 0830h POSTER

A Generalized Planetary Acoustic, Ray-tracing Model with Example Application to Bolide Detection on Mars

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Planetary acoustics has been relatively unexplored on planets other than Earth yet has the potential to provide equally convenient remote measurement techniques and to yield equally rich scientific data sets. We present the first generalized planetary acoustic, ray-tracing model which takes into account environmental conditions and viscous, thermal, and molecular relaxation of multi-gas atmospheres. We show a specific Martian application to making use of terrestrial techniques for bolide detection and influx estimates, and introduce concepts for identifying and tracking general sound sources such as dust devils.

Meteors penetrating deep into the terrestrial atmosphere are known to generate large well-characterized acoustics signals. Similar explosive events provide acoustic sources in the Martian atmosphere that should be detectable by sensors on the surface. We present an end-to-end comparison between Earth and Mars of a meteor event from the bolides entry, through detonation and acoustic transmission of the shockwave, to what is heard by ground detectors (this includes intensity, frequency response, and region of detectability). With the use of an array of detectors detonation events can be spatially localized. We place constraints on the practicality of an instrument and compare with equivalent seismic meteor detection. This analysis leads to a measurement method for estimating bolide influx rates in the Martian atmosphere. This rate is currently highly uncertain and significantly affects results of modeled absolute crater retention ages.

Pending work includes the application of similar acoustic localization techniques to develop an instruments concept for the detection and tracking of dust devils such as those observed in both Pathfinder and Mars Global Surveyor images. Further, with minimal reconfiguration, our model and the above analysis can also be applied to Venus and Titan.

P11A-0352 0830h POSTER

Earth Co-orbital Objects

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The recent discovery of asteroid 2002 AA_{29} by the LINEAR survey and the realization of its co-orbital relationship with Earth lead us to consider the characteristics of Earth Co-orbital Objects (ECOs) in general. An object with semimajor axis between 0.99 and 1.01 AU is in 1:1 resonance with the Earth. To be co-orbital in the sense of moving along the Earth's orbit, an object must further have its other orbital parameters similar to those of the Earth. Clarification is needed as to what range of orbital parameters can be regarded as similar enough to permit classification as an ECO. ECOs would be expected to librate on tadpole or horseshoe orbits, be relatively easy to access with spacecraft, and to sometimes exhibit quasisatellite behavior. 2002 AA_{29} is on a horseshoe orbit and was discovered in a general asteroid survey while near Earth at one end of the horseshoe orbit. Searches for Earth Trojan asteroids, which would be members of the ECO class on tadpole orbits near a triangular Lagrange Point, have not yet been successful. While 2002 AA_{29} has an orbit even less eccentric than Earth's, it has an inclination of about 10 degrees. 2000 PH_5 and 2001 GO_2 are on horseshoe orbits and interact gravitationally with Earth to 'bounce' when they approach the Earth from either side. With eccentricities of .23 and .17 respectively, they do not have decidedly Earth-like orbits despite inclinations less that 5 degrees. When in quasi-satellite mode, a body exhibits a looping motion relative to Earth in some ways resembling a satellite orbit. Several resonant bodies including 3753 Cruithne exhibit this behavior at times, but ECOs remain close to Earth while doing it. We suggest that directed searches be used to discover ECOs and characterize this class of objects. Orbital simulations suggest the best target spaces, which are only partially covered by present general searches.

P11A-0353 0830h POSTER

Investigation of Lunar Crustal Magnetic Fields, Surface Properties, and Impacts

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The Magnetometer/Electron Reflectometer experiment onboard Lunar Prospector (LP) produced a global map of lunar crustal magnetic fields. The most prominent features of this map are weak surface fields (<0.2 nT) within large impact basins and strong fields (>40 nT) diametrically opposite to these same sites, thus showing the importance of basin forming processes in producing the current distribution of the lunar crustal magnetic fields. The only other clear-cut global correlation is between surface magnetic fields and albedo swirls of the Reiner Gamma class, although recently, the Cayley formation has been shown to correlate with strong surface magnetic fields, suggesting that some Imbrian impact ejecta are magnetized.

To conduct a systematic global search for other correlations, we performed cluster analysis of the surface magnetic field intensity, surface topography, and free-air gravity anomalies. This analysis yields five distinct clusters. The two dominant clusters reproduce the strongly magnetic antipodal zones and the previously known correlations between weak surface magnetic fields and impact basins with their associated topographic and gravitational signatures. The remaining three clusters cover the part of the Moon away from the basin impact sites and their antipodes. These clusters comprise strong (>20 nT) magnetic anomalies not antipodal to large impact basins and reveal associations with albedo features and impact ejecta. These groups are also distinguished by their gravitational component.

P11A-0354 0830h POSTER

Sm-Nd, Lu-Hf and Nb-Zr Constraints on the Early Differentiation of the Moon

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The dominant chemical and mineralogical differentiation process on the Moon is most likely associated with the formation and subsequent crystallisation of a magma ocean. The major evidence in favour of the existence of a magma ocean is the ancient anorthositic crust that once covered the lunar surface. The complementary heavier minerals that crystallised as cumulates from the magma ocean must have included olivine, orthopyroxene, clinopyroxene, spinel, ilmenite, and possibly garnet. Partial melts from these differentiated silicate and oxide layers gave rise to younger mare basalts that now cover parts of the Moons surface. Radioactive parent-daughter systems such as ^{147}Sm-^{143}Nd, ^{176}Lu-^{176}Hf and ^{92}Nb-^{92}Zr can provide important time constraints on early lunar differentiation processes, particularly if parent-daughter pairs are sufficiently fractionated during magmatic processes. Therefore we obtained Sm-Nd, Lu-Hf and Nb-Zr isotope data for a variety of well dated lunar samples including KREEP basalts, low and high-Ti mare basalts and lunar soils. $^{92}Zr/^{90}Zr$ and $^{96}Zr/^{90}Zr$ in mare basalts agree with the chondritic value within the analytical errors of ± 0.5 and ± 1.5 ϵ-units (2σ), respectively. The absence of ^{92}Zr-isotope anomalies and the presence of small ^{182}W anomalies in mare basalts [1] confine the crystallisation age of the magma ocean to ca. 4.52 - 4.51 Ga (assuming initial $^{182}Hf/^{180}Hf$ of $1x10^{-4}$ and $^{92}Nb/^{93}Nb$ of $1x10^{-3}$). The initial ϵHf (ϵNd) range from 1.9 (-2.7) in the KREEP rocks to +16.6 (6.6) in high-Ti mare basalts. The initial Hf and Nd isotope ratios define two trends that deviate significantly from the terrestrial Hf-Nd array. The initial ^{176}Hf-^{177}Hf values for mare basalts (+7.3 to +16.6 ϵ) are consistent with the data from Beard et al. [2] (0 to +8 ϵ) using the revised ^{176}Lu decay constant [3], but expand the known compositional range of mare basalts. The high ϵHf compared to the ϵNd in the low-Ti basalts requires that garnet played an important role in the early differentiation of the Moon and the development of the low-Ti basalt source rocks. Variable degrees of ilmenite assimilation (low ϵHf) during magma ascent may have enhanced the observed decoupling of Hf and Nd isotope compositions.

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[1] Lee et al, (2001) Meteoritics and Planetary Science 36(9), A111; [2] Beard et al, (1998), Geochim Cosmochim Acta, 62, 525-524; [3] Scherer et al, (2001), Science, 293, 683-687.

P11A-0355 0830h POSTER

Origin of the Moon Unveiled by its Heavy Iron Isotope Composition

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The origin of the Moon has long been of interest and although the Giant Impact theory is currently the preferred explanation, unequivocal supporting evidence has been lacking. We have measured the iron isotope compositions of Shergotty-Nakhla-Chassigny meteorites and eucrites thought to come from Mars and Vesta, as well as samples from the Moon and the mafic Earth using high precision plasma source mass spectrometry. The mean iron isotope composition of the lunar samples, expressed in the conventional delta notation (d57Fe/54Fe) with respect to the IRMM-14 isotopic standard, is heavier (0.221 per mil (0.041: one standard deviation, 10 samples)) than those of the Earth (0.119 per mil (0.044, 7 samples)), which themselves are heavier than Martian meteorites (0.009 per mil (0.024, 6 samples)) and the eucrites measured (0.033 per mil (0.038, 7 samples)). Student's t-test calculations show that the Moon and Earth means are different from each other and from those of the other planetary bodies at >99% level of significance. The iron isotope compositions show no simple relationship with planetary heliocentric position, mantle oxygen fugacity, volatile content, or planet size. Similarly, these results do not support an origin of the Moon through co-accretion with the Earth, or as a fragment ejected from the Earth's mantle, or as another planet captured by the early Earth. In contrast, these data can be explained if the Earth, and especially the Moon, went through partial vaporisation and condensation leading to kinetic iron isotopic fractionation. Our data are also consistent with the suggested levels of enrichment of refractory elements for the bulk Earth and Moon. These new iron isotope results thus provide strong support for the origin of the Moon through a giant impact between the proto-Earth and another planet. Raleigh kinetic fractionation calculations indicate that only 1% loss of the current Fe budget of the Moon is required to explain its heavier isotopic composition. This is consistent with the small total losses computed in dynamic simulations of the Giant Impact.

P11A-0356 0830h POSTER

Future Instrumentation for Planetary Gamma-Ray Spectroscopy

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At the Space Sciences Laboratory, U. C. Berkeley, we are beginning a study of advanced instrument designs for planetary gamma-ray spectroscopy. This includes coincidence-mode spectrometers and neutron-activation spectrometers for landers, and a Compton telescope for detecting composition from high orbits or during flybys, where a simple spectrometer would be too insensitive. Detector technologies to be evaluated include germanium strip detectors, mercuric iodide detectors, and coplanar-grid CdZnTe detectors.

P11B MCC: 131 Monday 0830h

New Results From Mars Odyssey I

(joint with C, G)

Presiding: **J J Plaut,** Jet Propulsion Laboratory**; R S Saunders,** Jet Propulsion Laboratory

P11B-01 0830h INVITED

2001 Mars Odyssey: Science Mission Overview

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The 2001 Mars Odyssey orbital science mission officially began February 19, 2002. The spacecraft carries three science instrument packages: the Gamma Ray Spectrometer suite (GRS), the Thermal Emission Imaging System (THEMIS), and the Martian Radiation Environment Experiment (MARIE). The GRS suite of three instruments includes the Gamma Sensor Head (GSH), the Neutron Spectrometer (NS) and the High Energy Neutron Detector (HEND). THEMIS consists of two cameras sharing a single set of telescopic optics: a 5-band visible imager and a 10-band thermal infrared imager. Spacecraft and instrument performance have been nominal to this point in the science mission. Gamma and neutron observations of the high latitudes have been used to identify water-ice-rich soil to 1 m depth at latitudes poleward of 60 degrees north and south. A focus of THEMIS infrared and visible data acquisition has been the candidate landing sites for the MER 2003 landers. Daytime and nighttime infrared imaging shows a remarkable diversity of temperature signatures of surface materials, suggesting that THEMIS will truly provide a new view of Mars. MARIE began operating on March 13, 2002 following recovery from an instrument operation anomaly. The instrument has detected radiation signatures from the high solar activity during the first 5 months of operations. Odysseys nominal science mission will extend for 917 days, until August 24 2004. Extended mission operations appear to be feasible, given the current inventory of propellant. In early 2004, the orbiter will serve as a relay platform for the MER landers, and possibly for the Mars Express Beagle2 landers.

URL: http://mars.jpl.nasa.gov/odyssey/

P11B-02 0845h INVITED

Subsurface Ice Content in the Polar Region of Mars: Comparison Between North and South

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Recently we published results concerning the subsurface ice content in the south polar region of Mars (Boynton et al. 2002, Science 297:81-85) showing that from latitudes south of about -45 degrees, the regolith consists of two layers: a hydrogen-poor layer overlaying a hydrogen-rich layer. The upper, hydrogen-poor layer has a hydrogen content equivalent to about 1% water, similar to that seen elsewhere on Mars. The lower layer has the equivalent water content of 35% +/- 15% by weight. The upper layer decreases in thickness going poleward from -45 degrees to -77 degrees. We concluded that the hydrogen in the lower layer was in the form of ice, based both on the large hydrogen concentration and the fact that it was only found in regions where ice is predicted to be stable.

The northern polar region was covered with its seasonal carbon dioxide cap at the time we published our earlier work, but it is now receding. At the time of this writing we can see as far north as 65 degrees latitude, and the hydrogen content appears to be nearly identical to that in the south at the equivalent latitude. As the cap recedes we expect to be able to collect sufficient data that we can perform a quantitative analysis of the hydrogen content similar to that done in our earlier work. We shall report the results at the meeting and compare the results to our earlier results from the south.

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

P11B-03 0900h INVITED

Time Variation of the North Polar Seasonal Frost Cap of Mars

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Maps of thermal, epithermal, and fast neutrons covering latitudes northward of +45 degrees were studied to determine the time variation of CO2 frost at northern latitudes during late winter and early spring. Data measured between 18 Feb. and 31 Aug. 2002, were broken into eleven, roughly 7.5 degree intervals of areocentric longitudes, Ls, spanning 321 to 55 degrees. The edge of the CO2 frost cap is seen in thermal neutrons to steadily recede during this interval, revealing subsurface deposits of water-rich soil. Simultaneously, the intensity of thermal neutrons near the pole first increases and then decreases. The thermal flux measured near the pole relative to that measured at the Viking 1 landing site is too low, and those for the epithermal and fast neutrons are too high, to be consistent with fluxes simulated using MCNPX for a roughly meter-thick CO2 layer overlying water-ice rich soil. Agreement of measurements with simulations seems to require a strong neutron absorber in either the overlying atmosphere (such as nitrogen) or the CO2 frost cap (such as dust). Our preferred interpretation is in terms of a nitrogen-rich residual atmosphere that forms in consequence of the freeze-out of CO2 gas from the pre-winter polar atmosphere.

P11B-04 0915h INVITED

Mapping of High Energy Neutrons from Mars: Results from Odyssey

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The first 290 days of Martian mapping in high energy neutrons by High Energy Neutron Detector (HEND) on board of NASA 2001 Mars Odyssey spacecraft manifest very strong variation of flux of neutrons at different points above the surface of the planet. The largest areas with deficits of high energy neutrons are observed at regions with high latitudes around both south and north pPoles of Mars. The interpretation of the signature of neutrons depression is presented, as the evidence for large provinces on Mars with water ice bearing layers in the upper sub-surface. The evidence for seasonal variations of neutron flux from Mars is also presented and discussed.

P11B-05 0930h

Analysis of Mars Odyssey Fast Neutron Data to Constrain the Hydrogen Abundance and Stratigraphy Near the South Pole

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