Planetary Sciences

P11A MCC: 2000 Monday 0800h

Earth's Moon *(joint with V)*

Presiding: **R M Nelson,** Jet Propulsion Laboratory, California Institute of Technology**; M Anand,** Planetary Geosciences Institute, University of Tennessee

P11A-01 0800h

Lateral Heterogeneities of the Lunar Crustal Thickness

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During the seventies, the Apollo missions set up a seismic network on the nearside of the Moon, which allowed to address the fundamental questions of lunar science. Recently this dataset was reinvestigated in order to shed light on ambiguous results of ancient studies. One of them was the proposed 60 km crustal thickness below the Apollo station 12 and 14 sites. Our previous study achieved a new view of the lunar interior where the lunar crust, as seen by the Apollo seismic data, is 30 km thick. Lateral variations of crustal thickness can be determined from inversions of gravity and topography data. These inversions must be anchored at a single point, with a seismic determination. This present work goes further. In this study, we constrain lateral variations of crustal thickness with seismic data only. We use a Markov-Chain Monte-Carlo method to invert for the lateral crustal thickness, determined by the arrival times of impacts at the 4 Apollo stations. Each impact and station site is associated to an independent Moho depth. The topography of the different sites, as determined by Zuber et al. (1994) whith the Clementine dataset, is also taken into account for the first time. Thus, we put independent seismological constraints on the Moho depth at 31 locations, instead of one. We present here the preliminary results of this study of lunar crustal thickness heterogeneities, in terms of an integrated view of the seismic and gravity information.

P11A-02 0815h

Topography Dependent Photometric Correction of SELENE Multispectral Imagery

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The SELENE mission to the Moon in 2005 includes the Multiband Imager (MI) [1], a visible/near-infrared imaging spectrometer, and the Terrain Camera (TC), a 10m panchromatic stereoimager for global topography. The ~1TB of TC data will take years to reduce; initial photometric correction of MI data will not include the effect of topography. We present a method for prioritizing analysis of TC data so topography can be included in photometric correction of MI data at the earliest time to regions of the lunar surface where the effects of topography are most significant. We have calculated the general quantified dependence of photometric correction on incidence angle, emission angle, phase angle, and local topographic slopes. To calculate photometric correction we use the method used for Clementine [2,3] with the following corrections: The factor of 2 is included in the X_L function (see [3]), $P(\alpha,g) = (1-g^2) \div (1+g^2+2g\cos(\alpha))^{1.5}$, and $g1 = D*R_{30} + E$. In order to predict the topography of the Moon to determine the regional distribution of local slopes at the resolution of MI (20m and 62m), we performed a fractal analysis on existing topographic data derived from Clementine LIDAR [4], Earth-based radar of Tycho crater [5], and Apollo surface-based stereoimagery [6]. The fractal parameter H, which describes the relationship between scale and roughness, is 0.65±0.02, 0.64±0.01, and 0.69±0.06 [6] at the 20-75km, 150m-1.5km, and 0.1-10mm scales, respectively. Based on the consistency of H at these disparate scales, we interpolate H=0.65±0.03 (a weighted average) at the 20m and 62m scales of the MI cameras. The second fractal parameter, σ(L0), is calculated from Clementine LIDAR data for overlapping 3x3 degree segments over the lunar surface. From this, we predict local topographic slopes for all regions on the Moon -60° to $+60^\circ$ at the 20m and 62m scales based on H=0.65 and σ(L0) as determined for each pixel. These results allow us to prioritize TC data analysis to maximize the scientific return from MI data during the first years of data analysis. This work was supported by the Japan Society for the Promotion of Science and the National Science Foundation's East Asia Summer Institutes. References: [1] Ohtake, M. LPSC XXXIV, abs 1976, 2003. [2] McEwen, A.S. LPSC XXVII, 841-842, 1996. [3] McEwen, A. et al. LPSC XXIX, abs 1466, 1998. [4] Smith, D.E. et al., JGR, 102(E1), 1591-1611, 1997. [5] Margot, J.-L. et al. JGR, 104(E5), 11875-11882, 1999. [6] Helfenstein, P. & M.K. Shepard. Icarus, 141, 107-131, 1999.

P11A-03 0830h

An Unexpected Finding Regarding the Opposition Effect in Planetary Regoliths

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Understanding how to model the Opposition Effect (OE) in remote sensing data is a requirement to fitting photometric models which will produce meaningful results. Our previous work has found that the OE in particulate materials is due to two processes, Shadow Hiding (SHOE) and Coherent Backscattering (CBOE)(Nelson, et al. 2000; 2002). SHOE arises because, as phase angle approaches zero, shadows cast by regolith grains on other grains become invisible to the observer. CBOE results from constructive interference beween rays traveling the same path but in opposite directions. We measured the angular scattering properties of 9 mixtures of Aluminum Oxide and Boron Carbide powders of the same particle diameter (25 microns). The reflectance of the materials ranged from 7-91%. Along with the reflectance phase curve we measured the circular polarization ratio, CPR-the ratio of the intensity of the light returned with the same helicity as the incident light to that with the opposite helicity. An increase in CPR with decreasing phase angle indicates increased multiple scattering and is consistent with CBOE. It might be expected that materials of higher albedo would exhibit increased multiple scattering and that CBOE would increase as albedo increases. Remarkably, we find the highest albedo samples did not have the strongest CBOE opposition peaks. Instead, the maximum CBOE contribution was for the samples with reflectance between 15 and 40%. We derived a theoretical model which reproduces the data quite satisfactorily. This model shows that the reflectance where we find the CBOE amplitude to be a maximum is where the contribution of second order scattering is largest relative to the other orders. Hence, for closely packed media the maximum contribution of CBOE does not occur in materials of highest albedo but where the relative contribution of second order scattering is largest. Nelson, et al. 2000. Icarus, 147, 545-558. Nelson, et al., 2002, Planetary and Space Science, 50, 849-856. This work was done at JPL and Pitt and was supported by NASA's PGG program.

P11A-04 0845h

Role of Impact-Induced, Vapor-Phase Deposition in the Lunar Regolith Formation: Clues from the New Mineral, Hapkeite

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To correctly interpret the spectral properties of airless planetary bodies such as the Moon, Vesta, etc., it is important to understand the complex space-weathering processes responsible for their soil formation. In the absence of water and atmosphere, micrometeorite impacts play the dominant role in soil development on such airless bodies. Kinetics of such transient impacts can result in ultra-high-temperature events and cause melting and vaporization of even less-volatile elements in the soil. A regolith-breccia clast in lunar meteorite Dh-280 contains small (e.g. 10-20μm) opaque mineral grains consisting of three distinct new lunar mineral phases- FeSi, Fe2Si, FeSi2 [Anand et al., 2002, 2003, LPSC]. We have named the Fe2Si mineral, HAPKEITE, in honor of Prof. Bruce Hapke. We are using a new X-ray microdiffraction technique with beamline 7.3.3 of ALS to refine and determine the crystal structures of these Fe-Si phases. Preliminary results indicate the possibility of superlattice structures in some cases. The presence of Fe-Si phases in a lunar soil fragment in Dh-280 indicates extreme reducing conditions. The two most plausible reduction mechanisms include impact-induced a) melting, evaporation, and vapor deposition and b) solar-wind hydrogen reduction. Our preferred scenario for the formation of these phases involves the melting and vaporization of lunar soil by micrometeorite impact. The transient, ultra-high-temperature impact could cause vaporization and thermal dissociation of FeO and SiO2 into their constituent atoms. The ubiquitous presence of np-Fe in silica-rich glass on the surface of most mature, lunar-soil grains has already been confirmed (Keller & McKay, 1993, Science). We propose that with further dissociation, the Si in the vapor phase could readily combine, in various proportions, with Fe, and condense as Fe-Si grains. These observations necessitate further careful investigation of lunar soils for the presence of Fe-Si phases, as these can significantly contribute towards the spectral reflectance of lunar soils, the actual material observed remotely.

URL: http://web.utk.edu/~anandm/phd-research.htm#lunar-res

P11A-05 0900h

Testing the Relationship Between UV-VIS Color and TiO_2 Content in the Lunar Maria.

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Remotely sensed data are used to classify the lunar maria on the basis of "color"; where mature maria with steep UV-VIS continuum slopes are defined as "red", and those with relatively flatter continuum slopes are termed "blue". The canonical view is that large apparent color variations are due to TiO_2 concentration, as TiO_2 is the primary variable in lunar basalts, ranging from <1 wt.% to >14 wt.% TiO_2. This interpretation was based on the observation of compositional and color extremes juxtaposed in Mare Serenitatis and Tranquillitatis. Lunar Prospector (LP) data allows direct testing of the assumption of the control of lunar UVVIS color by TiO_2 in the mare. We compare LP gamma-ray (GRS) and neutron spectrometer (NS) data for TiO_2 with Clementine Spectral Reflectance (CSR) data in order to examine basalts with a full range of TiO_2 concentrations. Areas were selected on the basis of uniform color over 2-degree areas, to match the resolution of the LPGRS data. First we conducted a comparison between LP-GRS and LP-NS data. This comparison yields an approximate two-to-one correlation (the NS data exhibiting higher values), a significant amount of scatter ($R2 = 0.63$), and an offset +1.7 TiO_2 NS data. This is an important observation as it shows that even direct measurements of surface TiO_2 contain considerable uncertainty, even for the best possible scenario for determining TiO_2 contents in the maria. A comparison of LPGRS TiO_2 and CSR color data yields a poor correlation ($R2 = 0.53$), that is, UV-VIS color is a poor predictor of LPGRS TiO_2 in mature mare. A comparison of LPNS and CSR color data, however, yields a better correlation ($R2 = 0.85$). On the basis of this preliminary analysis, we conclude that TiO_2 controls UVVIS color in the mare. However, we will continue this analysis at the higher resolution accessible to LPNS data to further explore the correlation between data sets. We will present an empirical model that uses a relationship between LPNS and CSR UV-VIS data to predict TiO_2 contents globally and at full Clementine resolution (250 m/pixel).

P11A-06 0915h

Mineral Maps of the Moon

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Determining the global distribution of minerals on the Moon has been an important goal of lunar science[1]. We analyzed a 1 km resolution four-band global mosaic of the Moon derived from the USGS Flagstaff digital image model using a Hapke-based [2] spectral analysis model. This model includes the ability to vary modal abundance, grain size, Mg-number, glass abundance and composition and degree of space weathering via inclusion of the effects of submicroscopic iron [3]. We precalculated over 2,500 different model spectra of varying abundances of the lunar minerals and space weathering parameters. For each Clementine four-band spectrum all precomputed models are compared. Models matching the data within 0.5 percent are retained. The result are relatively sparse images of the abundance of plagioclase, clinopyroxene, orthopyroxene and olivine. We then interpolated the sparse data using a nested resolution algorithm to produce a gridded data set similar to that produced for topography of Mars from MOLA data. The plagioclase image shows a distribution similar to the inverse of iron as derived from LP and Clementine data. The highlands show high values of plagioclase abundance (up to nearly 100 percent) with the mare showing low values near 40 percent. The clinopyroxene image is similar to an iron map: values are high in the mare and low in the highlands. The olivine image shows enhanced values in the western maria as previously observed by Staid and Pieters [4] and isolated exposures in other mare and the highlands. No other regional deposits of olivine are present on the Moon. Images of the ratio of olivine to the sum of mafics shows a strong variation in the highlands. The central farside shows the anorthositic material is essentially free of pyroxene. This is consistent with the observation by Pieters and Tompkins [5] that troctolites in central peaks seem concentrated in an equatorial band. Our results show this olivine enrichment includes extends to the surface. Elsewhere in the highlands, the mafic assemblage is dominated by orthopyroxene in plagioclase-rich units. References: [1] LExSWG Final Report (1995). [2] Hapke, B. (1993) Theory of Reflectance and Emittance Spectroscopy, Cambridge Univ. Press, Cambridge. [3] Lucey, P. G. (2002) GRL, 29 (10), 2001GL014655. [4] Staid, M. and C. M. Pieters (2001) JGR, 106 (E11), 27887-27900. [5] Pieters, C. M. and S. Tompkins (1999), JGR, 104 (E9), 21,935-21,949.

P11A-07 0930h

Color-Reflectance Trends in the Mare: Implications for Mapping FeO Using Multispectral Imaging of the Moon

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Clementine-based FeO measurements provide a new resource for mapping mare basalts and cryptomare. These FeO estimates are based on algorithms that are intended to minimize the effect of maturity that strongly affects reflectance and ratio images, and maximize the effect of iron. The algorithms are based on an observation that terrains with plausibly uniform composition but varying maturity seem to form radial patterns on a plot of reflectance versus 950/750nm ratio. This behavior was parameterized using a simple rotational algorithm that placed the origin near the apparent convergence point of these trends. The technique is successful in the sense that there is a high degree of correlation between FeO estimates and measurements using lunar samples and Lunar Prospector data, and in most terrains the effects of maturity, for example owing to the presence of small craters, are minimized to $<1\%$ FeO. More recently, it has been reported that some mare show subparallel, not radial trends, and this observation has been used to call into question the validity of the entire method of FeO derivation. To confirm these new observations and investigate in more detail the maturity trends in the mare, we acquired data for the multiple maria: Procellarum, Frigoris, Nectaris, and Tranquillitatis. On the whole, spectra from 20 representative fresh craters from each of the maria do produce maturity trends that formed radial patterns. Scatter plots from Mare Frigoris, however, show maturity trends that are subparallel to the other maria, as suggested by previous workers. This subparallel behavior leads to apparent FeO anomalies being present in these areas associated with fresh craters. These FeO anomalies are plausibly real, as it is not known that Frigoris is uniform in FeO content with depth. A mare surface dusted with highland debris should show non-radial trends as FeO content declines with distance from the crater. Or, thin lava flows of varying compositions should also lead to non-radial trends. In other words, local deviations from radial behavior do not necessarily invalidate the accuracy of FeO estimates. Our efforts will be to document additional mare regions that do not exhibit maturity trends that originated from a single common point. We will also present model results to constrain what variables other than stratigraphy (i.e. mineralogy, grain size, Mg#) can account for the differences observed and results of semi-empirical corrections.

P11A-08 0945h

The D-CIXS X-Ray Spectrometer, And Its Capabilities For Lunar Science

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The purpose of the D-CIXS (Demonstration of a Compact Imaging X-ray Spectrometer) instrument recently launched on the ESA SMART-1 mission is to provide high quality spectroscopic mapping of the Moon by imaging fluorescence X-rays emitted from the lunar surface. In order to obtain adequate statistics for what can be very weak sources, it is essential to have a large effective area, while maintaining a low mass. The solution is to make a thin, low profile detector. D-CIXS can derive 42 km spatial resolution images of the lunar surface from a spacecraft at 300 km altitude with a spectral resolution of 200 eV or better. The instrument is based around the use of advanced dual microstructure collimator and Swept Charge Device X-ray detector technologies. D-CIXS will provide the first global map of the Moon in X-rays. During normal solar conditions, it will be able to detect absolute elemental abundances of Fe, Mg, Al and Si on the lunar surface, using the on-board solar monitor to obtain a continuous measurement of the input solar spectrum. During solar flare events, it will also be possible to detect other elements such as Ca, Ti, V, Cr, Mn, Co, K, P and Na.The global mapping of Mg, Al and Si, and in particular deriving Mg#, the magnesium number (MgO/[MgO+FeO]), represents the prime goal of the D-CIXS experiment. This data will represent an important new data set for Lunar science

URL: http://www.ssd.rl.ac.uk/SMART-1/

P11B MCC: Level 2 Monday 0830h

Mars and Venus Geomorphology Posters *(joint with H)*

Presiding: **M S Gilmore,** Wesleyan University**; N Martineau,** McGill University

P11B-1031 0830h POSTER

Basal Melting of Snow on Early Mars: Possible Origin of Valley Networks.

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Simulations suggest that early Mars could not have been warmed enough by a CO2-H20 greenhouse to permit rainfall. The vulnerability of an early atmosphere to impact erosion, the likely rapid scavenging of CO2 from the atmosphere by weathering if warm conditions did occur, and the lack of detection of weathering products from orbit all support the supposition of a cold early Mars. Yet valley networks appear to be cut by liquid water. One possibility is that the valley networks formed as a result of basal melting of thick snow and ice deposits that formed at low latitudes during periods of high obliquity, when ice would have sublimated from the polar regions. Basal melting on early Mars is facilitated by the high heat flows expected at that time. The depths to melting of a snow pack on early Mars were estimated by scaling pressure-density relations for terrestrial dry snow packs to Mars, using empirically derived thermal conductivities for different density ices, and taking estimates of the heat flow from various modeling studies. The results suggest that a snow pack a few to several hundred meters thick would undergo basal melting on early Mars, depending on the heat flow. Such basal melting could provide runoff to cut the valley networks directly or to recharge the groundwater system and so enable groundwater sapping. That basal melting did occur is supported by the emergence of large channels from under the Dorsa Argentea Formation near the south pole.

P11B-1032 0830h POSTER

Possible Temperature-Related Slope and Surface Roughness Differences Between the North and South Walls of Coprates Chasma, Mars

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This study is concerned with the effect of temperature on the topography of the near-equatorial trough of Coprates Chasma. One of the outstanding questions concerning the evolution of the Valles Marineris troughs, and of equatorial landforms in general, concerns the possible presence of ground ice and its role in landscape evolution. Over geologic time, surface heat (by its influence on the stability and rheology of ice-rich frozen ground) may be a factor in the evolution and morphology of the trough walls by controlling the distribution of ground ice. This study aims to determine whether the expected surface temperature difference between the north and south walls of Coprates Chasma, results in a measurable difference in trough wall stability, slope angle, and surface roughness. To determine whether temperature is a factor, systematic variations in topographic parameters with predicted mean annual surface temperature, location (latitude and longitude), and trough geometry (wall height, rim elevation, and trough width) were examined, as were differences in topographic parameters (slope angle, curvature, and surface area ratio) between the north and south walls of Coprates Chasma. Slope angles, surface roughness, and other derivatives were calculated from the 1/64 degree MOLA gridded elevation dataset. 247 profiles were drawn across the trough, extracting topographic data, which was related to surface temperature, location, and trough geometry. Comparisons of differences in topographic and other parameters between the north and south walls were made. Predicted mean annual surface temperature varies from 202-212 K along the north wall and from 216-218 K on the south wall. The temperature difference between the two walls varies from 7.5 K at the western end of the trough to 11.5 K at the eastern end, and averages 9.7 K. The north and south walls have average slope angles of 22.4° and 21.1° respectively, the north wall being steeper by 1.3°. Because the ranges of slope angle are similar for both walls, but the temperature range differs, slope angle decreases as a function of temperature at 6° of slope per K for the south wall, compared with 1° per K for the north wall. The difference in slope angle between the two walls for all the profiles measured correlates significantly with the surface temperature difference between the two walls. Correlations of slope angle and slope angle difference with location or trough geometry factors are weaker or insignificant. In addition, the pattern of slope angle variation along the trough is not associated with known or suspected faulting patterns. Furthermore, the slope angle asymmetry is not due to an asymmetric graben geometry for the trough as there is no tilt on the floor across the trough. Rock mass strength differences between the walls are unlikely given that layering in the walls appears to be horizontal. All these results suggest that it is temperature differentials, rather than location or trough geometric factors that have produced the systematic, trough-averaged difference in slope angle between the two walls. The results are consistent with a differential presence and depth of ground ice within the north and south walls. The depth to the ice table is shallower underneath the north wall by a few tens to 100 meters, and the cryosphere deeper by 1 km; the ice table is also predicted to be colder underneath the north wall. Given the known increase in the strength and resistance of ice to deformation with decreasing temperature, the north wall is considered to be more stable and stronger, and therefore can maintain steeper slope angles on average than the south wall.

URL: http://joern.jernsletten.name/rice/Dissertation.html

P11B-1033 0830h POSTER

Comparing Topography of Martian and Terrestrial Drainage Basins Using Integral-Geometry Morphological Image Analysis – Implications for Origin of Martian Channel Networks

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The origin of Martian channel networks located on Noachian terrain remains undetermined despite extensive studies. Whereas previous studies have focused on morphology of the channels themselves, we concentrate on topography of underlying drainage basins to diagnose an erosion process. DEMs based on the MOLA data (Mars, 500 m resolution) and the SRTM data (Earth, degraded to 450 m resolution) are used to delineate 28 Martian and 26 terrestrial drainage basins. Our analysis is based on the novel idea to use integral-geometry morphological image analysis to characterize quantitatively basin's topography. Each basin is represented by a 3-D digitize surface extracted from a DEM. The method is to "scan" this surface by a large number of horizontal planes labeled by relative elevation z. Each plane divides basin's pixels into those above