[1]Dept. Geology and Geophysics, Yale University, Kline Geology Lab, New Haven, CT 06520, United States

Data collected by the Mars Odyssey Gamma Ray Spectrometer (GRS) and Mars Exploration Rover Alpha Particle X-ray Spectrometers (MER-APXS) will allow for unprecedented chemical information to be obtained from the Martian surface. Phosphorous and iron are two elements that should be measured with some accuracy by MER-APXS (as opposed to MPF). The well-known affinity of iron oxide/hydroxides for sorption of phosphate in oceans, lakes, rivers, and soils will be used to assess the utility of P/Fe (in conjunction with other elements and element ratios measurable by MER-APXS) as an indicator of aqueous activity at the two 2004 MER landing sites. Iron oxide/hydroxides are also an effective sink for Th in terrestrial waters; thus, GRS data may also be valuable in evaluating the nature of aqueous alteration (or lack thereof) at the MER landing sites. For example, the hematite-bearing deposit in Sinus Meridiani (2S, 4W) has a high Th concentration and low K/Th, suggesting that sorption of Th by specular hematite in aqueous solution may have occurred at some point in the geologic history of this region of Mars. Experiments on the sorptive properties of specular hematite and palagonite for PO4 and Th will be used to develop a model for the role of water in formation of deposits at the two MER landing sites.

P31A MCC: 2000 Wednesday 0800h

Planetary Interiors and Geodynamics II *(joint with GP, S, T, V, MR)*

Presiding: **D M Jurdy,** Northwestern University**; S Stanley,** Harvard University

P31A-01 0800h

Convection in giant planets with and without inner cores

Martha Evonuk[1] (mevonuk@es.ucsc.edu)

Gary A Glatzmaier[1] (glatz@es.ucsc.edu)

[1]University of California Earth Sciences Dept., 1156 High St., Santa Cruz, CA State/Pr, United States

We investigate convection in the interior of an extra-solar giant planet using a simple disk-shaped 2D finite volume model with radial gravity. The finite volume method allows us to easily track fluid motion through the center of the disk (the origin point) for a case without a solid inner core. Our anelastic simulations have a cold, impermeable outer boundary and a radial density stratification. A radial heating source simulates heating by gravitational contraction. We compare convection with and without a solid inner core.

P31A-02 0815h

The Active Period of the Core Dynamo of Mars

Jafar Arkani-Hamed ((514) 398-6772; jafar@eps.mcgill.ca)

Earth and Planetary Sciences McGill University, 3450 University Street, Montreal, QC H3A 2A7, Canada

The tremendous amount of magnetic field data acquired during the mapping phase of Mars Global Surveyor (MGS) provides a unique opportunity to derive a more accurate magnetic anomaly map of Mars. A most reliable anomaly map is constructed on a global scale through covariance analysis of the spherical harmonic models derived using data from different periods of the mapping phase. I also constructed most reliable magnetic anomaly maps on regional scales, using the covariance analysis in the Fourier domain. Many weak magnetic anomalies are newly detected over the northern lowlands, which are likely relicts of stronger anomalies that have been partially demagnetized by the lowlands formation process and the subsequent low-temperature hydration. The north-south dichotomy of the magnetic anomalies may not have been as drastic before the formation of the lowlands. The lack of distinct magnetic anomalies associated with the entire Valles Marineris, the dike swarms, and the shield volcanoes, as also confirmed by the science phase and aerobreaking phase MGS data, suggests that the upper at least 5 km of the crust in Tharsis bulge is not significantly magnetized. Rifting a magnetized layer of 5km thickness, with a magnetization similar to that of the mid-ocean ridge basalt (MORB), on the scale of Valles Marineris would have produced an appreciable magnetic anomaly that could have been detected by MGS. A dike cutting the magnetized layer will create a magnetic anomaly. Although the magnetic anomaly of a single dike decays fast with elevation and cannot be detected by MGS, the collective magnetic field of a wide dike swarm can produce a detectable field. Also, the magnetized layer would have been thermally demagnetized by the over lapping shield volcanoes and could have given rise to detectable magnetic anomalies at MGS altitudes. The upper crust of Tharsis bulge is basaltic and expected to have appreciable magnetic minerals, and the bulge has always been a highland where low-temperature hydration may not have been appreciable. If so, then the core dynamo ceased, or considerably reduced in intensity, before the formation of the upper crust in Tharsis bulge.

P31A-03 0830h

Models for Mars' Magnetic Scalar Potential

Donna M Jurdy[1] (847/491-7163; donna@earth.northwestern.edu)

Michael Stefanick[1] (mike@earth.northwestern.edu)

[1]Northwestern University, Department of Geological Sciences; 1850 Campus Drive, Evanston, IL 60208-2150, United States

Mars Global Surveyor MAG/ER measured strongly magnetized crust, despite Mars' weak field at present, the intensity reaches about 10 times that of Earth's magnetic lineations. We analyze the magnetic lineations in an octant centered at 40°S, 180°W ±40°, concentrated in the more heavily cratered Southern hemisphere. Data from the mapping phase of Mars Global Surveyor, MAG/ER magnetic measurements at an altitude of 404 ±34 km, were made available by Connerney conveniently binned into degree boxes. Using a rotated spherical co-ordinate system centered at 40°S, 180°W, we perform a two-dimensional Fourier analysis over this region. This can be shown to be a good approximation: results can be used to reconstruct the original components as a check. The magnetic field components can be described by the curl of a vector potential or the gradient of a scalar potential. The scalar potential is especially attractive as it can be obtained from the Fourier transform of the vertical magnetic component, H_z. The gradient of this field generates the horizontal magnetic components which can be compared with the rotated horizontal components. The corresponding fields are nearly identical, thus an independent check as the horizontal components were not used to construct the scalar potential. We model the magnetic field using the observed scalar potential. With vertical dipoles we determine depths and magnitudes for selected centers and average surroundings, and find that 8 sources account for 80% of the variance. (Only 4 sources already account for 60% of the variance.) These sources range in depth 260±130 km, and the source magnitudes range over a factor of 4. Using the autocorrelation of the scalar potential, we estimate that there are only 20-30 independent components of the field (which corresponds to a resolution of 4x5 or 5x6).

P31A-04 0845h

Can Mercury's Weak Surface Magnetic Field be Generated by a Dynamo?

Sabine Stanley[1] (stanley@geophysics.harvard.edu)

Jeremy Bloxham[1] (bloxham@geophysics.harvard.edu)

William E. Hutchison[2] (hutch@mit.edu)

Maria T. Zuber[2] (mtz@mit.edu)

[1]Harvard University, Department of Earth and Planetary Sciences, 20 Oxford St., Cambridge, MA 02138, United States

[2]Massachusetts Institute of Technology, Department of Earth, Atmospheric and Planetary Sciences, 54-918, Cambridge, MA 02139-4307, United States

Mariner 10 observed Mercury's magnetic field during 3 flybys of the planet between 1974 and 1975, revealing the presence of a magnetic field of internal origin with a dipole moment of $\approx 300\text{nT}-R_M^3$ ($1R_M = 2440$ km). Such a field is probably too large to be explained by induction effects or remanent magnetization; however, energetic considerations suggest that it may be too small to be consistent with dynamo action, at least for an Earth-like dynamo. More specifically, energetic considerations provide an estimate of the toroidal magnetic field strength that the dynamo should generate: if the dynamo is Earth-like in the sense that it has similar toroidal-poloidal field strength scaling as the Earth, then the poloidal field should be much stronger than that observed. Before abandoning a dynamo explanation for Mercury's field, we question whether the same toroidal-poloidal scaling should hold for Mercury. If a dynamo is operating in Mercury's iron core, part of the core must be fluid. Thermal evolution calculations estimate that the solid inner core comprises between 0.5 and 0.8 of the total core radius, much larger than the Earth value of 0.35. As a result, the fluid convecting outer core where the dynamo is generated is much thinner for Mercury than for Earth. Here we use 3-D numerical dynamo modeling to investigate dynamos operating in thin shell geometries. We find that the magnetic fields produced by thin shell dynamos can have larger toroidal to poloidal field ratios than Earth-like dynamos. This suggests that a hydromagnetic dynamo may be consistent with the weak surface field observed at Mercury and alternative explanations may not be required.

P31A-05 0900h

Estimating the k2 Tidal Gravity Love Number of Mars

David E. Smith[1] (301-614-6010; David.E.Smith@nasa.gov)

Maria T. Zuber[2] (617-253-6397; zuber@tharsis.gsfc.nasa.gov)

Mark H. Torrence[3] (301-794-3000; mtorrenc@geodesy2.gsfc.nasa.gov)

Peter J. Dunn[3] (301-794-3000; Peter_J_Dunn@raytheon.com)

[1]NASA Goddard Space Flight Center, NASA GSFC Code 920, Greenbelt,, MD 20771, United States

[2]Massachusetts Institute of Technology, Department of Earth, Atmospheric, and Planetary Sciences 54-518, Cambridge,, MA 02139-4307, United States

[3]Raytheon Information Technology and Scientific Services, 4500 Forbes Blvd., Lanham,, MD 20706, United States

Analysis of the orbits of spacecraft can be used to infer global tidal parameters. For Mars, the Mars Global Surveyor (MGS) spacecraft has been used to estimate the second degree Love number, k2 from the tracking DSN tracking Doppler and range data by several authors. Unfortunately, neither of the spacecraft presently in orbit are ideally suited to tidal recovery because they are in sun-synchronous orbits that vary only slightly in local time; and, further, the sub-solar location only varies by about ±25 degrees in latitude. Never-the-less respectable estimates of the k2 tide have been made by several authors. We present an updated solution of the degree 2 zonal Love number, compare with previous values, and analyze the sensitivity of the solution to orbital parameters, spacecraft maneuvers, and solution methodology. Estimating the k2 Tidal Gravity Love Number of Mars

P31A-06 0915h

Tharsis: Consequence of Mars' Dichotomy and Layered Mantle

Mark J. Wenzel[1] (510-642-2575; markw@seismo.berkeley.edu)

Michael Manga[1] (510-643-8532; manga@seismo.berkeley.edu)

A. Mark Jellinek[2] (416-946-8130; markj@physics.utoronto.ca)

[1]Department of Earth and Planetary Science, University of California, Berkeley, 307 McCone Hall, Berkeley, CA 94720, United States

[2]Department of Physics, University of Toronto, 60 St. George St., Toronto, ON M5S 1A7, Canada

The two largest and most striking features on Mars are the crustal dichotomy, the nearly hemispheric division in topography, gravity, crustal thickness, and age, and Tharsis, a volcanic center active from the Noachian to the present. Tharsis' long-term persistence of localized volcanism is, to the best of our knowledge, unique in the solar system. Explaining the timing of Tharsis volcanism, from initiation early in martian history to recent activity, has been an enduring challenge.

Here we present an model of the martian mantle that can explain early and persistent volcanism at Tharsis by incorporating the effects of the crustal dichotomy and a compositionally layered mantle. As the crust is expected to be enriched in heat-producing elements, this dichotomy in thickness leads to a dichotomous heat flux boundary condition on the mantle, which affects the internal dynamics. The evidence for layering includes the ability of a layered mantle to simultaneously meet a chondritic bulk composition and the moment-of-inertia factor (Elkins-Tanton et al., in revision), which can not be done with a one-layered mantle. In addition, studies of the martian meteorites suggest that the martian mantle is heterogeneous, a constraint that can be met with layering.

We perform analog laboratory experiments with corn syrup to simulate Mars' thermal evolution. We vary the presence of a partial insulating lid, to simulate the effect of the dichotomy, and layering in the convecting fluid. We show that in the case of a layered mantle and an insulating lid, a large swell, which acts to localize upwelling plumes under the lid, forms early and endures for the scaled equivalent of billions of years.

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Linda T. Elkins-Tanton, E. M. Parmentier, and P. C. Hess, "Magma ocean fractional crystallization and cumulate overturn in terrestrial planets: implications for Mars," in revision for *Meteoritics and Planetary Science.*

P31A-07 0930h

Martian Mantle Analogues - Properties of Fe-Rich Silicate Melts

Marcel Potuzak[1] (498921804221; potuzak@min.uni-muenchen.de)

Philippe Courtial[1]

Donald B. Dingwell[1]

[1]University of Munich, Earth and Environmental Sciences, Theresienstrasse 41/III, MUNICH 80333, Germany

Data from Mars missions have revealed that the planet has a very active igneous history and that it may still be volcanically active. To improve and understand the hypotheses regarding the formation and evolution of Mars a model for its interior must be developed. This requires a knowledge of the physico-chemical properties of Martian magmas that control their dynamics. Two different simple Fe-bearing systems have been studied to date: (i) anorthite-diopside eutectic composition (AnDi) with variable amount of Fe (up to 30 wt%) as a basalt analogue and (ii) sodium disilicate (NS2 up to 10 wt% Fe). In addition, the compositional range has been extended to include the more complex SNC meteorite composition (more relevant to Mars). The high-T viscosities (1594-1200°C) have been measured using the concentric cylinder method in air. The low-T viscosities (817-711°C) have been measured using the micropenetration method in an Ar atmosphere for samples that could be quenched to glasses. High-T density measurements (1026-1567°C) have been performed on investigated Fe-bearing melts using the Pt-based double-bob Archimedean method. The oxidation state of Fe has been determined on quenched glasses at regular T steps by wet chemistry method. Differential scanning calorimetry (DSC) measurements have been performed on glassy samples at heating and cooling rates of 5, 10, 15 and 20 K/min in order to define the glass transition temperature (Tg). Isothermal viscosity decreases from 0.15 to 0.22 log Pa.s (high-T) and from 0.8 to 1.2 log Pa.s (low-T) with the addition of each 5 wt% Fe into the AnDi eutectic system. The viscosity of all these melt compositions shows non-Arrhenian behaviour across the whole T-range investigated. The density of the melts increases by about 0.05 g.cm^{-3} with each addition of 5 wt% of Fe. Fe^{3+} content decreases with increasing T (i.e., about 10% between 1300-1600°C). The DSC measurements suggest that the Tg decreases about 19°C with the addition of each 5 wt% Fe at a given cooling/heating rate. Low viscosities, which result from the high Fe content of Martian magmas, promote highly fluid lava behaviour, with implications for lava runout distances, eruptive styles and the landforms produced.

P31A-08 0945h

Investigation of the Cooling Capacity of Plate Tectonics and Flood Volcanism in the Evolution of Earth, Mars and Venus

Peter van Thienen[1] (++31-30-2535141; thienen@geo.uu.nl)

Nico J. Vlaar[1] (vlaar@geo.uu.nl)

Arie P. van den Berg[1] (++31-30-2535072; berg@geo.uu.nl)

[1]Department of Theoretical Geophysics, Utrecht University, P.O. Box 80021, Utrecht 3508 TA, Netherlands

The cooling of the terrestrial planets from their presumed hot initial states to the present situation has required the operation of one or more efficient cooling mechanisms. In the recent history of the Earth, plate tectonics has been responsible for most of the planetary cooling. The high internal temperature of the early Earth, however, prevented the operation of plate tectonics because of the greater inherent buoyancy of thicker oceanic lithosphere (basaltic crust and depleted mantle) produced from a hotter mantle. A similar argument is valid for Venus, and also for Mars. An alternative cooling mechanism may therefore have been required during a part of the planetary histories. Starting from the notion that all heat output of planets is through their surfaces, we have constructed two parametric models to evaluate the cooling characteristics of two cooling mechanisms: plate tectonics and basalt extrusion / flood volcanism. We have applied these models to the Earth, Mars and Venus for present-day and presumed early thermal conditions. Our model results show that for a steadily (exponentially) cooling Earth, plate tectonics is capable of removing all the required heat at a rate comparable to or even lower than its current rate of operation during its entire history, contrary to earlier speculations. The extrusion mechanism may have been an important cooling agent in the early Earth, but requires global eruption rates two orders of magnitude greater than those of known Phanerozoic flood basalt provinces. This may not be a problem, since geological observations indicate that flood volcanism was both stronger and more ubiquitous in the early Earth. Because of its smaller size, Mars is capable of cooling conductively through its lithosphere at significant rates. As a result may have cooled without an additional cooling mechanism during its entire history. Venus, on the other hand, has required the operation of an additional cooling agent for probably every cooling phase of its possibly episodic history, with rates of activity comparable to those of the Earth.

P31B MCC: Level 2 Wednesday 0830h

Applications of Planetary Radars I Posters *(joint with G)*

Presiding: **K Larsen,** Jet Propulsion Laboratory, California Institute of Technology**; K Williams,** Center for Earth and Planetary Studies, Smithsonian Institution

P31B-1055 0830h POSTER

A new concept for seismology on Venus using orbiting radar instead of landers

Philippe Lognonne[1] (+33-145114251; lognonne@ipgp.jussieu.fr)

Raphael Garcia[1] (+33-145114152; garcia@ipgp.jussieu.fr)

Giovanni Occhipinti[1] (+33-145114272; occhip@ipgp.jussieu.fr)

Barbara Romanowicz[2] (+1-510642-3977; barbara@seismo.berkeley.edu)

W. Bruce Banerdt[3] (+1-818354-5413; bruce.banerdt@jpl.nasa.gov)

[1]Departement de Geophysique Spatiale et Planetaire Institut de Physique du Globe de Paris, 4 Avenue de Neptune, Saint Maur des Fosse 94107, France

[2]UC Berkeley Seismological Laboratory, 215 McCone Hall #4760, Berkeley, CA 94720-4760, United States

[3]Jet Propulsion Laboratory, Mail Stop 183-501 4800 Oak Grove Drive, Pasadena, CA 91109, United States

Magellan images of Venus show extensive faulting and fracturing, suggesting movement of the planet's crust and the current possibility of frequent Venus quakes. The high surface temperature and pressure of the planet is, however, such that a long lived network would be extremely challenging and probably financially prohibitive. We propose therefore to use the strong coupling between the atmosphere and the solid planet for detecting surface waves generated by quakes on Venus. After a quake, the surface of a planet is vibrating horizontally and vertically. By continuity, the atmosphere at the surface must move with a vertical velocity equal to the surface vertical velocity, and this vibration is then propagated upward. Its kinetic energy is conserved as long as the atmospheric viscosity does not produce significant attenuation. Due to the exponential decay of density with altitude, the amplitude of the wave increases exponentially and produces significant perturbations of the electron density in the ionosphere. Such signals are now commonly observed on the Earth for large quakes, both with ground Doppler HF sounders and space-based GPS satellites. We show that the dense atmosphere of Venus amplifies this effect by a factor of about 100 compared to the Earth. Moreover, the structure of the ionosphere makes radar observations of these signals from above easier than on Earth. We present simulations and estimates of the detection threshold of this new strategy for Venus seismology. A general concept of the experiment is then proposed.

P31B-1056 0830h POSTER

Investigating Impact Crater Related Surficial Deposits on Venus With Arecibo Multi-Polarization Radar Images

Lynn M. Carter[1] ((607)-255-3317; lcarter@astro.cornell.edu)

Donald B. Campbell[1] (campbell@astro.cornell.edu)

Bruce A. Campbell[2] (campbellb@nasm.si.edu)

Jean-Luc Margot[3] (margot@gps.caltech.edu)

[1]Cornell University, Space Sciences Building Cornell University, Ithaca, NY 14853, United States

[2]Smithsonian Institution, Center for Earth and Planetary Studies Smithsonian Institution, Washington DC 20560, United States

[3]California Institute of Technology, Department of Geological and Planetary Sciences California Institute of Technology, Pasadena, CA 91125, United States

Magellan spacecraft images of Venus revealed several different types of impact crater related deposits on Venus. Examples include the hundreds of kilometers in length parabolic-shaped deposits and the smaller (tens of km) dark halos. Wind streaks are associated with some of these features, confirming the presence of mantling material. These areas on Venus may look significantly different at optical wavelengths, since radar can penetrate several wavelengths into the surface and reveal underlying terrain. Linear polarization analysis can be used to investigate whether there is a surficial deposit in a given region. A circularly polarized wave can be decomposed into two orthogonal linear-polarized waves of equal magnitude. If a circularly polarized radar signal penetrates into a surface that is smooth at wavelength scales, and is scattered by embedded rocks or a sub-surface layer, the received echo will have a linear-polarized component. This linear polarization is produced because the "horizontal" and "vertical" components of the incident circular wave have different transmission coefficients into and out of the surface layer. If there is no sub-surface reflection, there will be no linear polarization. We used the 13-cm wavelength Arecibo radar system to observe Venus during two inferior conjunctions. We transmitted a circularly polarized wave and received both of the reflected circular polarizations. From these data, delay-Doppler images in all four Stokes polarization parameters were created, and a map of the degree of linear polarization was formed. Our data reveals linear polarization associated with impact craters, volcanic dome fields, and areas of wind streaks. In particular, we note significant linear polarization from areas near 44 craters, including 5 of the craters with parabolic deposits. The linear polarization signature is usually associated with the diffuse, featureless radar-bright areas near the crater. In addition, the craters that show a linearly polarized echo component often have dark halos or bright floors, and thus are likely be younger in age. This technique can be used for other objects as well, including possibly determining whether there is regolith covering the polar ice deposits on Mercury and searching for regolith on asteroids.

P31B-1057 0830h POSTER

Eastern Sahara Paleohydrology from JERS-1 Radar Data: Potential Analog to Mars

Philippe Paillou[1] (Philippe.Paillou@obs.u-bordeaux1.fr)

Tom G Farr[2] (818-354-9057; tom.farr@jpl.nasa.gov)

Ake Rosenqvist[3] (ake.rosenqvist@nasda.go.jp)

[1]Astronomical Observatory of Bordeaux, 2 rue de l'Observatoire, Floirac BP 89, 332, France

[2]Jet Propulsion Laboratory, California Institute of Technology, MS 300-233, Pasadena, CA 91109, United States

[3]NASDA/EORC, Roppongi First Building, 13F, Tokyo 106-0032, Japan

The recent geological and hydrological history of the eastern Sahara is still mainly hidden under large regions of wind-blown sand. The subsurface geology is generally invisible to optical remote sensing techniques (LANDSAT, SPOT), but radar images obtained from the Shuttle Imaging Radar missions were able to penetrate the superficial sand layer to reveal parts of the paleohydrological networks. However, the incomplete geographic coverage of the SIR missions did not allow regional-scale mapping of the hidden hydrological and tectonic structures of the eastern Sahara, and scientific interpretations of available data remain partial and incomplete. Nevertheless, complete L-band radar coverage of the eastern Sahara exists and can be exploited: it was obtained by JERS-1, a Japanese satellite for Earth observation that was operated by NASDA from 1992 to 1998. We have produced the first radar mosaic of the eastern Sahara covering Egypt, Sudan, Libya and Chad, from existing archives of JERS-1 L-band radar images, at a final resolution of 50 meters. Such a data set will help in discovering unknown subsurface structures (river channels, former lakes, faults, impact craters, etc.) and will contribute to answering several key questions about the recent climatic, geological, and hydrological history of the eastern Sahara. As the eastern Sahara represents a good terrestrial analog to Mars, our work may also be applied to the exploration of Mars. Much of the surface of Mars has been