are the most abundant form of matter in the outer solar system - the Galilean moons, Pluto, Charon and the KBOs. However, until now, no one has suggested that the giant planets themselves are so composed, moreover that these bodies alone comprised the original solar system. The terrestrial planets result from later, high energy impacts on the giant planets. Fortunately, the birth of a new terrestrial planet, Venus, occurred within proto-history and the entire process is documented in ancient writings. It formed as a result of the impact on Jupiter cited above, expelling a plasma cloud several times the mass of Venus and thousands of times the volume of Jupiter. Most escaped Jupiter and entered an eccentric planetary orbit, while contracting to a star-like proto-Venus, with a temperature above 10,000K. Its perihelion, close to the ancient interior orbit of Mars, and its aphelion, at the orbit of Jupiter, gave it a period of some five years. But its great orbital energy was rapidly reduced, due to repeated interactions with Mars and the Sun at perihelion. The tidal force of the Sun and its magnetic field combined to heat the ionized, fluid body, slowing its orbital velocity. Each pass reheated it, further reducing its aphelion and increasing the frequency of interactions. Its repeated heating caused the out-gassing of most lighter elements to space by Jeans escape. Thus the loss of orbital energy resulted in the increasing of its average density from 1.3 gm/cm3, the density of Jupiter, to over 5.5 g/cm3, the density of Venus. This is how all terrestrial planets were formed. This catastrophic birth ensures the concentration of iron in the core, the rising of hot radioactive elements Th, Ur, K, and the less dense materials to the surface. Although the volatiles, H2, C, N, O2, which comprised the vast majority of the rebounded cloud, were initially lost, they remained in the inner solar system, to be captured later by the proto-planet as it cooled or by extant planets, thereby rapidly providing the elements necessary for life.

## P22A CC: 519 B Tuesday 1030h

### Planetary Science General Contributions II *(joint with A, GP, T, V, NG)*

***Presiding:*** **M Grande,** Rutherford Appleton Laboratory**; W B Moore,** University of California, Los Angeles

#### P22A-01 1030h

#### Atmospheric Science by the Mars Exploration Rovers.

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While the Mars Exploration Rovers were primarily designed to address geologic questions on Mars, they have also proved to be capable and innovative atmospheric science platforms. We have used the rovers for both characterization and monitoring studies of the martian lower atmosphere in both the Gusev and Meridiani sites. The bulk of our observations fall in the following categories: (1) Thermal infrared spectra of the Martian sky taken by the Miniature Thermal Emission Spectrometer (Mini-TES). The actual sequences consist of both standard 200-second integrations and long “stares” of up to (almost) an hour. These data are highly diagnostic of vertical thermal structure (from 10 meters to 3-5 kilometers), aerosol optical depth along with particle size, and under the right thermal conditions, the water column. (2) Direct solar imaging using the Panchromatic Camera (Pancam) with the 440/880 nm + neutral density (ND5) filters, providing accurate measurements of visible optical depths. (3) Near-sun and “sky-arc” sequences using Pancam’s full suite of geological filters, intended to capture the forward-diffraction peak and the phase function characteristics of the aerosol particles. (4) Carbon dioxide (15 micrometer band) profiling of the Mini-TES surface observations, providing an average near-surface (1 m) air temperature. The above activities have been used to characterize short-term, diurnal and secular trends, and to also examine spatial variability. In addition, serendipity has provided the unique opportunities of watching the decay of a moderate dust storm from two widely-separated sites as well as of multiple simultaneous orbiter-rover observing “campaigns.” The latter group includes thus far the Mars Express over-flights of Spirit on sols 13A and 29A and the nearly-nadir Mars Global Surveyor over-flight of Opportunity on sol 22B and Spirit on sol 45A. Finally, we have taken sunset movies to further diagnose the aerosol scattering properties and their vertical distribution. During our presentation, we will summarize the breadth of the atmospheric results, highlighting the novel contributions that the MER suite of instruments has provided to advance our understanding of the martian atmosphere.

#### P22A-02 1045h

#### Initial Results on the Mineralogy and Geochemistry of the Mar Exploration Rover Gusev Landing Site

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The Spirit rover has investigated the geochemistry and mineralogy of the Gusev crater site using in situ Alpha Proton X-Ray, Mossbauer, visible, and infrared spectroscopy. The Gusev site is covered with angular to sub-rounded rocks that are typically less than 1 m in maximum dimension. More than 90 percent of these rocks are dark-toned, with the remainder being lighter-toned rocks that may predominantly be dark rocks with a thin (10’s of microns) coating of easily removed fines. APXS analysis has been obtained of a rock (Adirondack) following the removal by grinding of the surface dust and the upper few mm of the rock surface. These data give a modal mineralogy corresponding to olivine basalt. High quality Mini-TES data have not been obtained of a completely dust-free rock surface. The Mini-TES data of Adirondack do show long wavelength (15-25 microns) absorptions due to olivine of composition Fo60. All of the rocks observed are very compositionally homogeneous in the Mini-TES spectra. These findings are consistent with the detection of olivine-bearing basalt at this site from orbital TES infrared spectroscopy. Mossbauer spectra of Adirondack show the presence of forsteritic olivine and magnetite, with possible pyroxene. The soils at Gusev are a mixture of reddish fine-grained to sandy materials, granular-sized particles that occur in ripple forms, and minor pebbles. Mini-TES spectra of the soil show an excellent match to the TES spectra of high-albedo, fine-grained material found in regional bright regions that is interpreted to be windblown dust. This agreement suggests at least the uppermost layer of the soil at Gusev has been accumulated from airfall dust. By analogy with prior analysis of TES data these materials contain several percent carbonate, minor bound water, and a framework silicate interpreted to be either feldspar or zeolite. APXS spectra show similar oxide abundances to those determined for the Pathfinder site, except for higher MgO, and lower total iron. The preliminary potassium abundances are lower than predicted from orbital GRS data. The material that fills small hollows is finer-grained than the surrounding soils based on temperatures from Mini-TES, and may be predominantly airfall dust. To date there is no evidence from the mineralogy and geochemistry of the materials at Gusev to support the hypothesis that the surface materials being sampled were deposited in a lacustrine or evaporite environment. The data are consistent with materials formed by volcanic processes similar to those found throughout much of the equatorial and mid-latitudes, and locally redistributed by impact and aeolian processes.

#### P22A-03 1100h

#### Isolating Diffraction Signatures in New Horizons Multi-tone Radio Occultation Data and Resolving Their Related Structures at Pluto

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A planetary radio occultation experiment typically consists of a single tone transmitted toward a receiver as the line of sight is obscured by, or emerges from, the planet limb. Phase shifts in the tone are recorded and are attributed, in part, to the presence of a refracting atmosphere. Under the assumption of a spherically symmetric atmosphere with no “small-scale” structure, the Abel inversion may be applied to the phase data in order to recover an atmospheric refractivity profile. Unfortunately, being rooted in geometrical optics, the Abel inversion does not account for wave optics effects such as diffraction, which can arise from sub-Fresnel-scale structure (e.g., temperature inversions, waves, planet limb). When applied in the presence of such features, the Abel inversion produces atmospheric profiles blurred by diffractive ringing. To resolve sub-Fresnel-scale structure, more advanced inversion techniques, such as back propagation, have been developed that allow for profiles with resolutions better than the size of the first Fresnel zone - an order of magnitude better in some cases. By using multiple tones that are closely spaced in frequency, the New Horizons Radio Occultation Experiment (REX) will attempt to generate several atmospheric profiles of Pluto from a single fly-by, which includes both ingress and egress occultations. Since Pluto has a very tenuous atmosphere, it is expected that limb diffraction from each tone will dominate over any phase signature from atmospheric structure. Consequently, successful construction of atmospheric profiles for Pluto requires an inversion method that accounts for limb diffraction from not one but multiple carriers. This research presents the results of ongoing investigation into the interaction of multiple tones in radio occultation (most notably for New Horizons REX) and the effect of additional carriers upon wave optics inversion methods, i.e., back propagation. Also, various techniques for isolating each carrier, including their corresponding frequency signatures from planetary structure (diffractive and otherwise), are explored.

#### P22A-04 1115h

#### Shock Features of the Vargeão Dome Structure, Santa Catarina, Brazil

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The circular Vargeão structure, approximately 12 km in diameter, lies in western Santa Catarina state, Brazil. The structure is characterized by a central domed uplift of shocked and brecciated late Paleozoic/Mesozoic quartzose sediments, surrounded by brecciated basaltic flows of the early Cretaceous Serra Geral Formation within the Paran á Basin. Structural aspects of possible impact origin include radial and annular fracture patterns with apparent vertical slickenlines. Distinct mesoscale shock features (ie. especially an ejecta blanket and impact melt) are absent, presumably due to erosion, but their absence has promoted the consideration of alternative geologic origins. Qualitative and quantitative documentation of petrofabric shock features are presented that are consistent only with a meteorite impact origin. Four distinct orientations of planar deformation features in quartz and shock features in plagioclase along with secondary zeolitization will be described. Detailed studies of unit cell dimensions emphasizing shocked quartz are underway. The Vargeão impact structure is one of few known terrestrial impacts in basalt target rocks; comparisons with the other terrestrial impacts in basaltic target rocks will be presented.

#### P22A-05 1130h

#### Saturn’s Atmosphere and rings: A Recent Assessment Using Infrared Imaging

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For the past several years, a program devoted to understanding the Saturn system prior to the arrival of the Cassini spacecraft has used thermal infrared imaging to define the variability of temperature, cloud properties, and minor constituents in the atmosphere, together with thermal properties of the ring system. This research, sponsored by NASA programs at the Infared Telescope Facility and the W. M. Keck Observatory on Mauna Kea, Hawaii, has used images at wavelengths between 5.2 and 24.3 $\mu$m. Thermal features have been noted which change with time, particularly in Saturn’s south polar region. Upper stratospheric temperatures are distinctly higher at latitudes poleward of 83°S; this is also true of the lower stratosphere/upper troposphere where the region within 1° of the pole is paricularly warm. A series of alternating warm and cool axisymmetric bands characterizes the morphology of the tropospheric temperature field at “midlatitudes” from approximately 45° to 83°S. Zonal wave features are present in Saturn’s upper troposphere, achieving particular prominence in a moderately warm band between approximately 35° and 45° S and in the warmest band

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between 25° and 25°S, planetocentric. The equatorial region (15°N to 15°S) is much cooler than the rest of the planet in both the troposphere and the stratosphere, with a slightly warmer band detectable in the upper stratosphere within 1–2° latitude of the equator. Besides the prominent zonal wave structure in Saturn's troposphere, the most prominent zonal features are those which are observable at 5.2 $\mu$m, showing the optical thickness of clouds at the $NH_3$ condensation level. Distinct brightening of the ring system is apparent as a function of placement in orbit, with the coolest portion of the rings being those in shadow behind the planet. Ring brightess as a function of distance from the planet generally follows the same qualitative trend of optical thickness as in the visible.

## P31A CC: 519 B Wednesday 0830h

### Magnetic Field of Planetary Lithosphere I *(joint with GP)*

***Presiding:*** **M Purucker,** NASA Goddard Space Flight Center**; J Arkani-Hamed,** McGill University

### P31A-01 0830h INVITED

#### Mars' Magnetic Lithosphere: Candidate Minerals

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Mars' southern-hemisphere magnetic anomalies require a large Martian magnetic field at the time the lithosphere acquired thermoremanent magnetization (TRM), large magnetic mineral concentrations compared to Earth's lithosphere, a mineral or minerals whose grain size and resulting domain structure generate intense TRM, and/or a high Curie temperature and deep Curie-point isotherm. Based on Martian meteorites and spectroscopy of the Martian surface, the magnetic minerals likely to be important in Mars' lithosphere are magnetite, hematite and pyrrhotite. Martian anomalies are likely an integrated effect over a depth interval of 20-30 km. Pyrrhotite has a low Curie point (320oC) and is found only in specialized settings on Earth, although demagnetization around Hellas and Argyre craters may favor pressure-induced cycling of near-surface pyrrhotite through its 2.8 GPa phase transition. More promising as deeper sources are magnetite and hematite, which are ubiquitous on Earth and have high Curie points (580 and 675oC). TRM of magnetite decreases inversely with increasing grain size, while the opposite is true for hematite. The two minerals have the same TRM intensity around 10-20 micrometers, close to both the upper limit for pseudo-single-domain (PSD) behavior in magnetite and the critical single-domain size of hematite. The lack of any substantial self-demagnetizing field permits a TRM in multidomain hematite orders of magnitude larger than the TRM of multidomain magnetite for field strengths like the Earth's. Either single-domain/ PSD magnetite or multidomain hematite could explain strong anomalies. Single-domain magnetite requires less concentration but has restrictively small (submicron) grain sizes. Recently single-domain hematite has been found to have more intense TRM than previously measured, and it too could be viable. Depending on magmatic conditions, fine-grained magnetite and hematite can occur as segregated phases within titanomagnetite and titanohematite. Ultrafine subdivision might give rise to lamellar magnetism, as reported for terrestrial titanohematites. Thermoviscous magnetization is probably negligible for Mars because of the small present field and the minor enhancement of TRM that likely occurred in ancient fields.

### P31A-02 0900h INVITED

#### A review of our knowledge of the crustal magnetic field of Mars

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The data collected by the magnetometer experiment aboard the Mars Global Surveyor since 14 September 1997 have been used by numerous investigators to define the structure of that field, which has turned out to be only of crustal origin to the accuracy of the observations. The various techniques used include representations by spherical harmonics of the global potential function, averages of field at altitude, or by magnetized elements at the surface. Data were collected from the highly elliptical braking orbits down to an altitude of 102 km from the planet's surface during mainly daytime conditions. Such data were found to contain contributions from the interactions of the planetary atmosphere with the solar wind, including ionospheric currents so generated. After being placed into a "mapping" orbit in March 1999 it was then possible to utilize data from the dark side, presumably nearly free of such external influences, but the lowest altitudes were no less than about 365 km and ranged up to about 435 km. The local times since then have been kept to nearly 2 pm and 2 am for non–polar latitudes. This review evaluates the accuracy of the models and maps of field, and estimated magnetization parameter derived from the data and models.

URL: http://geomag.gfdi.fsu.edu/mars/index.html

### P31A-03 0930h

#### A Coherent Magnetic Field Model of the Martian Crust

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The tangential components of the magnetic field of Mars measured by Mars Global Surveyor (MGS) have appreciable contributions from the external magnetic field than the radial component. The immense amount of data acquired during the mapping phase of MGS provides good opportunity to derive a more accurate model of the magnetic potential field of the Martian crust using only the least contaminated radial component data. For this purpose the radial component data measured since the satellite resumed its mapping phase are divided into 2 sets of data, acquired from March 1999 to February 2001, and from February 2001 to April 2003. Each set is expanded in spherical harmonics using harmonics of degree up to 65, and their most repeatable signatures are selected through covariance analysis. The model tangential components derived from the model potential field are significantly different from those of the observed ones. Not only their small-scale features are different, but also their global scale features specified by spherical harmonics of degree 1-3 show appreciable differences, indicating the global scale external magnetic field contribution. Although the external field has negligible contribution to the strong anomalies of the south hemisphere, it may have appreciable contribution to the weak magnetic anomalies. The more reliable magnetic field model allows us to downward continue the anomalies to the surface of the planet and better delineate the relationship between the tectonic processes and the magnetic anomalies of Mars. The downward continued maps show numerous small scale magnetic anomalies over the northern lowlands, but no significant anomalies inside the giant impact basins.

### P31A-04 0945h

#### Correlated Magnetic and Gravity Anomalies West of the Isidis Basin, Mars and Implications for Plains Magnetism

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The magnetic field of Mars reflects strong crustal magnetism resulting from an ancient internal field. The crustal anomaly pattern parallels the geologic dichotomy in that most of the anomalies detected by the Mars Global Surveyor are located within the persumably older southern highlands while the northern lowlands has weak or no magnetic signature at satellite atltiudes. We have analyzed a section of the dichotomy boundary whose geology has been studied extensively in order to examine the implications of correlations between gravity and magnetic anomalies for the regional distribution of magnetic sources. The study area contains some of the strongest magnetic anomalies observed outside the area of high-amplitude anomalies found within the Terrae Cimmeria and Sirenum sector of the southern highlands. Several strong magnetic and gravity anomalies in the area of the Ismenius quadrangle are associated with a mapped normal fault, but the magnetic and gravity peaks and troughs are out of phase. The isostatic gravity anomalies indicate higher density bodies flanking the mapped normal fault. If we assume common sources of both the gravity and magnetic anomalies, and a coherent direction of magnetization within a spatially variable source layer, we acheive the best fit to both the gravity and magnetic fields using a low inclination for the magnetization direction ( 30 degrees), in general agreement with published paleopole estimates for Mars. This solution requires a continuous magnetic source layer extending north beneath the plains to avoid a large edge effect anomaly; this layer produces near-zero field away from the fault. An alternate model assumes that the gravity anomalies correspond to areas of demagnetization of a preexisting continuous magnetic source layer. This model fits best for an inclination near -45 degrees and does not require a source layer in the northern plains. Candidate geologic processes that could have produced such source distributions in the study area include extension and volcanic intrusion focused near the dichotomy boundary, and hydrothermal alteration which created, destroyed, or reduced the magnetism. The product of layer thickness and magnetic intensity implied by these models is roughly 5-10 times less than inferred in the highly magnetized region of the southern highlands, indicating significantly different genesis or evolution of the crust occurred in that region as compared to the rest of Mars.

## P32A CC: 519 B Wednesday 1030h

### Emerging Views of Mars: Formation, Evolution, and Current State I *(joint with GP, T, V, C, NG)*

***Presiding:*** **D Stegman,** Monash University**; M Jellinek,** University of Toronto

### P32A-01 1030h INVITED

#### Mars Magnetic Field: Implications for Crustal Formation and Evolution

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One of the most dramatic discoveries of the Mars Global Surveyor (MGS) mission is that of crustal magnetic field sources of multiple scales, strength and geometry. Current global field models exhibit similar large-scale features: intense magnetic fields (requiring crustal magnetizations approximately an order of magnitude greater than on Earth) over the Noachian-age Terra Cimmeria southern hemisphere region, weaker isolated anomalies over the northern hemisphere and over other southern hemisphere areas, and a general paucity of strong magnetic fields over the major impact basins. Challenges in constructing such models include the variable maximum spatial resolution in the magnetic field data, and the removal of magnetic fields of non-crustal origin. Three hypotheses for the timing of a dynamo have been proposed. In the first hypothesis, dynamo onset post-dates the youngest observed impact basins on Mars. In the second hypothesis, the dynamo is short-lived, with onset in the early Noachian and cessation prior to the formation of Argyre and Hellas. In the third hypothesis, early Noachian dynamo onset is invoked, but duration into the late Noachian or early Hesperian is permitted. Fundamental to distinguishing among these various hypotheses and to explaining the observed global distribution of magnetic anomaly amplitudes is establishing the relative timing of crustal formation, the duration of any dynamo regime (and indeed the driving mechanism for such a dynamo), and the effect of post-emplacement crustal modification on any acquired magnetic remanence. Accordingly, in this talk we review progress in addressing the following issues essential to understanding the history of Mars' magnetic field: (1) The timing of crustal formation in northern and southern hemispheres, (2) A quantitative assessment of magnetic anomalies in the major impact basins (specifically Hellas and Argyre), (3) Potential candidates for the magnetic carrier, along with rock magnetic properties that are important to remanent acquisition and any subsequent demagnetization, (4) An assessment of the effectiveness of thermal, hydrothermal, and shock demagnetization mechanisms, and geographically where these may have been active, (5) Energetics available to drive a martian dynamo. Based on