current understanding, our preferred hypothesis is an early short-lived global magnetic field. Open questions critical to further progress include the relative timing of dynamo cessation and the onset of Tharsis magmatism, and the process(es) responsible for formation of the dichotomy.

P32A-02 1045h INVITED

Martian Igneous Compositions Revealed by MGS-TES and Mars Odyssey THEMIS

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Most rock-forming minerals have distinctive absorptions in the thermal infrared portion of the spectrum (roughly 5-50 microns). This useful property is the primary motivation for sending a series of thermal infrared instruments to Mars: The Thermal Emission Spectrometer (TES) on the Mars Global Surveyor, the Thermal Emission Imaging System (THEMIS) on the Mars Odyssey, and the Miniature Thermal Emission Spectrometers on the two Mars Exploration Rover spacecraft. The massive volume of data returned from these instruments has provided the means to determine the global and local scale mineralogical compositions of the Martian surface. A broad question that the Martian surface mineralogy addresses is: What is the timing and extent of igneous processes on a planet that does not have plate tectonics? TES data has revealed that the Martian surface displays a striking hemispheric dichotomy in surface composition. Basalts or basaltic andesites similar in bulk composition to those commonly found on Earth dominate the southern highlands. A more silica rich surface that closely matches typical terrestrial basaltic andesites or andesites is present everywhere on the planet, though the highest concentrations are found within the younger northern lowlands. Though this dichotomy may be explained by two different igneous compositions, the high-silica glass in the more silicic composition could instead be a secondary mineral related to an alteration process rather than volcanism. Regardless of the source of the glass, Martian meteorite compositions are not typical of much of Martian igneous compositions. Mars Odyssey THEMIS data has exposed local scale compositional variability and provided an enhanced spatial context for the TES results. Layered olivine rich units appear in Valles Marineris, Ares Valles, and Nili Fossae. A quartz and feldspar lithology appears near the central peaks of two craters in Syrtis Major. In addition, a spectrally distinct unit is associated with surface units near Apollinaris Patera. The combined mineralogical information provided by TES with the geologic context provided by THEMIS have provided a picture that is emerging that Mars is perhaps more interesting than expected from an igneous perspective. A variety of processes and mechanisms must be present to produce the range of compositions seen from orbit.

P32A-03 1100h

Tharsis Bulge: Melt Migration in a Giant Mantle Plume

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Tharsis bulge formed through major volcanic activities in Noachian and early Hesperian, although minor volcanism likely continued to the recent past. There is a general consensus that major part of the Tharsis rise has been produced by basaltic flows. Syria planum has been identified as a long-lived (Noachian to early Amazonian) region of volcanism and tectonic activity on Tharsis, which emplaced voluminous sheet lavas on Mars in late Hesperian. Two sets of complex radial tectonic structures have originated from the planum. One set has resulted in the well-developed Valles Marineris, occurred in the Noachian and the tectonics continued at least to Hesperian. The other has produced the Claritas Fossae and Thaumasia normal faults and complex grabens, formed in Noachian to Amazonian. Both tectonic sets cut through the original volcanic structure of Tharsis bulge, they occurred later than the prominent volcanism that created the major part of the bulge. We studied the dynamics of a giant mantle plume in a compressible Martian mantle model, using a temperature and pressure dependent mantle viscosity, a temperature dependent thermal conductivity, and a pressure dependent thermal expansion coefficient in an axis-symmetric cylindrical coordinate system. We investigated the criteria required to produce a giant plume at the base of the mantle that could ascend fast and produce a large amount of basaltic melt within 500 Myr of the planet's history. The plume partially melts as it ascends through the mantle. Because of its very high buoyancy, the melt moves upward trough the partially molten porous plume much faster than the bulk solid residue of the plume. This causes a vast amount of volcanism well before the bulk part of the plume impinges the overlying lithosphere. The volcanism continues at relatively lower rate as the plume further ascends. The bulk solid residue of the plume finally impinges the lithosphere and exerts strong tension, creating tectonic features.

P32A-04 1115h INVITED

Buried and Visible Impact Basins on Mars: Constraints on the Timing of Major Events in Early Martian History

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The large population of buried impact basins found in MOLA elevation data on Mars provides compelling evidence for a "pre-Noachian" crust below the oldest visible Early Noachian surface units, and lowland crust below the younger plains that is Early Noachian in age, older than much of the visible highlands, but not as old as the buried "pre-Noachian" highlands. The large (D greater than 200 km) buried basins are suggested by "Quasi-Circular Depressions" (QCDs) that are not apparent in image data, and include features up to 3000 km diameter in both the lowlands (Utopia) and highlands (a newly found "Ares Basin"). There are about a dozen QCDs larger than 1000 km diameter which we can place in a relative age sequence based on superimposed smaller QCD. This and the N(200) crater retention age for the highlands and lowlands provide a chronology for early Mars, including when the global magnetic field may have died. The youngest and most obvious large basins (Hellas, Argyre, Isidis) lack magnetic anomalies within their main rings and may have formed after the magnetic field died. These all have an N(200) less than 2.5. The oldest, most subdued basins (including Ares) with N(200) greater than about 4.0 have many strong magnetic anomalies within their main ring and likely formed before the main magnetic field died. Intermediate age, "lowland-making" basins (Utopia, Chryse, Acidalia) have only a few weak anomalies. These, and the lowlands they created, occurred at about N(200) about 3.0-3.2.

P32A-05 1130h

Growth of the hemispheric dichotomy and the cessation of plate tectonics on Mars

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Although Mars is currently not tectonically active, it may have experienced plate tectonics early in its history. The southern hemisphere of Mars possesses a thick crust which probably renders the lithosphere positively buoyant. We present numerical and scaling arguments which show that if the area of positively buoyant lithosphere grows beyond a critical fraction, plate tectonics will stop. Heat transfer through the buoyant lithosphere is inefficient which causes mean mantle temperatures to increase as the surface area of buoyant lithosphere increases. The resulting reduction in mantle viscosity reduces shear stresses; if these shear stresses drop below the yield strength of the lithosphere, plate motions will ceases and the planet will behave as a one-plate system. Thus, the end of plate tectonics on Mars may be a natural consequence of the growth of the southern highlands. The implications of this model for volcanism will also be explored.

P32A-06 1145h INVITED

Evidence for Pervasive Cold Climates Throughout Most of Mars History

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Evidence from a variety of sources suggests that Mars has a significant water inventory. However, it appears that this inventory has been frozen throughout much of Mars history. Infrared spectral mapping by the TES and THEMIS orbital instruments has shown that the martian surface is dominated by unweathered volcanic rocks, including olivine-rich basalts in numerous areas. THEMIS 100-m scale multispectral imaging reveals compositional variations at these scales. However these compositional differences are due to differences in the composition of igneous materials. Regions of high (20 percent) olivine abundance basalts have been mapped at the scales of individual flows and rock layers, including exposures at multiple layers with the Valles Marineris system, demonstrating that large regions of Mars have not experienced significant surface or sub-surface water at any time in their history. THEMIS has not detected mineralogical evidence for carbonate rock layers at 100-m scales, despite the discovery by the MGS TES of minor carbonate in the martian dust. The existing carbonates can be produced by surface-atmosphere interactions, without requiring the presence and erosion of a carbonate rock source. THEMIS imaging has, however, shown evidence for extensive ice deposits in the mid- to high-latitude regions, some of which show evidence for recent downslope flow. These mantles preferentially occur on pole-facing slopes in mid-latitudes and are interpreted to be remnants of once-extensive snows deposited during recent periods of high obliquity. Melting of these deposits during intervening warmer periods may form the young gullies that are also observed at these latitudes. A pervasive surface mantle found from 30 to 50° in both hemispheres has been interpreted by Mustard et al. (2001) to result from ice-cemented soils that have formed recently and are currently being devolatilized. The poleward transition from a dissected to continuous surface on this mantle corresponds to a sharp increase in near-surface ice abundance seen by the GRS, suggesting that the mid-latitude portion of these mid-latitude mantles may be the same ice-rich material detected by the GRS at high latitudes, but whose upper few meters have been thoroughly desiccated. Together these observations suggest extensive mid-latitude surface ice deposits that come and go on time scales of 50,000 to several million years. Limited melting may occur in these deposits, but the low temperatures and short durations of liquid water appear to have severely limited the degree of global chemical weathering.

P33A CC: 220 C-E Wednesday 1330h

Magnetic Field of Planetary Lithosphere II Posters *(joint with GP)*

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

P33A-01 1330h POSTER

Annihilators at Mars: Are there Alternative but Reasonable Magnetization Distributions in the Martian crust that Explain the MGS Magnetic Field Observations

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There are an infinity of magnetization distributions that produce no external magnetic field, a result demonstrated by Runcorn to bring attention to the non-uniqueness inherent in the interpretation of lunar magnetic field observations. These distributions have been given the name annihilators. Runcorn's example, that of a uniformly magnetized spherical shell, is not a reasonable explanation for the Mars that we think we know. But other, more reasonable, annihilators have been proposed for the Earth. But those are not appropriate for the Martian case because of the absence of a dominant present day core field. We concentrate in this talk on two questions: 1) How do we ensure uniqueness in our inversions?, and 2) what alternative, but still reasonable, magnetization distributions might explain the Martian magnetic field observations?

P33A-02 1330h POSTER

Paleomagnetic Pole Positions of Mars

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Attempts have been made to estimate the position of the paleomagnetic dipole field axis of Mars using its magnetic anomalies. The results strongly depend on the accuracy of the anomalies. The immense amount of the magnetic data, measured by Mars Global Surveyor during its mapping period, provides good opportunity to derive highly accurate magnetic anomalies. We extract the least contaminated radial component of the magnetic data, and only those acquired at nighttime to further minimize contribution from the external magnetic field. The data are separated to two sets of almost equal size, acquired from March 1999 to February 2001 and from February 2002 to April 2003. The low altitude science and areobreaking phase data are not considered because they are daytime data and are contaminated by the external magnetic field. Each set of data is bined over 0.5x0.5 degree girds, and the mean value of a grid is determined. We model the source bodies of the 9 small and isolated magnetic anomalies we had previously identified, by a uniformly magnetized vertical prism of elliptical cross section using a space domain algorithm. Four models are calculated for the source body of each magnetic anomaly, as follows. The first two models are directly obtained using the two bined data sets. The other two are obtained using the low-pass filtered version of the bined data sets. For this purpose we extract the magnetic data over a given anomaly from the two bined data sets, and select their covariant parts using the Fourier domain algorithm. Assuming that a model source body is magnetized by a dipole magnetic field, we calculate the position of the dipole axis. This results in 4 paleomagnetic pole positions for each isolated magnetic anomaly. The 4 pole positions of 6 anomalies almost overlap indicating the high reliability of the pole positions. The 4 pole positions differ by no more than 10 degrees for the other 2 anomalies, indicating that the external field has minor contribution to these magnetic anomalies. The 4 pole positions of the remaining anomaly differ by as much 30 degrees, implying appreciable contribution from the external field. The pole positions show clustering in general agreement with those obtained by other investigators. We will discuss the geophysical implications of the new results.

P33A-03 1330h POSTER

Crustal Magnetic Spectra from Correlated Sources on Mars

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The spectral method for distinguishing crustal from core-source magnetic fields has been re-examined, modified and applied to both a comprehensive geomagnetic field model and an altitude normalized magnetic map of Mars [Voorhies, Sabaka and Purucker, 2002; JGR]. These observational spectra are fairly fitted by theoretical forms expected from certain elementary classes of magnetic sources. For Earth we found fields from a core of radius 3512 +/- 64 km and a crust represented by a shell of random dipolar sources at radius 6367 +/- 14 km. For Mars we found only a field from a crust represented in same way, but 46 +/- 10 km below the planetary mean radius. More realistic theoretical spectra, allowing for crustal thickness, oblateness and magnetization by a planet centered dipole, were derived and discussed, as were spectral effects of laterally correlated sources. The main effect of laterally correlated sources is to soften the spectrum at high degrees. We tend to over-estimate source shell depth when this is omitted. To include this effect simply, size and magnetization distribution functions for extended sources are recast as a characteristic diameter and mean square magnetization amplitude for an ensemble of vertically magnetized spherical caps on a shell. For small caps, and at moderate degrees, the partial derivatives of the log-theoretical spectrum with respect to amplitude, shell radius, and cap diameter are approximately proportional to 1, n, and -n**2, respectively. Separation of diameter from amplitude and depth should thus be straightforward, unlike separation of amplitude from layer thickness. Results from applications to observational spectra are discussed, noting that there are now several fine field models for Mars [Cain et al., 2000; Connerney et al., 2001; Arkani-Hamed, 2001, 2002; Hutchinson and Zuber, 2002; Langlais et al., 2002]; moreover, the terrestrial magnetic spectrum at high degrees, as revised [Sabaka, Olsen and Langel, 2002], updated with high precision Oersted data, and upgraded with high resolution Champ data, appears softer than before.

P33A-04 1330h POSTER

Interpretation of the Mackenzie River Magnetic Anomaly, Canada, From Satellite, High- and Low-Altitude Magnetic Data

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We characterize the nature of the source of the high-amplitude, long-wavelength, Mackenzie River magnetic anomaly (MRA), Yukon and Northwest Territories, Canada, based on magnetic field data collected at three different altitudes: 300m, 3.5 km and 400 km. The MRA is the largest amplitude (13 nT) satellite (CHAMP) magnetic anomaly over the Canadian landmass. In aeromagnetic data, the MRA is contiguous to the so-called Fort Simpson anomaly (FSA) that extends over 1000 km south to British Columbia. Within the MRA, source depth estimates (8-12 km) from Euler deconvolution of low-altitude aeromagnetic data show some coincidence with basement depths interpreted from reflection seismic data. The character of the MRA and FSA, i.e., a belt of long-wavelength, positive, high-amplitude magnetic anomalies suggests that they are caused by a magmatic arc. Estimated magnetization levels from inversion of high-altitude aeromagnetic data are similar to other sampled and modeled arc complexes. Only the FSA basement has been sampled but the intersected granitic lithologies support the arc interpretation. For the long-wavelength part of the MRA and FSA, the source is expected predominantly from the middle crust (10-25 km). The upper crust in the region is mainly sedimentary and only weakly magnetized (with the exception of some short-wavelength contributions from sills and dykes). The contribution from the lower crust remains undetermined.

P33B CC: 220 C-E Wednesday 1330h

Emerging Views of Mars: Formation, Evolution, and Current State II Posters *(joint with GP, S, T, V, NG)*

Presiding: **P R christensen,** Arizona State University**; H L Redmond,** Purdue University

P33B-01 1330h POSTER

Martian Dust Devil Electric Fields: The Connection of Fluid Physics to Electrodynamics

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It is known that dust devils generate large electric fields via tribo-electricity (contact electrification between mixing grains). By analogy, it is anticipated that the larger dust devils on Mars will also generate electric fields. In this work, we present an analytical argument for the generation of these field, starting with the basic fluid processes in the dust devil that account for grain lifting and the microscopic grain-grain tribo-charging processes through to the development of the electric field based on current flow in the dust devil. With this model, we can then predict the anticipated large scale electric fields based upon macroscopic meteorological parameters.

P33B-02 1330h POSTER

Slope Measurements of Terraces in Melas Chasma as an Example for 3D Basin Analysis from Remote Sensing Data of Layered Deposits on Mars

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An interesting problem for planetary scientists interpreting depositional and erosional histories of features evident in many satellite photos of Mars, such as scarps, terraces, plateaus and layering, is the correlation of linear and planar features between images to construct a regional or basin-wide three-dimensional visual model. As high resolution (10m/pixel) topographic digital elevation models becomes available, the measurement of linear and planar slopes may be accomplished with ordinary GIS software. The software used to make measurements of the strike/dip of selected features was the GIS package ArcView 3.1 with the 3D Geology extension provided by the Geological Survey of Canada. Additional work used GoCAD to construct three-dimensional visual models of the measured structures. The Geological Survey of Canada has produced an extension for GoCAD called SPARSE that allows the construction of three-dimensional visual models of the measured planar and linear features. This package would be useful in constructing models of basins from satellite imagery and topography data. The Melas Chasma region of the Valles Marineris on Mars is used as an example since it is one of the few regions for which 10-meter digital elevation models are publicly available. Plateaus in Melas Chasma are examined using techniques described in this poster presentation to reconstruct local stratigraphic relationships. An interpretation of features observable in images of Melas Chasma is offered.

P33B-03 1330h POSTER

Dry or wet conditions in the Martian mantle: Constraints from crustal evolution and magnetic field history

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Surface structures on Mars indicate that a significant amount of water had been present during the early evolution of the planet's surface. However, it is strongly debated how much water had been present in the Martian mantle and whether it is still present or not. The chemistry of the SNC meteorites has been interpreted to suggest that the Martian mantle stayed relatively dry since the time of core formation. New geochemical evidence from the shergotty meteorites, however, suggests water contents of up to 1.8 % in the pre-eruptive magma and places some doubts about the earlier assumption of a dry mantle, although, the origin of this water, from the mantle or the crust, is uncertain. Furthermore, the analyses by the APX on Mars Pathfinder and TES on MGS have identified rocks with chemical compositions similar to those of andesitic rocks. Several hypotheses for the origin of these rock types have been suggested. The andesitic rocks can either be explained by hydrous melting from a wet mantle or by weathering processes close to the surface. The latter might eliminate the need for hydrous melting and may also be consistent with a dry mantle. Water is a dominant factor influencing the rheology of the mantle; a dry Martian mantle composition suggests a stiff mantle with a high viscosity, whereas the presence of water suggests a weak mantle with a low viscosity. In the present study, the influence of the viscosity and the initial temperature distribution after core formation has been investigated on models of the crustal and the magnetic field evolution. Those models use a parameterized scaling law assuming for Mars a stagnant lid regime throughout its entire evolution. To explain both the observed crustal thickness of about 50 to 100 km with a continuous decline of global volcanism since the Noachian and the lack of a present-day core dynamo, a dry Martian mantle with a viscosity of 10^{21} Pas at a reference temperature of 1600 K and an initial mantle temperature of about 2000 $\pm$ 100 K is required. A wet Martian mantle with a viscosity of less than 10^{20} Pas at a reference temperature of 1600 K can easily explain the crustal evolution but is difficult to reconcile with the present lack of a self-generated magnetic field. A weak mantle rheology would result in an efficient cooling of the interior with core temperatures decreasing below the melting temperature of about 1900-2000 K (assuming a core sulphur content of 14 % as derived from the SNC meteorites). The associated freezing of the inner core then would induce chemical convection in the outer core due to the release of positively buoyant light material. This chemical convection in the core can efficiently drive a dynamo and would be active till the present day; inconsistent with the lack of a self-generated magnetic field.