landing-site geomorphology. A short-period seismometer and a wide-angle camera complete the payload to achieve these objectives.

The Naiades mission strongly resonates with the main "Follow the Water" theme of the MEP, but in ways that are not currently within the scope of the MEP or that of NASA's international partners. The combination of established terrestrial methods for groundwater exploration, robust flight systems, and cost effectiveness proposed for the Naiades is a relatively low-risk approach to answering key questions about water on Mars within the Scout framework.

P12A-0369 1330h POSTER

Mars CryoScout: Subsurface Exploration of the North Polar Cap

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The well documented layering of the Mars PLDs suggests that the polar caps, and the north polar cap in particular, are repositories of a climate archive that possibly spans many millions of years. Far more accessible, terrestrial ice sheets have been studied by coring to retrieve the pristine record of past chemical and physical properties, and to evaluate modification induced by time and stresses within the ice. On Mars' north polar cap, thermal probes are feasible and can provide a means, analogous to coring, of making subsurface observations. To explore the dominant climate cycles, it is postulated that tens of meters of depth, corresponding to the vertical separation of the major "MOC" layers, should be explored. Optical and spectroscopic analyses of the layers, which are presumably demarcated by embedded dust, contributes to the reconstruction of a timeline. Meltwater analysis is a convenient way to determine the soluble chemistry of that embedded dust, and to monitor gradients of the isotopic ratios of hydrogen and oxygen that reflect atmospheric conditions at the time the layer was deposited. As on Earth, local thermal measurements can be used to determine bulk mechanical properties of the cap, as well as estimating the geothermal gradient. A proposed mission that performs these observations will be described.

P12B MCC: Hall D Monday 1330h

New Results From Mars Odyssey II Posters *(joint with C, G)*

Presiding: **A McEwen,** University of Arizona**; A B Ivanov,** Jet Propulsion Laboratory

P12B-0370 1330h POSTER

Thermophysical and Morphologic Unit Mapping of Gusev Crater Using THEMIS Infrared and Visible Imaging

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Gusev Crater (160 km diameter) is hypothesized to have been a lacustrine depocenter, making it a prime landing site candidate for Mars Exploration Rover (MER) missions. Primary flow and sediment transport originated from Ma'adim Vallis, a large channel that debouches into Gusev, with outflow through the NW crater rim. Interior units of Gusev have been interpreted as deposits from fluvial resurfacing during the Noachian, Hesperian, and early Amazonian periods. Previous crater counting work suggests that the Gusev-Ma'adim hydrologic system was active from 0.7-2 Ga. Geomorphic and topographic features in Gusev and Ma'adim Vallis are critical to the hypothesis that water emptied and ponded periodically in the basin. MOLA topography indicates Gusev's floor <2500 m below the adjacent highlands. Some interpretations of Viking imagery suggest shoreline terraces, dissected deltaic deposits, and sedimentary structures consistent with deposition in an ice-covered lake. Higher-resolution MOC images, however, reveal no obvious lacustrine features. Mars Odyssey's Thermal Emission Imaging System (THEMIS) provides visible (18 m/pixel) imagery, and when compared to Viking and MGS-MOC data, shows low-albedo material being re-distributed over the last 25 years. Visible imagery also reveals multiple (4+) wind directions. THEMIS visible and thermal infrared (100 m/pixel) data were also used to delineate 8 units based on thermophysical and morphologic properties. Thermophysical units were qualitatively characterized by albedo and daytime-nighttime IR determined temperature differences. Morphologic units were characterized by topography, crater densities, erosional features, lineations, etc. Six of the 8 units lie within the MER landing ellipse. Use of both THEMIS and MGS-MOLA data allows a stratigraphic sequence to be inferred; however, uniquely lacustrine features have not been identified. Comparisons with previous photogeologic maps of Gusev show some discrepancies between mapped units, which may relate to lithologic characteristics only observable in thermal emission data at high spatial resolution.

P12B-0371 1330h POSTER

THEMIS Spectral Mapping of Melas Chasma, Mars

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The Melas Chasma trough, in the central complex of Vallis Marineris, provides an ideal site for testing a preliminary approach of deriving surface emissivity from the thermal infrared data produced by the Thermal Emission Imaging System (THEMIS) on the Mars Odyssey spacecraft. Melas Chasma exhibits layered deposits, regional collapse deposits descending from amphitheatres in the walls of the canyon, and various aeolian features. This variety of morphologic features indicates a complex geologic history and a likelihood of compositional heterogeneity in the deposits. The Thermal Emission Spectrometer (TES) on Mars Global Surveyor (MGS) reveals some of the expected spectral variability in this region. However, the 3 km x 6 km pixel resolution of the instrument makes it difficult to associate these variations with geomorphic units visible in the MGS Mars Orbiter Camera (MOC) images or in the THEMIS temperature images. The 100 m pixel size of the THEMIS infrared bands should provide the spatial resolution to associate spectral variability with geomorphology and provide insight into the geologic history of this site.

THEMIS data is processed to produce calibrated radiance using the most current calibration model. Camera reflections and other image artifacts are removed or minimized in this process. Geometric corrections of the data are applied to co-register the bands and allow for accurate spectral analysis. Emissivity is produced through a Temperature/Emissivity Separation algorithm. An empirical atmospheric correction using TES derived surface emissivity is used as a proxy for the radiative transfer model atmospheric correction that is not yet available for THEMIS data analysis. Spectral maps are produced from the resulting THEMIS data and the spectral characteristics compared with atmospherically corrected TES and the uncorrected THEMIS data to assess the accuracy of this technique. Evaluation of the nature and composition of these deposits from spectral analysis will follow after a thorough assessment of the accuracy of our emissivity data and atmospheric corrections.

P12B-0372 1330h POSTER

Using THEMIS Visible and Infrared Data for Crater Population Studies of Mars

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Aboard the currently orbiting Mars Odyssey spacecraft is the Thermal Emission Imaging Spectrometer (THEMIS) that acquires both visible (VIS) and thermal (IR) wavelength images of the surface. The visible images can be used to conduct crater population studies as is traditional with visible photographic planetary data. However, this study shows that infrared images also may be utilized successfully for crater population studies. THEMIS collects both daytime (VIS and IR) and nighttime (IR only) data, but the nighttime data are less useful for the crater counting analyses than are either daytime data set because counts using the nighttime images are routinely underestimating the number of craters present. For this study, the THEMIS data were utilized to study the Sinus Meridiani landing site crater population.

P12B-0373 1330h POSTER

THEMIS Observations and TES Surface Compositions of Low-Albedo Intracrater Materials and Wind Streaks in Western Arabia Terra

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High-resolution thermal infrared images (100m/pixel) from the Mars Odyssey Thermal Emission Imaging System (THEMIS) are used for thermophysical analyses of low-albedo intracrater materials and wind streaks in Western Arabia Terra and comparisons with Mars Global Surveyor (MGS) Thermal Emission Spectrometer (TES) derived surface compositions.

Atmospherically corrected thermal emissivity data from TES have been used to identify two global-scale spectral surface units. The Surface Type 1 end-member is interpreted as largely unweathered basalt while the Surface Type 2 end-member has been interpreted as andesite and/or partly weathered basalt. Deconvolved TES spectra of low-albedo intracrater materials reveal both Surface Type 1 and 2 compositions within individual craters. Surface Type 1 compositions form a central core in dark features on crater floors while Surface Type 2 compositions form a surrounding arc on the dark downwind sides of crater walls. The transition between these compositions appears to occur near the floor-wall interface and is correlated with a transition from high-thermal inertia dune materials to low thermal inertia dune-free materials. Surface Type 1 and 2 compositions are also observed in adjacent low albedo wind streaks; however, a mixing trend is not as evident as within the impact craters.

THEMIS day/IR observations of low-albedo intracrater materials appear to show relatively lower average temperatures for Surface Type 1 compared to Surface Type 2 while THEMIS night/IR observations appear to reveal higher average temperatures for Surface Type 1 compared to Surface Type 2. There does not appear to be a discernable temperature trend for surface materials in adjacent low-albedo wind streaks.

Temperature variations observed in THEMIS images can be produced by a combination of topographic (solar heating) and thermophysical (thermal inertia and albedo) effects; however, combining multiple datasets can minimize uncertainties. The transition from Surface Type 1 to Surface Type 2 intracrater materials is interpreted to reflect decreasing particle sizes controlled by mineralogic differences between an unweathered basalt component and an andesite/altered basalt component. Relatively coarse dune materials are cool (dark) during the day while finer dune-free materials are warmer (bright). Intracrater floor materials are interpreted as eolian sediment blown into craters while wall materials are interpreted as either eolian sediment sorted by particle size, or eroded material from in-place crater wall lithologies.

P12C MCC: 131 Monday 1330h

Outer Planet Satellite Interiors II *(joint with GP, T, V)*

Presiding: **W B McKinnon,** Washington University**; T Spohn,** Westflische Wilhelms-Universitt

P12C-01 1330h INVITED

Inside Jupiter's Galilean Satellites: Uncertainties Abound

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Flybys of the Galilean satellites of Jupiter by the Galileo spacecraft revealed much about the interiors of the moons. For example, we know that Io, Europa, and Ganymede have large metallic cores, and that Callisto does not. We know that ice and rock are well separated in Europa and Ganymede but not in Callisto, and that Ganymede is the only one of the four moons with a magnetic field. We are fairly certain that Europa has an internal liquid water ocean, that Callisto probably has one too, and that Ganymede might have one. This presentation will discuss some of the major questions we still have about the interiors of these moons. For Io, we would like to know the thickness of the crust and lithosphere, the degree of partial melting in the mantle, and why there is no magnetic field. For Europa, the major unknown is the thickness of the ice crust above the liquid water ocean. Inferences about this from crater studies and theoretical models give ice shell thicknesses of tens of kilometers, while estimates from geologic indicators of nonsynchronous rotation and polar wander give ice shells only several kilometers thick. For Ganymede we need to ask if there really is a subsurface liquid water ocean and how the satellite generates its magnetic field. For Callisto, we are uncertain about the details of the ice-rock distribution with depth.

P12C-02 1345h INVITED

Magnetic Sounding of the Galilean Satellites

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The magnetic properties of differentiated bodies of the solar system give valuable insight into the properties of their interiors. It is generally accepted that a permanent magnetic moment requires a fluid conducting layer in the interior, although in some cases, remanent magnetism has been suggested as a source of an internal field. Of the four Galilean satellites, only Ganymede was found to have a significant permanent magnetic moment. Orbital perturbations as Galileo passed near Ganymede are consistent with a metallic core and some scenarios of thermal evolution are compatible with the presence of metallic fluid in the core. The small values of internal moments of higher than dipole order are consistent with a deeply buried core. There is now evidence that the three icy Galilean moons of Jupiter respond inductively to the periodic rocking of the magnetic field of the Jovian magnetosphere. Inductive fields of detectable amplitude must be driven by currents that flow close to the surface, and therefore an inductive response implies a current-carrying layer in the outer ice shell. Although the evidence for the inductive response is clear, the signatures are partially masked by the presence of perturbation fields arising from currents flowing in the ambient plasma. Models that correct for the externally driven perturbations and improve our ability to constrain internal moments will be discussed. The complexity of the plasma signatures around Io have restricted our ability to place useful upper limits on its permanent magnetic moment, but estimates will be presented. If time permits, we will comment on expectations for Cassini's observations at Titan.

P12C-03 1400h INVITED

Satellite Formation around Gas Giant Planets

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We consider a scenario in which the regular satellites of gas giants form within circumplanetary accretion disks produced during the end stages of gas accretion (e.g., Lubow et al. 1999; DÁngelo et al. 2002). Assuming some inflow rate of gas and solids, a steady-state circumplanetary gas disk is produced through a balance of the inflow supply and the diskś internal viscous evolution (Lynden-Bell and Pringle 1974). The diskś radial thermal profile is determined by a balance of radiative cooling from the disk with heating from the planetś luminosity, viscous dissipation, and ambient nebular insolation. Once in circumplanetary orbit, inflowing solids accumulate into objects large enough to decouple from the gas on time scales much shorter than their lifetime against inward decay due to gas drag. The total mass of solids thus builds-up over time, with satellites accreting at a rate regulated by the inflow flux.

In the Jovian system, the ice-rich composition of Ganymede and Callisto, as well as the apparently only partially differentiated state of Callisto (e.g., Anderson et al. 1998, 2001), both provide constraints on the disk environment in which the regular satellites formed. In addition, the presence of the four large Galileans implies that at least the last generation of satellites were able to survival against radial inward decay due to Type I interaction with their precursor disk. We have found that these constraints can be best satisfied for a circumjovian disk supplied by a slow gas inflow rate, F, of $F < M_J/(few \times 10^6 yrs)$, where M_J is a Jovian mass (Canup and Ward 2002, in press). Such a slow inflow rate yields a much lower steady-state gas surface density than is implied by augmenting the mass of the current satellites to solar elemental composition, as has been done previously (e.g., Lunine & Stevenson 1982; Coradini et al. 1989). This implies that the overall formation times of the Galilean satellites were long ($> 10^5$ years) and that the end stages of growth occurred in a relatively gas free environment. In addition, some inward migration of Galilean-sized satellites due to Type I torques is predicted for many disk conditions.

P12C-04 1415h INVITED

A Primordial Origin of the Laplace Relation Among the Galilean Satellites

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If the Galilean satellites accumulated with comparable time scales in a mass starved disk of gas and particles during the last stages of accretion of Jupiter (Canup and Ward, 2002), a more rapid disk induced inward migration of Ganymede compared with Europa and Io allows capture of the satellites into the Laplace relation, $n_1 - 3n_2 + 2n_3 = 0$, where n_i are the mean orbital angular velocities of Io, Europa and Ganymede respectively. The rapid growth of the orbital eccentricities during migration must be damped by a disk interaction to prevent instability. The eccentricities during migration within the resonances are e_1, e_2, $e_3 \approx$ 0.065, 0.15, 0.002 if $\dot{e}_i/e_i = 30\dot{a}_i/a_i$, compared to 0.0041, 0.0101 and 0.0006 today, where a_i and e_i are orbital semimajor axes and eccentricities. Whether or not these larger eccentricities will influence the thermal histories of the satellites depends on the duration of the migration phase. At the present time conjunctions of Io and Europa occur at Io's periapse and Europa's apoapse, and conjunctions of Europa and Ganymede occur when Europa is at its periapse and Io is on the opposite side of Jupiter. The phase of Ganymede during conjunctions is not constrained. For the large eccentricities during migration, conjunctions occur at odd angles. Continued eccentricity damping after the migration has stopped because of disk dispersal brings the system to the current configuration—even the detail of the resonance angle that includes Ganymede's periapse longitude changing from libration to circulation. This scenario differs drastically from the currently accepted origin of the resonances, where differential expansion of the orbits from tides raised on Jupiter results in sequential capture in the Io-Europa resonances and the Europa-Ganymede resonance along with the Laplace 3 body resonance, with intense tidal dissipation in Io damping the amplitudes of libration to very small values (Yoder, 1979). The constraints on Q_J of Jupiter imposed in the Yoder scenario are not relaxed for a primordial origin. There is no a priori reason to assume that Q_J could not be presently near $\sim 2 \times 10^4$ (a factor of 3 smaller than the historically averaged lower bound) to maintain the current configuration in equilibrium with the measured heat flux of $3\,\mathrm{W/m^2}$, although a theory is still being sought to support such a low Q_J.

P12C-05 1430h

Gap-opening and the Survival and Composition of the Galilean Satellites

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We expect that large objects forming in the planetary subnebula truncated the gas disk in which they were formed (Mosqueira and Estrada 2002a,b). The inertial mass (Ward and Hourigan 1989) can be used to constrain the disk surface density as a function of position at the time of gap-opening. Given weak Type II migration, this may explain the survival of the Galilean satellites in the subnebula.

It has often been noted that the compositional gradient of the Galilean satellites suggests a temperature gradient in the subnebula at the time of their formation. However, this is not a sufficient condition to expect such a trend. There are at least three issues that complicate the picture considerably. First, the satellites themselves may have migrated from cool regions to hot regions of the disk due to the gas tidal torque. Second, water may be delivered to satellites inside the water-ice condensation line by satellitesimals that form outside this location and then drift in by the effects of gas drag. Third, a satellite inside the water-ice condensation line at one time may still receive water from its own feeding zone following planetary cooling and water condensation, i.e., the water-ice condensation line itself will drift inwards, which might lead to inhomogeneous accretion, but would not deprive a satellite of its water component. Yet, a detailed model of accretion in the dense Jovian subnebula in the presence of a strong temperature gradient may lead to a compositional gradient as observed. First, because Ganymede probably underwent limited radial migration before it opened a gap. Second, because Ganymede probably intercepted most satellitesimals originating outside the water-ice condensation line. Third, because gap-opening will clear the gas between Io and Ganymede in a timescale considerably shorter than the planetary cooling time.

P12C-06 1445h INVITED

High-Pressure Hydrothermal Processing in Large Icy Satellites

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We have conducted a series of experiments designed to simulate chemical processes within large icy satellites. Few phase equilibria data exist which are relevant to the chemical evolution of moons such as Jupiter's Europa and Ganymede, Saturn's Titan and Neptune's Triton; however, models of their interiors are critically dependent on their internal chemistry and density. An internally generated magnetic field has been observed for Ganymede which implies the existence of a liquid metallic core, and accordingly an interior temperature exceeding 1000˚C. This observation, coupled with the known abundance of water ice on Ganymede, suggests that rock - water interactions at high temperatures and pressures (prospectively in the past) would control the interior mineralogy of these satellites. Additionally, organic material has been observed on the surface of Ganymede, and in conjunction with the large complement of water ice, it has been suggested that icy satellites possess the prerequisites for life to originate; however, the stability of organic material under high-pressure hydrothermal processing is unclear. We used a piston-cylinder press to react material of carbonaceous chondrite chemistry with H_2O at a range of temperatures and oxidation states at a pressure of 1.5 GPa, and make the following observations: 1) At temperatures below ~850˚C the density of the rock interior will be largely that of hydrated ferromagnesian silicates (serpentine - chlorite - talc depending on temperature and oxidation state), 2) Iron and sulfur alloy readily under these conditions, forming the mineral pyrrhotite – a metallic core of this chemistry is therefore likely, and 3) Hydrothermal processing of organic species of carbon at temperatures above 450˚C produces carbonate minerals – the prerequisite materials for life are not preserved deep within icy satellites.

To further investigate the high-pressure hydrothermal processing of organic material we are conducting experiments that allow in situ observations on less complicated systems using a diamond anvil cell. We used Raman spectroscopy to examine the compression of nCH_2-polyethylene (a simple polymerized alkane) in the presence of H_2O at room temperature. Additionally, we have laser heated samples of polyethylene and polyethylene plus $CaSiO_3$-wollastonite in the presence of H_2O at pressures between 1 and 2.5 GPa. We observe the formation of graphite and methane in the polyethylene and water experiments with no evidence for the formation of either a clathrate or filled-ice structure. The addition of wollastonite causes the formation of carbonates: this is likely a result of an increased fO_2 and supply of Ca.

P12C-07 1500h

Origin and Composition of the Rock+Metal Interiors of the Galilean Satellites

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Accurate densities and moments-of-inertia for the Galilean satellites provide powerful constraints on primary interior characteristics, but are inadequate to determine important next-level features, such as the Fe/Si ratio, without ancillary assumptions. These include cosmochemical, geochemical, and geophysical constraints. The Galilean satellites formed in the jovian subnebula, which is a late byproduct of Jupiter's growth in the solar nebula. Solid materials at Jupiter's position, well beyond the solar nebula "snow line," were ice rich and are best represented today by dark, presumably carbonaceous asteroids of the outer belt and Trojan clouds, types C, P, and especially D. In traditional (minimum-mass) models of the jovian subnebula, heating and thermochemical requilibration of these materials imply accretion of oxidized and hydrated minerals (e.g., serpentine and magnetite). New, gas-starved disk models provide heating but much less opportunity for thermochemistry, so direct incorporation of anhydrous minerals and free metal, for example, should be possible, although oxidation and hydration may still occur within the satellites. Metallic core formation in Io, Europa, and Ganymede did not occur as in the inner solar system, through massive accretional heating and/or early intense radiogenic heating due to ^{26}Al, because of smaller body sizes, buffering by ice melting, and later accretion times for the satellites. Rather, once rock from ice (water) differentiation occurred, metallic core formation would have occurred in classic Elsasser style, driven by long-lived radiogenic, and if available, tidal heating. If free iron were available, Fe-FeS eutectic melting would occur, but core formation would be inefficient because of surface tension effects, unless convective temperatures were overdriven by tidal heating; nevertheless, metal would remain in the mantles. In contrast, if the rock+metal interiors were oxidized, eutectic melting would occur along the FeS-Fe_3O_4 join. Experiments indicate that the higher oxidation state relieves the surface tension constraint, and core formation would be efficient, and the cores formed would be relatively low density (S and O rich). Rock+metal interiors containing only FeS metal (with the remaining Fe in silicates) *cannot form cores.*

P12C-08 1535h

Oceans in the Icy Galilean Satellites of Jupiter?

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Equilibrium models of heat transfer by heat conduction and thermal convection show that the three satellites of Jupiter, Europa, Ganymede and Callisto, may have internal oceans underneath ice shells tens of kilometers to more than a hundred kilometers thick. A wide range of rheology and heat transfer parameter values and present day heat production rates have been considered. The rheology was cast in terms of a reference viscosity calculated at the melting temperature and the rate of change of viscosity with inverse homologous temperature. The temperature dependence of the thermal conductivity of ice I has been taken into account by calculating the average conductivity along the temperature profile. Heating rates are based on a chondritic radiogenic heating rate of 4.5 pW kg^{-1}, but have been varied around this value over a wide range. The phase diagrams of H_2O (ice I) and H_2O + 5 weight-% NH_3-ice have been considered. The ice I models are worst-case scenarios for the existence of a subsurface liquid water ocean because ice I has the highest possible melting temperature and the highest thermal conductivity of candidate ices and the assumption of equilibrium ignores the contribution to ice shell heating from deep interior cooling. Europa is the satellite most likely to have a subsurface liquid ocean. Even with radiogenic heating alone the ocean is tens of kilometers thick in the nominal model. If tidal heating is invoked, the ocean will be much thicker and the ice shell will be a few tens of kilometers thick. Ganymede and Callisto have frozen their oceans in the nominal ice I models, but since these models represent the worst-case scenario, it is conceivable that these satellites also have oceans at the present time. The most important factor working against the existence of subsurface oceans is contamination of the outer ice shell by rock. Rock increases the density and the pressure gradient and shifts the triple point of ice I to shallower depths where the temperature is likely to be lower then the triple point temperature. Ammonia produces one of the largest reductions of the melting temperature. If we assume a bulk concentration of 5 weight-% ammonia we find that all the satellites have substantial oceans. For a model of Europa heated only by radiogenic decay, the ice shell will be a few tens of kilometers thinner than in the ice I case. The underlying rock mantle will limit the depth of the ocean to 80 - 100 km. For Ganymede and Callisto, the ice I shell on top of the H2O-NH3 ocean will be around 60-80 km thick and the oceans may be 200 to 350 km deep. Previous models have suggested that efficient convection in the ice will freeze any existing ocean. The present conclusions are different mainly because they are based on a parameterization of convective heat transport in fluids with strongly temperature-dependent viscosity rather than a parameterization derived from constant viscosity convection models. The present parameterization introduces a conductive stagnant lid at the expense of the thickness of the convecting sub-layer, if the latter exists at all. The stagnant lid causes the temperature in the sub-layer to be warmer than in a comparable constant viscosity convecting layer. We have further modified the parameterization to account for the strong increase in homologous temperature, and therefore decrease in viscosity, with depth along an adiabat. This modification causes even thicker stagnant lids and further elevated temperatures in the well-mixed sub-layer. It is the stagnant lid and the comparatively large temperature in the sub-layer that frustrates ocean freezing.

P12C-09 1550h INVITED

Effect of Tidal Heating on Thermal Evolution Models of Europa and Titan

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It is well known that the eccentricity of Galilean satellites such as Io or Europa can lead to important values of tidal heating. The amount of tidal heating deposited in the different layers that compose such a satellite depends on the viscosity of these layers. For values of viscosity in agreement with laboratory experiments, this heating source can be up to two orders of magnitude larger than the heat produced by the decay of the radiogenic elements in the silicate fraction of the satellite. Heat is likely to be transferred by subsolidus convection through the outer ice I layer of Europa. We have carried out 2D thermal convection numerical models which include temperature dependent viscosity and heterogeneous tidal heating. Tidal heating is computed at each grid point and at each time step using the temperature/viscosity field. The amount of tidal heating limits the amount of heat which can be transferred at the lower thermal boundary layer. This amount can even be smaller than the heat flux due to the radiogenic decay in the silicate core. Numerical simulations suggest that the silicate core could eventually differentiate into a dense iron rich inner core and an iron-depleted silicate mantle very late in the history of the satellite (Some models predict that a liquid iron core formed only 500 My ago). In all cases, it prevents the satellite to freeze completely and suggest that an ocean would still be present at a 20 km depth. It can be noted that if tidal heating is not taken into account, a pure H2O ocean would freeze out in less than 200 My for reasonable values of viscosity.

Applied to Titan, such a model (with the same viscosity law) suggests that the thickness of the outer ice I layer (or the depth of the ocean) is around 120 km. For values of viscosity in agreement with laboratory measurements, tidal heating can be maximum in the hot upwelling leading to partial melt at depth around 20 km. We are including damage equations and shear heating due to slip motion along the faults in the present models in order to investigate how faults, initiated by tidal stresses in the brittle outer layer, could propagate at depth and reach the area where ice is partially molten, and we compute. This may provide a reasonable process in order to explain the replenishment in CH4 of Titans atmosphere.

P12C-10 1605h

Tidal Response and Stability of Two-phase Media: Implications for Io, Europa and Titan

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Most models of planets and satellites assume homogeneous or layered media in which each layer is one phase. However, real planets and satellites may have two phase media (e.g., solid plus liquid) throughout a significant portion of their interior. I concentrate here on percolation media (a deformable solid matrix with an interconnected fluid-filled pore space that allows fluid redistribution under the action of stress). In such a medium, the phases are individually incompressible but Darcy flow from one region to another could lead to an overall effective compressibility, pumping of liquid in spite of the overall tendency towards gravitational separation, and possibly an additional heat transfer mechanism. In particular, I answer here the following questions, which appear to be unrelated but are in fact closely related: (1) Could a partially molten asthenosphere of Io behave like a compressible medium and allow decoupling of the lithosphere from the deeper interior? (2) Could tidally -driven flow of water in the ice of Europa's crust lead to net upward transfer of liquid water? (3) Can tidal response of an ethane/methane-bearing outer layer of water ice on Titan (i.e., a hidden ocean) satisfy the requirement that the large orbital eccentricity persist over geologic time? The answers are (1) No. (2) Maybe. (3) Yes. The common factors in treating these problems are: (a)The comparison of tidal stress to the stress associated with the hydrostatic head arising from a density difference of solid and liquid over an interesting distance (e.g., 10km). Typically, these two stresses are comparable. (b)The compaction length which is the scale below which viscous stresses of a deforming solid matrix are more important in determining flow than the simple Darcy flow formula. This is typically small (e.g., 10km or less) except in outermost regions (e.g. Titan). (c) The tidally driven Darcy flux (expressed as a velocity) in comparison to the velocity of time-varying equipotentials (which is about the velocity of the surface of a body if it responds to tides like a fluid). In Io, tidal velocities cannot be matched by plausible flow velocities except for a permeability so high that the matrix would disassemble. Thus a decoupled lithosphere requires a magma ocean. In Europa. only tiny amounts of water can be pumped by tides but it can still correspond to potentially kilometers of ice thickness growth on million year time scales. On Titan, the porous region is near surface and reasonable pore sizes prevent significant relative motion during the tidal cycle, thus avoiding the dissipation that results form a true shallow sea. Thus, Titan's eccentricity can be preserved.

P12C-11 1620h

Causes, characteristics and consequences of convective diapirism on Europa

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Some of the most visually distinctive features on Europa's surface are the $\sim$ 10 km-diameter roughly circular lenticulae. Many are domes, showing positive elevations of up to $\sim$ 100 m, and sometimes displaying surrounding moats. Most explanations for lenticulae formation have suggested some kind of diapiric or convective activity though icy volcanism and melt-through of the icy crust have also been considered.

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We investigate a specific model of dome formation by diapirism. In strongly temperature-dependent convection, a stagnant lid forms at the surface with approximately isoviscous convection occurring beneath this lid. The hot bottom boundary layer creates discrete buoyant regions which are often termed "thermals" or "diapir plumes". These diapirs will spread laterally as the stagnant lid is approached. The density difference between the diapir and the surrounding ice gives rise to the surface deformation, which will also be affected by the stagnant lid thickness. By using observations of dome diameter we can constrain the thickness of the top (stagnant) and bottom thermal boundary layers, and hence infer the characteristics of the convecting system. Most of the inferences are not sensitive to the thickness of the ice layer.

We use the observed lower limit on dome diameter of 4 km to deduce that the conductive (stagnant) lid thickness must be ≤ 5 km. Such a lid thickness implies a minimum surface heat flux of 90 mW/m^2, compatible with recent estimates of tidal heating. We also use the mean observed dome diameter to infer a lower thermal boundary layer thickness of $\sim$ 1 km. We find that the ice is probably deforming in the diffusion creep regime with a grain size in the range 0.02-0.06 mm. The fraction of internal heating is >0.5, the ice viscosity $10^{12} - 10^{13}$ Pa s, and the crustal solidification rate $<$ 5km/Ma.

P12C-12 1635h

Lava Lakes in Io's Paterae: Surface Expressions of Subsurface Processes

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Recent analyses of morphologies and temperatures of paterae (volcanic depressions) on Io reveal strong connections to well-supplied magma source regions in Io's interior. The uniformly dark, warm floors of many paterae are best explained as newly emplaced crusts of active lava lakes that periodically overturn as the lakes are recharged with new lavas [1,2]. One patera, Pele, is analyzed both for its similarities to and differences from other paterae. This volcano is the source of a consistently active giant plume eruption, and appears to contain a large, actively overturning, fountaining lava lake [3,4]. The 60 m/pixel, 2-filter Galileo SSI nighttime observations allow us to calculate color temperatures as high as 1620+-100K, in a few locations in the most active region in 3x3 pixel areas. Ultramafic silicates (primarily Mg-rich ol, px) have melting temperatures in this range and may be the primary component of many lava flows on Io [5,6]. Even if we assume that the source has a bulk composition on an undifferentiated Io, this would require on the order of 50% partial melting. To analyze eruption style, we calculated the fractional area of hot material across the Pele region, and determined that its highest concentration occurs in a central region about 60-80 km2, while the material in the rest of the 600 km2 region remains remarkably cool. Thus, fountaining and overturn at the lava lake in Pele Patera (and other paterae) may occur in small, localized regions, while the majority of the lava lake remains insulated under a cool crust. The thermal output from the high temperature components of the Pele eruption is 280 GW, and indicates a mass flux into the volcano of 6.44-8.89 x10^5 kg/s [7]. As there is no evidence of large lava flows emerging from Pele, all of this material is confined to the patera, or is recycled back into the source region. This is true for most paterae, since they have insignificant to inexistent shields, and thus no flank eruptions. Thus the large disparity between the tremendous mass flux into Pele and other paterae and observed erupted material is best explained if there is access to a global, subsurface, magma ocean that is continually being partially melted due to tidal heating [8]. This way, well established magma conduits are fed by an essentially inexhaustable magma supply, which can explain why most large volcanic centers on Io appear to persist over long periods of time. These paterae, with strong subsurface connections, appear to be the primary conduits for heat to escape to Io's surface, which implies that the heat flow through this energy-laden body is spatially discrete.

P12C-13 1650h

Gravity Field, Topography, and Interior Structure of Amalthea

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A close Galileo flyby of Jupiter's inner moon Amalthea (JV) occurred on 5 November 2002. The final aimpoint was selected by the Galileo Radio Science Team on 5 July 2002. The closest approach distance for the selected aimpoint was 221 km from the center of mass, the latitude was - 45.23 Deg and the west longitude was 266.41 Deg (IAU/IAG/COSPAR cartographic coordinate system). In order to achieve an acceptable impact probability (0.15%), and yet fly close to Amalthea, the trajectory was selected from a class of trajectories running parallel to Amalthea's long axis. The Deep Space Network (DSN) had the capability to generate continuous coherent radio Doppler data during the flyby. Such data can be inverted to obtain information on Amalthea's gravity field.

Amalthea is irregular and neither a triaxial ellipsoid nor an equilibrium body. It has a volume of about 2.4 $\times$ 10^6 km^3, and its best-fit ellipsoid has dimensions 131$\times$73$\times$67 km. Its mass can be determined from the 2002 flyby, and in combination with the volume, a density can be obtained accurate to about 5%, where the error is dominated by the volume uncertainty. Similarly, gravity coefficients (C_{nm} S_{nm}) can be detected up to fourth degree and order, and the second degree field (quadrupole) can be measured. Topography data are available from Voyager imaging and from images taken with Galileo's solid state imaging system at various times between February and June 1997. By combining the gravity and topography data, new information can be obtained on Amalthea's interior. For example if the gravity coefficients agree with those calculated from the topography, assuming constant density, we can conclude that Amalthea is homogeneous. On the other hand, if the gravity coefficients are smaller than predicted from topography, we can conclude that there is a concentration of mass toward Amalthea's center. We are presenting preliminary pre-publication results at the Fall meeting.

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P21A MCC: Hall D Tuesday 0830h

Advances in Planetary Geodesy, Mapping, and Imaging I Posters *(joint with G)*

Presiding: **J Barriot,** Observatoire Midi-Pyrenees/GRGS**; G A Neumann,** Massachusetts Institute of Technology

P21A-0356 0830h POSTER

A New Class of Imaging Spectrometer for Planetary Science

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A NASA-funded Planetary Instrument Definition and Development Project (PIDDP) has led to the development of a new class of imaging spectrometer that combines the principal advantages of two traditional techniques used for imaging spectrometry: the signal collection advantage offered by the interferometric or Fourier Transform Spectrometer (FTS) class, and the no-moving-parts advantage offered by the dispersive and filter-array classes. This new class of imaging spectrometer, referred to as windowing interferometric, has no filters, no slit, and no moving parts. The advantage of having no moving parts provides high reliability, low cost, and allows the interferometer to be monolithic and therefore extremely rugged. The high signal collection ability of this instrument allows it to be miniaturized for use from a rover or small orbiter while still obtaining a high signal-to-noise ratio. The high signal collection ability also makes this approach ideal for missions to the outer planets.

In order to put these advantages in perspective we have developed a comprehensive classification of imaging spectrometers, and a novel graphical technique for describing the principal of operation and relative signal collection abilities of the classes of imaging spectrometers. We divide imaging spectrometers into a matrix of classes based on their method of obtaining spatial information and their method of obtaining spectral information. Methods of acquiring spatial information include whiskbroom, pushbroom, staring, and a new class we refer to as windowing. We use the term windowing to describe the new class of instruments that employ a two-dimensional FOV which moves across the object in the along-track direction during each acquisition. The classifications by spectral approach include the familiar filtering, dispersive, and interferometric techniques. A novel graphical technique for comparing the classes of imaging spectrometers is to plot the transmittance as a function of the along-track spatial dimension and the wavelength. The temporal evolutions of these transmittance functions describe the methods of operation and provide ready insight into the relative signal collection abilities of the entire family of imaging spectrometers.

We present the design of our demonstration instrument of the windowing interferometric class, and performance results obtained in laboratory and field testing.

P21A-0357 0830h POSTER

Towards Regional Lunar Gravity Fields Using Lunar Prospector Extended Mission Data - Simulations and Results

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Until this date, the lunar gravimetric inverse problem has mainly been posed as a global problem, solving for gravity fields over the whole of the Moon. The asymmetric sampling of the force field requires that some sort of regularisation be applied in order to have a meaningful global solution that does not provide spurious information on the far side. On one hand these global solutions work very well in terms of overall orbit quality and consistency, despite the fact that roughly one half of the surface lacks sampling. On the other hand, excellently sampled regions cannot be determined at maximum spatial resolution without affecting too much the solution on the far side, which in itself is highly unstable.

Since the Lunar Prospector mission, there are many of such excellently sampled regions on the near side of the Moon. In order to exhaust the information present in the tracking data of this satellite, regional methods for solving the gravity field of well-sampled areas become interesting.

We present a method to extract regional gravity information from Doppler and Range tracking of the Lunar Prospector spacecraft. The method incorporates the GEODYN II software package for tracking data processing and orbit determination, and a software package to analyse the residuals from the orbit determination process, and to transform these residuals into gravity anomalies on the lunar surface by means of a Stokes method. Simulations will show how well a gravity signal in the residuals can be recovered. Results from orbit determination using 20 days of Lunar Prospector Extended Mission data will be shown, to demonstrate the readiness of the method to process real-life satellite data.

With missions in the future such as SELENE, which will provide the first global tracking data set of the Moon ever, global and regional methods to solve for gravity field products will remain equally of interest, since they both can give complementary insight into the low and high resolution gravity field. Regional methods can not only be used to investigate non-uniformly sampled force fields, they can also provide a localisation at higher resolution in the space domain. The method presented here can be extended to other celestial bodies of interest in planetary geodesy.

P21A-0358 0830h POSTER

Lunar Gravity Studies from the Lunar Prospector Line-of-Sight Acceleration Data: Isostatic Compensation of Medium Sized Craters

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