data from four nights in which the observation's subradar track was within five degrees of latitude of the planned landing site. High resolution, approximately five kilometers per pixel, radar imaging of the landing site indicates a site that will be of low risk to the rover and provides testable predictions of the local surface roughness that the rover will encounter.

P31B-1063 0830h POSTER

Surface Penetrating Radar Simulations for Jupiters Icy Moons

Thorsten Markus[1] (301-614-5882; Thorsten.Markus@nasa.gov); Prasad Gogineni[2] (gogineni@ittc.ku.edu); James L Green[3] (James.L.Green@nasa.gov); Bodo W Reinisch[4] (bodo_reinisch@uml.edu); Paul Song[4] (paul_song@uml.edu); Shing Fung[3] (fung@mail630.gsfc.nasa.gov); Robert F Benson[5] (Robert.F.Benson@nasa.gov); William L Taylor[3] (taylor@mail630.gsfc.nasa.gov); John F Cooper[3] (jfcooper@pop600.gsfc.nasa.gov); Leonard Garcia[3] (garcia@mail630.gsfc.nasa.gov); Dennis L Gallagher[6] (Dennis.L.Gallagher@nasa.gov)

[1]NASA/GSFC, Code 975, Greenbelt,, MD 220771, United States

[2]ITTC, University of Kansas, Lawrence, Lawrence, KS 66045, United States

[3]NASA/GSFC, Code 630, Greenbelt, MD 20771, United States

[4]Ctr. f. Atmospheric Research, Univ. of Mass., Lowell, Lowell, MA 01854, United States

[5]NASA/GSFC, Code 692, Greenbelt, MD 20771, United States

[6]NASA NASA, Marshall Space Flight Center, Huntsville, AL 35812, United States

The icy moons of Jupiter (Europa, Callisto, and Ganymede) are of similar overall composition but show different surface features as a result of different subsurface processes. Furthermore, each of these moons could have a liquid ocean of water buried underneath the icy crust, but their depth can only be speculated. For Europa, estimates put the thickness of the ice shell anywhere between 2-30 km, with a few models predicting up to 100 km. Much of the uncertainties are due to the largely unknown temperature gradients and levels of water impurities across different surface layers. One of the most important geological processes is the possible transportation of heat by ice convection. If the ice is convecting, then an upper limit of about 20 km is set for the depth of the ocean underneath. Convection leads to a sharp increase in temperature followed by a thick region of nearly constant temperature. If ice is not convecting, then an exponentially increasing temperature profile is expected. The crust is thought to be a mixture of ice and rock, and although the exact percentage of rock is not known, it is expected to be low. Additionally, the ice crust could contain salt, similar to sea ice on Earth. The exact amount of salt and how that amount changes with depth is also unknown. In preparation for the Jupiter Icy Moons Orbiter (JIMO) mission, we performed simulations for a surface-penetrating radar investigating signatures for different possible surface and sub-surface structures of these moons in order to estimate the applicability of using radar with a frequency range between 1 and 50 MHz. This includes simulations of power requirements, attenuation losses, layer resolutions for scenarios with and without the presence of a liquid ocean underneath the ice, cases of convecting and non-convecting ice, different impurities within the ice, and different surface roughnesses.

P31C MCC: 2008 Wednesday 1020h

Faulting and Fault-Related Processes on Planetary Surfaces I *(joint with T)*

Presiding: **D A Ferrill,** Southwest Research Institute**; R A Schultz,** University of Nevada, Reno**; R T Pappalardo,** University of Colorado, Boulder

P31C-01 1020h

The Mechanics of Pseudotachylite Formation in Impacts

H. Jay Melosh (520 621 2806; jmelosh@lpl.arizona.edu)

Lunar and Planetary Lab, University of Arizona, Tucson, AZ 85721, United States

Geologist James Shand first recognized pseudotachylites near the Vredefort structure in 1916. They appear to be black, glassy veins that often contain broken fragments of country rock. The veins range from millimeters thick to masses many meters in extent. Since this discovery they have puzzled several generations of geologists. Pseudotachylites are evidently due to rapid melting of rock in place and seem to be associated with environments, such as faulting, landslides and impacts, where rock is put into rapid motion. I examine the basic constraints controlling the formation of pseudotachylites in the rapidly sheared rocks in the vicinity of a large meteorite impact. The prevailing opinion among many geologists is that pseudotachylites are formed by friction melting of rock. The principal mystery of pseudotachylite formation is not that friction can cause melting, but that it seems to form thick masses of it. Yet such thick masses ought to preclude melting by reducing the friction between sliding rock masses. I propose that a solution to this conundrum is that the melt produced by sliding on narrow shear zones is extruded into the adjacent country rock, thus keeping the sliding surfaces narrow while thick masses of melt accumulate in pockets opened by slip on faults oriented at large angles to the sliding plane.

P31C-02 1035h

Earth Versus Mars: dike-induced topography resolved by MOLA

Cheryl L. Goudy[1] (775-784-6464; cgoudy@mines.unr.edu)

Richard A. Schultz[1] (schultz@mines.unr.edu)

[1]University of Nevada, Reno, Mackay School of Mines/ 172, Reno, NV 89557

Graben on Mars have often been interpreted to result from dike intrusion. On Earth field observations, geodetic data, and numerical models show that dike intrusion and normal faulting typically result in graben subsidence. Topography across the Krafla rift zone in Iceland has been successfully fit to the combined effects of subsurface dike inflation plus slip along two inward-dipping, dike-induced normal faults. Topographic profiles of graben in the Tharsis and Elysium regions on Mars show similar morphometric features. This morphologic similarity suggests a similar process at depth. Quantitative mechanical models of dike-induced graben topography on Mars have been elusive. We have now developed a boundary element model capable of predicting the topography of graben that have evolved through the combined processes of dike intrusion and related normal faulting. By analogy with the Krafla rift zone example and the previous model results, we calculate the amount of surface displacement expected on Earth for a vertical dike with a height of 4.5 km (dike top depth = 1.5 km, and dike bottom depth = 6.0 km), accompanied by two faults 6.0 km apart dipping toward the graben center at 55 degrees with a downdip length of 6.0 km. The horizontal stress gradient is equal to the vertical lithostatic gradient (principal stress ratio = 1.0) for Earth assuming magmatic density of 2200 kg/m^3 and crustal density of 2600 kg/m^3, and the shear modulus is 24 GPa. We find that if gravity is the main factor affecting graben-related topography, Martian graben would produce topographic displacements that are 25% less than that of a terrestrial counterpart. Our models predict approximately 4 m and 3 m of maximum vertical displacement on Earth and Mars, respectively. Larger dikes suggested for Mars could produce uplifts of 10's of m. This relief is within the vertical precision of the MOLA data and will provide a direct test of the volcanic hypothesis of Martian graben.

P31C-03 1050h

Topographic and Structural Analysis of Devana Chasma, Venus: A Propagating Rift System

Walter S. Kiefer[1] ((281) 486-2110; kiefer@lpi.usra.edu)

Laura C. Swafford[2]

[1]Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058, United States

[2]Dept. of Geology, Michigan State University, East Lansing, MI 48824, United States

Devana Chasma is a rift system on Venus that formed due to extensional stresses from the Beta Regio and Phoebe Regio mantle plumes. Devana has often been compared to the East African Rift system on Earth. Here, we focus on the portion of Devana in the lowland plains between Beta and Phoebe, 20 North - 4 South, a distance of 2500 km. Over this region, Devana is typically 150 to 250 km wide. Recent gravity modeling (Kiefer and Peterson, Geophys. Res. Lett., Jan. 2003) demonstrated that most of this segment of the rift is presently underlain by hot, low density mantle material. The rift has a 600 km lateral offset near 8 North latitude, where the gravity results show no evidence for hot mantle. This lead Kiefer and Peterson to propose that Devana is actually two propagating rifts, one propagating southward from Beta Regio and the other propagating northward from Phoebe Regio. As a test of this hypothesis, we have examined the detailed structural geology of this section of the rift using topographic profiles and radar imagery from the Magellan mission. We constructed a series of topographic transects spaced at approximately 50 km intervals along the rift and measured the average flank height and the maximum rift depth. We measured the total vertical offset along faulted surfaces and converted this to horizontal extension assuming a characteristic normal fault dip of 60 degrees. Plots of these quantities as a function of distance along the rift reveals several characteristic zones. Average flank height has maximum values near the edges of Beta Regio (3.5 km) and Phoebe Regio (2.75 km) and decreases rapidly as the rift crosses the intervening plains. This is consistent with the rift forming due to thermal anomalies centered at Beta and Phoebe. The virtual absence of elevated rift flanks in the offset region near 8 North is consistent with the absence of hot mantle in this region, as inferred from the gravity model. The horizontal extension decreases strongly with increasing distance from Beta Regio (20 - 10 N), whereas the horizontal displacement shows little trend with distance from Phoebe Regio (4 S - 7 N). The horizontal extension has a minimum in the offset region (8 N), consistent with the observed decrease in fault density in this region. Both the flank height and horizontal extension results appear to be consistent with the propagating rift model. The maximum depth along the rift is typically between -1 and -3 km, with no strong trend along the rift.

URL: http://www.lpi.usra.edu/science/kiefer/home.html

P31C-04 1105h

Wrinkles on the Crust of Venus

George E. McGill (413-545-0140; gmcgill@geo.umass.edu)

Department of Geosciences,, University of Massachusetts,, Amherst,, MA 01003, United States

Wrinkle ridges are very abundant on the plains of Venus, and thus they constitute an important source of kinematic information. Wrinkle ridges generally are inferred to be related to thrust or reverse faults. We can address some of the kinematic issues with a set of questions: Can the presence of wrinkle ridges be used to define stratigraphic material units? Can the formation of wrinkle ridges be used as a rough time line? Can wrinkle ridges define kinematics by determining temporal sequences of stress states? Intersection relationships of wrinkle ridge sets with each other and with other structures, and the ages of wrinkle ridge sets relative to the impact crater population provide the data needed. The area studied includes the 20 quadrangles bounded by 60 west and 90 east longitude, 50 north and south latitude, slightly less than one-third of the total surface area of Venus, and it includes 314 impact craters, slightly less than one-third of the total global population. Throughout most of the area studied wrinkle ridges occur as 2 or more sets with different orientations. Wrinkle ridges can be used to define a stratigraphic material unit only if it can be shown that wrinkle ridge formation was coeval with the processes forming the material unit. Relationships with older fracture fabrics and with the impact crater population effectively rule out formation of wrinkle ridges coeval with material emplacement. In the area studied, east-west trending wrinkle ridges appear to be the oldest set, and these probably formed quickly enough to define a regional time line. If one can unequivocally determine the relative ages of wrinkle ridge sets, the temporal sequence of stress states in the plains can be determined. Commonly, the earliest structures to form after plains emplacement are radar-bright lineaments inferred to be fractures or small faults. East-west wrinkle ridges formed after these lineaments, and after formation of a small but significant fraction of the impact crater population. A larger fraction of the impact crater population formed before wrinkle ridges with other orientations, and these commonly terminate at intersections with east-west wrinkle ridges. Thus at least a regional scale north-south contraction of plains materials was followed by rotation of the maximum contraction direction into various other directions, depending on locality.

P31C-05 1120h

Fine-scale Fractures on the Surface of 433 Eros: Implications for Structural Control and Tectonic Resurfacing of Craters

Louise Prockter[1] (240-228-6769; Louise.Prockter@jhuapl.edu)

Olivier Barnouin-Jha[1] (Olivier.Barnouin-Jha@jhuapl.edu)

[1] Johns Hopkins University Applied Physics Laboratory, MP3-E128, 11100 Johns Hopkins Road, Laurel, MD 20723, United States

Detailed lineament mapping of the surface of Eros is underway, using high-resolution images obtained by the NEAR-Shoemaker spacecraft during its recent highly successful mission. It is likely that most of the grooves on the asteroid's surface are the result of disturbances of regolith overlying deeper fractures in a coherent substrate, an interpretation that is also plausible for other asteroids and small bodies such as Ida, Gaspra, and Phobos. The presence of numerous single and cross-cutting grooves which may be continuous for several kilometers, implies that the underlying material of which Eros is comprised is largely coherent, and that it is likely not a rubble pile. In addition to grooves, some regions of Eros' surface have a high density of fine-scale lineaments, spaced tens of meters apart. Preexisting structural features have clearly influenced the shapes of some craters, leading to squared-off outlines. Close examination of the surface shows that fine-scale fractures may also be responsible for erasing craters. This type of "tectonic resurfacing" has been inferred on Ganymede, where there are examples of craters strained tens of percent by the formation of fractures and grooves. On Eros, examples can be found of craters that are highly degraded due to numerous parallel fractures running through their interiors. Topographic profiles across these craters show that some are unusually shallow, in part because of regolith infilling, but also possibly as a result of tectonic disruption. We examine the hypothesis that closely-spaced fractures within craters post-date crater formation, since they may not survive the impact process. Such fractures may be the result of reactivation of preexisting structure by later, possibly distant, impact events and may cause subsequent degradation.

P31C-06 1135h

Rifting and Faulting on icy Satellites

Francis Nimmo (nimmo@ess.ucla.edu)

University College London, Gower St, London WC1E 6BT, United Kingdom

Two kinds of rifting have been identified on the icy Galilean satellites [1,2]. Europa possesses $\sim$10 km wide extensional bands, characterized by very high degrees of local extension, internal deformation on a length-scale of $\sim$ 100 m, and a general resemblance to mid-ocean ridges on Earth [3]. Ganymede has $\sim$100 km wide areas of grooved terrain, characterized by km-scale tilted fault blocks [4,5], lower degrees of local extension (stretching factor $<$1.6 [5]) and a general resemblance to continental rifts on Earth [1]. The characteristic spacing of faults on Europa and Ganymede has been used to infer the depth to the brittle-ductile transition (BDT), which depends on the strain rate and the shell thickness [4,6]. Here I present another constraint on these quantities, obtained by considering the circumstances under which narrow (Europa-style) or wide (Ganymede-style) rifts may form. The model is based on an analysis of terrestrial continent rifting [7]. When an ice shell is extended, the thermal gradient increases and it becomes weaker, favouring further extension. The extension also gives rise to lateral shell thickness variations, which oppose further extension. However, these lateral thickness variations may be removed if the base of the ice shell can flow rapidly. If lateral flow is rapid, narrow zones of extension and high stretching factors are generated. If lateral flow is slow, wider rifts and lower stretching factors are favoured. Thick ice shells or high strain rates favour narrow rifts; thin ice shells or low strain rates favour wide rifts. The existence of wide rifts on Ganymede is consistent with a conductive shell thickness of 4-8 km at the time of rifting, and agrees with previous estimates of strain rates [8]. To produce narrow rifting and the inferred BDT depth on Europa requires a larger shell thickness (8-20 km) and a strain rate $\geq 10^{-15}$ s^{-1}. Based on the likely shell thicknesses, the inferred strain rates for Europa and Ganymede can be explained by differing mean stresses: 0.1-0.2 MPa for Ganymede and 0.3 MPa for Europa. These values are comparable to estimates of stress levels derived from flexural features [9,10]. The maximum strain a fault can withstand before breaking depends on the stress drop and the shear modulus [11]. Assuming that the stress drop is comparable to the remote stresses derived above, then the critical strain is $\sim 10^{-4}$, similar to terrestrial values. For a strain rate of 10^{-15} s^{-1} the recurrence interval is thus $\sim$3000 yrs for each fault. The moment release for a 10 km$\times$3 km fault plane is 10^{17} N m, equivalent to a $M_w = 5.3$ terrestrial earthquake.

[1] Pappalardo et al.,Icarus 135, 276-302, 1998. [2] Sullivan et al., Nature 391, 371-372, 1992. [3] Prockter et al., JGR 107, 5028, 2002. [4] Patel et al., JGR 104, 24057-24074, 1999. [5] Collins et al., GRL 25, 233-236, 1998. [6] Pappalardo et al., JGR 104, 24015-24055, 1999. [7] Buck, JGR 96, 20161-20178, 1991 [8] Dombard and McKinnon, Icarus 154, 321-336, 2001. [9] Nimmo et al., GRL 29, 1158, 2002. [10] Nimmo et al., GRL 30, 1233, 2003. [11] Scholz, Mechanics of earthquakes and faulting, CUP, 1991.

P31C-07 1150h

Secondary Fracturing as a Tool for Unraveling Strike-Slip Fault Slip Behavior on Europa

Simon A Kattenhorn[1] (208-885-5063; simkat@uidaho.edu)

Scott T Marshall[1] (208-885-5152; mars0776@uidaho.edu)

[1] Dept. of Geological Sciences, University of Idaho, PO Box 443022, Moscow, ID 83844-3022, United States

Secondary cracks are commonly produced at stress concentration points at the tips of faults. These so-called tailcracks form at an angle to the fault trace, with locations about the fault tips that indicate whether slip was left-lateral or right-lateral. Tailcracks are widespread on the surface of Jupiter's moon, Europa, and attest to the common occurrence of strike-slip faults. The crust of Europa is an ice shell at least several kilometers thick, potentially underlain by liquid water. The ice shell is constantly flexed by tidal forces that have been sufficiently high in the geologic past to pervasively fracture the ice. At any point on Europa, the tidal stresses are constantly rotating, causing shear stresses to be resolved onto pre-existing lineaments. There is clear evidence of lateral offsets across many large Europan lineaments, such as the 810 km long, right-lateral, Astypalaea Linea. We have identified tailcracks along many Europan strike-slip faults, with geometries compatible with the sense of slip. Nonetheless, the "take-off" angles between many of the faults and their associated tailcracks are less than the theoretical, and commonly observed, 70° angle that characterizes terrestrial tailcracks, which form along fault surfaces that remain in contact during slip (mode II in fracture mechanics terminology). Several tailcracks at the eastern tip of the 1500 km long Agenor Linea are oriented 30-35° to fault strike. Agenor has experienced at least 20 km of right-lateral motion, but has also apparently dilated and been infilled with material from below the ice shell to form a fault zone about 20-30 km wide. Low-angle tailcracks have also been identified along other dilated faults on Europa. We used linear elastic fracture mechanics models to test the effect on tailcrack angles by dilation during fault slip events (mixed-mode I-II). Our result for the pure mode II case predicts a take-off angle of 70°. However, as the amount of fault dilation increases during slip (increasing mode I/mode II ratio), tailcracks develop broader curvatures and lower take-off angles, similar to the tailcracks at the tip of Agenor Linea, which resemble the result for a mode I/mode II ratio of 2. This implies that Agenor may have dilated during slip by a factor of twice the amount of strike-slip motion. Such behavior is consistent with the observed evidence of dilation along Agenor and other faults with low-angle tailcrack geometries. Thus, dilation may be an important component of the process by which slip accumulates along many (but not all) Europan strike-slip faults. Such dilation during fault motion is compatible with the conceptual "tidal walking" model for Europan strike-slip faults, which hypothesizes repetitive cycles of opening and closing during shear motion, allowing faults to accumulate shear offsets like a ratchet. Finally, tailcracks on Europa commonly occur along lineaments that show no evidence of lateral offsets. The resolution of Europa images may thus be insufficient to resolve small strike-slip offsets along many lineaments that nonetheless slipped a sufficient amount to generate tailcracks at their tips. Therefore, there may be many more strike-slip faults on Europa than can be determined from lateral offset evidence. Accordingly, features that have conventionally been assumed to be pure mode I (tensile) fractures, such as cycloidal ridges (which commonly exhibit takeoff angles in the 60-70° range), may actually be associated with small shear motions and associated tailcracking.

P31C-08 1205h

Analysis of faults on the icy surface of Jupiter's moon Europa based on failure modes

Aydin Atilla (650 725 8708; aydin@stanford.edu)

Stanford University, Department of Geological and Environmental Sciences, Stanford, CA 94305-2115, United States

I have analyzed faults on the surface of Europa using high resolution images by the Galileo spacecraft. Based on the geometric characteristics of the faults and possible analog structures from the planet Earth, I have identified two mechanisms leading to fault formation on Europa. The first one is characterized by well organized sub parallel shear bands representing shear and perhaps volumetric strain localization. The second one is associated with mode-I fractures and their subsequent sliding/shearing. Faults in this group appear to be chaotic defined by zones of fragmentation and brecciation often with broad curvilinear boundaries. Where the two system overprint, the group with the sheared mode-I fractures is always younger suggesting a significant change in the environmental conditions at some time in the history of the planet. The shear band based faults are expected to be composed of ice deformed and perhaps transformed in situ with a lower permeability than the surrounding ice matrix. Whereas, the sheared fracture based faults may have significant pore space and therefore, may be conduits for subsurface mobile fluids to rise up to the surface of the planet. This later group has the potential to provide evidence for life in and on the planet.

P32A MCC: Level 2 Wednesday 1330h

Planetary Ionospheres and Magnetospheres I Posters *(joint with SH, SM)*

Presiding: **J R Espley,** Rice University**; D L Matson,** Jet Propulsion Laboratory, California Institute of Technology

P32A-1064 1330h POSTER

3D Boltzmann Simulation of the Io's Plasma Environment: Comparison with Observational Data

Michael R Combi[1] (1-734-764-7226; mcombi@umich.edu)

Alexander S Lipatov[1] (1-734763-6246)

[1] The University of Michigan, 2455 Hayward Street, Ann Arbor, MI 48109-2143, United States

The global dynamics of the ionized and neutral components in the environment of Io plays an important role in the interaction of Jupiter's corotating magnetospheric plasma with Io [Combi et al., 2002; 1998; Kabin et al., 2001]. The stationary simulation of this problem was done in the MHD [Combi et al., 1998; Linker et al, 1998; Kabin et al., 2001] and the electrodynamic [Saur et al., 1999; 2003] approaches. In this report, we study the comparative role of ionization processes and charge exchange in formation of the plasma environment near Io by means of kinetic simulation. The atmosphere of Io is considered as an immobile obstacle in simulation. The comparison of results of such simulations with the Galileo spacecraft data is also discussed in this report.

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M R Combi, T I Gombosi, K Kabin, *Atmospheres in the Solar System: Comparative Aeronomy. Geophys. Monograph Series,* **130**, 151, 2002.
K Kabin et al., *Planetary and Space Sci.,* **49**, 337, 2001.
J A Linker et al., *J. Geophys. Res.,* **103(E9)**, 19867, 1998.
J Saur et al., *J. Geophys. Res.,* **104**, 25105, 1999. J Saur et al., *ICARUS,* **163**, 456, 2003.

P32A-1065 1330h POSTER

The Structure of the Martian and Venusian Magnetic Pileup Boundaries

Cesar Bertucci[1] ((33) 5 61 55 66 50; bertucci@cesr.fr)

Christian Mazelle[1] (mazelle@cesr.fr)

Mario H Acuna[2] (mario.h.acuna@nasa.gov)

James A Slavin[3] (james.a.slavin@nasa.gov)

Christopher T Russell[4]

[1] Centre d'Etude Spatiale des Rayonnements, 9, Avenue du Colonel Roche, Toulouse 31028, France

[2] NASA Goddard Space Flight Center, Code 695, Greenbelt, MD 20771, United States

[3] NASA Goddard Space Flight Center, Code 696, Greenbelt, MD 20771, United States

[4] Institute of Geophysics and Planetary Physics, UCLA, Los Angeles, CA 90024, United States

The lack of global-scale intrinsic magnetic fields and the presence of an atmosphere at Mars, Venus and comets makes their interactions with the solar wind very similar, with the formation of a magnetic barrier in front of a highly conducting obstacle and an induced magnetic tail as their most prominent features. A sharp plasma boundary marks the entry into the magnetic barrier: the Magnetic Pileup Boundary (MPB). At Mars, the MPB has been identified by very clear observational signatures, including a gradient in the magnetic field magnitude (often as a sharp jump) accompanied by a decrease in the magnetic field fluctuations and a drastic decrease in the solar wind electron and proton densities, as exospheric-induced ions become more numerous. Recently, the presence of another MPB signature, the enhancement of the magnetic field draping, allowed to identify this boundary also at

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