U43A CC: 517 A Thursday 1330h

New Views of Mars and Its Environment I

Presiding: **A Haldemann,** Jet Propulsion Laboratory, California Institute of Technology**; S Squyres,** Cornell University

U43A-01 1330h

Initial Results from the MER Athena Science Investigation at Gusev Crater and Meridiani Planum

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The Mars Exploration Rover Spirit landed in Gusev Crater on January 4 (UTC), 2004. It was followed 21 days later by the rover Opportunity, which landed on Meridiani Planum. The landing site at Gusev crater lies on a flat, rock-strewn plain. The rock at Gusev that has been studied best to date has been named Adirondack. In its surface texture, Adirondack appears to be dense, fine-grained and sand-blasted. Three sets of measurements have been made on Adirondack with the full set of payload instruments: one of the natural rock surface, one of the same location after being brushed by the RAT, and one of the same location after removal of 2-3 mm of rock by the RAT. The concentration of presumably dust-borne elements like sulfur and chlorine diminished significantly with brushing, and diminished dramatically with grinding. All of the observations of Adirondack are consistent with it being an essentially unweathered olivine and magnetite-bearing, low-silica basalt. The only soil at Gusev that has been investigated in detail so far is one dominated by fairly coarse (100-300 micron) grains that have the appearance and behavior of well-cemented agglomerates. APXS spectra of this soil are similar to those of soils found at the Viking and Pathfinder sites. Mössbauer spectra show two ferrous doublets and a ferric doublet, with the stronger ferrous doublet assigned to olivine. Mini-TES spectra have been acquired for soils surrounding the the Spirit landing site, and show spectra nearly identical to globally averaged soil viewed by the TES instrument on Mars Global Surveyor. This includes identification of a small amount (a few percent) of carbonate. The landing site at Meridiani Planum lies inside an impact crater that is roughly 20 meters in diameter. The lander came to rest on soil that fills most of the crater. An outcrop of layered bedrock is exposed on the crater wall. The landing site was selected partly because coarse gray hematite was expected to be present on the basis of orbital data. Mini-TES data have confirmed the presence of this hematite in the soil. The soil within the crater has several components. Microscopic images of undisturbed surface soil show that one component is fine (100 micron) sand. Mössbauer spectra of the sand show two ferrous doublets (one of them due to olivine), a ferric doublet, and a weak magnetic sextet. APXS and Mini-TES data on this sand are consistent with a composition dominated by basalt. Another component of the soil consists of coarse (several mm) granules. These range in shape from subangular to rounded to remarkably spherical. In some locations, granules have been pressed down into the soil by the impact of the landers airbags. At those locations the concentration of hematite as determined by Mini-TES is sharply reduced, suggesting that at least some of the granules are hematite-bearing. The bedrock outcrop is finely laminated, with typical layer thicknesses of only a few mm. The texture of the outcrop as viewed in miroscopic images suggests that it is fine-grained, with well-expressed structure that is revealed by varying degrees of mechanical abrasion of layers of varying induration. Initial APXS results on this fine-grained matrix indicate sulfur concentrations significantly higher than any observed elsewhere on Mars. Embedded within the outcrop and weathering out of it are highly spherical granules with diameters of several mm. The visible to near-IR spectral properties of these embedded spherical granules, as determined by Pancam, are distinctly different from those of the matrix in which they are embedded.

U43A-02 1345h INVITED

Coordinated Mars Express OMEGA and Mars Exploration Rover Observations and Analyses

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The Spirit Rover touched down on the floor of Gusev Crater and the Opportunity Rover touched down in a 22 m diameter crater in Meridiani Planum in January, 2004. Equipped with the Athena Science Payload, these two rovers have been acquiring high fidelity multispectral (0.4 to 1.0 micrometers) images, emission spectra (5 to 29 microme-ters), and in-situ close-up imaging, APXS, and Moessbauer measurements on a variety of surfaces. As part of a co-ordinated set of experiments, the Mars Express Orbiter, with the OMEGA imaging spectrometer (0.38 to 5.1 mi-crometers, 352 bands, 350 m pixels, 16 pixels across swath), observed the sites while the rover imaging systems and emission spectrometers were acquiring atmospheric and surface measurements. Near-simultaneous measurements were acquired during several passes. Cross-instrument analyses by the OMEGA and Athena Science Teams allowed detailed verification and modeling of spectral signatures for the surface and orbital observations. Results of the joint experiments will be presented, focusing on evidence for the role of water in forming landforms and materials.

U43A-03 1400h INVITED

Geology of the Columbia Memorial Station, Gusev Crater, Mars

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The Mars Exploration Rover Spirit (MER-A) landed within the 160 km diameter Gusev crater (14.5692S, 175.4729E) on January 3rd, 2004. Landing occurred on a generally flat plain characterized by small, shallow depressions (referred to as hollows) and poorly defined ridges with only a few meters relief. Low hills and the rim of a 200 meter diameter crater (nick-named Bonneville) mark the horizon to the east-southeast and northeast, respectively. Gravel to cobble sized rocks cover 5% of the local surface and there are relatively few boulders. Surface albedo is 0.19, the lowest observed within the predicted landing ellipse, and is thought to reflect removal of fines during dust devil passage. Much of the surface is dominated by sand and silt and finer sized particles comprising soils and local drift deposits. Rocks are noticeably smaller than at previous Mars landing sites and display a broad range in size and angularity. Some are faceted and likely reflect wind erosion, whereas others are pitted and may possess vesicles. Fractured and fragmented rocks are more abundant than at previous landing sites. Most rocks are either embedded in the substrate or perched on the surface and the vast majority are dark in color. Variable dust covering likely accounts for the appearance of lighter rocks and all observed so far are compositionally consistent with olivine basalts. Relatively high albedo soils possess a honeycomb texture characterized by rare discrete grains and elevated sulphur and chlorine abundance. A few soil grains appear tabular, but most are unresolvable fines. Soils retain texture after placement of the Mossbauer instrument, thereby indicating some strength and are consistent with the presence of an orthochemical cement. Local eolian drifts occur as fines partially filling local hollows and as numerous accumulations generally in the lee of obstacles. By contrast, surfaces adjacent to some hollows possess abundant perched rocks and appear deflated. Examination of the grains comprising the coarser drift deposits reveals a bi-modal distribution of fine and coarse sand sizes with the coarse grains being rounded, sometimes oblate, and concentrated along the crests of the drifts. Grains also occur as small fillets at the base of some rocks and indicate sufficient strength to withstand saltation transport. Collectively, these properties indicate local bed forms are ripples, not dunes. Observations of the landing site to date reveal a surface dominated most recently by eolian, impact, and perhaps volcanic processes. While conclusive evidence for ancient water-lain deposits remains elusive, the action of these more recent processes may mask their signature. In an attempt to deconvolve the broader geologic history, the Spirit rover is traversing 250 meters to access the rim of crater Bonneville. A radial traverse across the Bonneville ejecta and view of any crater wall stratigraphy and interior deposits should lead to a better understanding of the full suite of processes that have operated in Gusev crater over geologic time.

U43A-04 1415h INVITED

Mars Exploration Rover Science Operations During Cruise, Prime, and Extended Mission

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The Mars Exploration Rovers (MER) Spirit and Opportunity landed safely on the martian surface in Gusev crater on January 4th, 2004 and in Meridiani Planum on January 25th, 2004, respectively. Each spacecraft required four trajectory correction maneuvers on their way to Mars after launches on June 10th and July 7th, 2003. Both were successfully guided through energetic interplanetary weather to Entry, Descent, and Landing (EDL), and both felt the effects of a decaying, mid-December 2003 regional dust storm. The MER science team contributed to cruise targeting decisions and to monitoring of martian weather for EDL. After 12 martian days, or sols, Spirit descended from her lander, and Opportunity accomplished the same after 7 sols. Since then, both have been guided for their prime mission by a daily cycle of overnight science-driven planning. The planning starts in the martian afternoon, using the critical portions of that sol's direct-to-Earth downlink to define that rover's science objectives for the following sol. The engineering team defines the resource boundaries for the operations planning and the science team works within the resources to develop an detailed activity plan for the instrument suite. This plan is checked and refined during the martian night and radiated to the rover after it wakes up in the morning. Two separate teams operate Spirit and Opportunity in Mars local solar time, which differs by some 12 hours between the two rovers. The operations structure is somewhat modified for the extended mission, nevertheless maximizing the science return with a reduced workforce. The MER Science team has met the significant challenge of discovery-driven mobile planetary exploration, operating two rovers simultaneously.

U43A-05 1430h INVITED

The 2001 Odyssey Science Mission: Providing a new View of Mars

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The 2001 Mars Odyssey mission has completed just over one Mars year of orbital science operations. Observations of Mars and its environment are being carried out by three science instrument packages: (1) the Gamma Ray Spectrometer suite (GRS), which is composed of the Gamma Sensor Subsystem (GSS), the Neutron Spectrometer (NS) and the High Energy Neutron Detector (HEND), (2) the Thermal Emission Imaging System (THEMIS), and (3) the Martian Radiation Environment Experiment (MARIE). Currently, two of the three science investigations are returning data. The MARIE instrument is in a powered off mode and is undergoing anomaly troubleshooting. The Odyssey mission has added significantly to our understanding of Mars. Gamma and neutron observations of the high latitudes have been used to identify water-ice-rich soil to 1-m depth at latitudes poleward of 60 degrees north and south along with identifying enigmatic deposits of hydrogen in mid-latitudes, with water equivalent mass fractions of 2-10%. In addition, Gamma ray emission maps for six elements have been constructed, and analysis is ongoing. The THEMIS instrument has provided daytime and nighttime infrared imaging over 72% and 98% of the planet respectively. These data show a remarkable diversity of temperature signatures, implying a large variability in surface properties, ranging from bedrock outcrops to areas with extensive dust coverage. A dedicated visible imaging campaign (36-m/pixel) has

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provided a comprehensive view of the south polar-layered deposits, facilitating comparisons in surface variations as a function of season. The MARIE instrument has detected radiation signatures from the high solar activity during the first 18 months of operations, including events with significantly different signatures at Mars and Earth. The orbiter has played a key role as a data relay platform for the Mars Exploration Rovers. In addition, coordinated observations between the rovers and Odyssey allow ground truthing of the orbital data. The nominal Odyssey science mission will cover 917 days, until August 2004. Extended mission operations appear to be feasible, given the current inventory of propellant. Goals for a possible extended mission include inter-annual comparative observations, global high- resolution mapping by the THEMIS visible camera, and synergistic science and operations support for other Mars missions.

U43A-06 1445h INVITED

The Martian Radiation Environment Experiment – Results and Status

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Ionizing radiation in space presents a potentially serious health hazard to astronauts on long-duration missions. Missions that take humans outside the geomagnetosphere (which provides significant shielding for crews in low-Earth orbit) are of particular concern. A mission to Mars would expose a crew to a substantial radiation dose from high-energy heavy ions in the Galactic Cosmic Radiation (GCR). Though not expected to cause acute effects, such exposures might endanger the long-term health of crewmembers, leading to increased risk of late effects such as cancer and cataract. Since the biological effects of these ions are not well understood, NASA cannot yet specify career limits for deep-space missions. While ground-based research in radiobiology continues, it is necessary to characterize the radiation field on the Martian surface. This is determined by the radiation incident on the top of the Martian atmosphere, the transmission properties of the atmosphere, and the production of secondary particles (neutrons in particular) in the upper part of the surface. The Martian Radiation Environment Experiment (MARIE), aboard the 2001 Mars Odyssey spacecraft, has returned the first detailed measurements of the radiation field incident on the atmosphere. MARIE consists of a stack of silicon charged-particle detectors, designed to measure the nearly-constant flux of energetic Galactic Cosmic Rays (GCR) and intermittent Solar Particle Events (SPE). The detector is optimized for the detection of solar protons and helium in the energy range from 30 to 75 MeV/nucleon, though higher energies and heavier ions are also detected. Despite considerable uncertainties in data normalization, the measured dose agrees with model calculations, to an accuracy well within the (conservatively) estimated errors. As of this writing (Feb. 2004), MARIE is off, having sustained damage during the large Solar Particle Event of Oct. 29, 2003. Attempts to recover the instrument will resume in the near future. If MARIE cannot be recovered, other instruments aboard Odyssey are sensitive to energetic charged particles and can be used to continue Odyssey's radiation monitoring program. We will report on the status of these efforts, in addition to giving an overview of the 20 months of MARIE data that were successfully recorded.

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New Views of Mars and Its Environment II

Presiding: **C M Weitz,** Planetary Science Institute**; J F Bell,** Cornell University

U44A-01 1530h

Geology of the Mars Exploration Rover

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The second of NASA's two Mars Exploration Rover spacecraft landed successfully on January 24, 2004 within the classical low albedo region Sinus Meridiani. The landing site has been confirmed by a variety of localization methods including direct orbital imaging to be within a small 22-m diameter crater at 1.95°S, 354.47°E. The crater has a maximum depth of only about 3 m, and is surrounded by a large expanse of flat, low albedo plains materials that have been shown from orbital spectroscopy to contain significant abundances of gray crystalline hematite. Initial Pancam imaging studies of the crater and the surrounding plains (where visible above the crater rim) reveal the average 750 nm albedo of the soils to be 0.15+/-0.02, consistent with the low bolometric albedo of the region derived previously from orbit. This is the darkest site yet visited by a landed Mars spacecraft, and high resolution Pancam and Microscopic Imager (MI) observations of the soils reveal the presence of sand-sized grains that are consistent with orbital near-IR and mid-IR telescopic and orbital predictions for the physical properties of this site. There have been several wonderful geologic surprises, however. First, the rover fortuitously landed only a few meters from an outcrop of brighter, redder deposits that may turn out to be only rarely exposed in this region. The deposits crop out roughly halfway up the inside of the crater wall and extend vertically only a few tens of cm but laterally around roughly half the circumference (about 30 m) of the crater's NW to NE rim sector. The outcrop appears to consist mostly of well-indurated or possibly lithified materials, some of which exhibit fine laminae/layers on the sub-cm scale. Smaller fractions of the exposed outcrop stratigraphy appear to consist of tabular or massive materials. The origin of the laminae is unknown, but aeolian, fluvial, and volcanic processes are being considered and more definitive evidence from observations of potential sedimentary structures is being pursued. At the scale of the MI images the outcrop materials appear to have undergone significant differential erosion, suggesting compositional diversity within the layers that is as yet unconfirmed by direct measurements. The second surprise is the discovery of a population of well sorted spherical grains ("spherules"), typically several mm in diameter, that have been observed to vary in relative abundance from place to place within the crater but generally increase in relative abundance closer to the outcrop. In some places the spherules can be seen to be randomly distributed or even overdispersed within the laminated matrix of the outcrop, and/or eroding directly out of the outcrop itself, suggesting that their origin is intimately tied to the origin of those deposits. Hypotheses for spherule origin include volcanic (e.g., accretionary lapilli), impact (impact spherules, tektites), or chemical precipitation (concretions, pisoliths), all of which are being explored and tested in detail as new imaging and compositional data are obtained. For example, no evidence has yet been found that the spherules are aggregated, in layers or otherwise, or (where broken spherules are seen) that they are themselves composed of concentric or laminated structures. This argues against an impact spherule/lapilli or oolite/pisolite origin, but certainly not conclusively. After exploring the outcrop the rover will most likely leave the crater and explore the surrounding plains. The goal of this next phase of the rover's mission will be to search for and determine the origin of the hematite deposits and other layered/outcropping materials thought to be part of the potentially aqueous sedimentary rocks mapped from orbit in this region of Mars.

U44A-02 1545h

Characteristics of the Soils at Meridiani Planum, Mars

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We have used the Pancam and Microscopic Imager on the Opportunity rover at Meridiani Planum to understand the soil characteristics within the 20 m diameter crater where the rover landed. The majority of the soils consist of a well sorted lag deposit composed of millimeter-size grains of multiple sources superimposed on a finer soil matrix. The millimeter-size grains vary in size and morphology across the crater floor, with the largest (2-10 mm diameter) and most spherical grains adjacent to the layered outcrop, and smaller, more irregular sizes moving away from the outcrop towards the center of the crater. The soil right next to the lander is mostly composed of very fine grains (avg. 150 microns) with larger grains between 1 and 2 mm in diameter. Adjacent to the outcrop, the soils are dominated by spherules that have weathered out intact from the layered outcrop. It's likely that some of the non-spherule millimeter grains represent outcrop material that has been weathered to finer particle sizes and subsequently mixed into the soil. Underlying the spherules is a darker, finer soil that is spectrally similar to the soils near the lander. Undisturbed hematite-poor and hematite-rich soils, as determined by the Mini-TES instrument, show no significant differences in grain shapes or sizes. Rover wheel tracks show that the spherules and millimeter-size grains have been pushed down into the finer soil by the movement of the rover, but they have not been crushed. A similar effect was seen both from the Mossbauer contact plate after it was pushed into the soil, and also in the airbag bounce marks where the larger spherules have disappeared within the bounce marks, most likely due to burial, and there is a corresponding lower hematite signature. A 10 cm deep trench dug by a rover wheel reveals a brighter substrate on the trench floor, and a bumpy texture of soil with embedded shiny spherules in the upper wall. The brighter trench floor may be a photometric effect from the compaction rather than a distinct soil type. Linear ripples spaced 5-8 cm apart are concentrated adjacent to the lander and near the center of the crater. The ripples lack the millimeter-size grains visible throughout the crater floor. Intraripple soil within the larger ripples contains patches of brighter material that is spectrally distinct from all other soils and rocks thus far analyzed by Pancam, including the layered outcrop. Based upon orbital images of the landing site, the crater floor has a lower albedo than the terrain outside the crater. Consequently, the soils we have analyzed thus far inside the crater may either contain a higher percentage of darker grains or they may not be representative of the soils covering the plains of Meridiani Planum.

U44A-03 1600h

Mineralogy and Geochemistry at the Meridiani Landing Site, Mars

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The Mars Exploration Rover (MER) Opportunity landed in Meridiani Planum on January 24, 2004 (PST). The scientific rationale for selecting this landing site (1.95 S, 354.47 E) centered on the discovery by the orbiting Thermal Emission Spectrometer of 10-20% grey crystalline hematite in association with basaltic rocks in this region. Formation of hematite requires either precipitation in iron-rich waters or thermal oxidation of iron-bearing volcanic rocks. Each MER rover carries instruments well suited for in situ and remote analyses of iron-rich materials. The mast-mounted visible/near-infrared multispectral Pancam system and thermal infrared Mini-TES spectrometer in combination with the arm-mounted alpha particle x-ray spectrometer (APXS), Moessbauer spectrometer (MB), Microscopic Imager (MI), and Rock Abrasion Tool (RAT) deliver complementary detailed information on the morphology, mineralogy and composition of the materials at this site. The exposure of relatively high albedo bedrock materials on the western crater rim and low albedo soils in the crater have been the main focus during the first 25 sols of rover operations. Results thus far include: (1) Subtle variability in the ferric and ferrous absorption features observed by Pancam in the soil and bedrock, consistent with poorly crystalline iron phases; (2) Confirmation by Mini-TES of gray hematite-rich soils, with hematite-free soils consistent with basalt; (3) Discovery of small (1-5 mm) grayish spherules embedded in and weathering from the bedrock, with as yet undetermined composition; (4) Moessbauer spectra consistent with olivine and a weak magnetic phase in the soils; (5) APXS soil data consistent with a basaltic composition and with S and Cl levels similar to other landing sites. Among current hypotheses for the bedrock formation, some involve fine-grained basaltic sediments as starting materials that underwent either (a) cementation by minerals and growth of spherical concretions; (b) alteration by acidic hydrothermal solutions; or (c) evaporative mineral precipitation followed by subsequent reworking of sediments by aqueous activity. Alternative hypotheses include impact ejecta deposits and/or hydrovolcanic deposition forming lapilli subjected to hydrothermal alteration.