

SORA is part of a test programme of the Agenzia Spaziale Italiana (ASI) in order to test the two penetrating radars that ASI has prepared for the Mars exploration. The first instrument is MARSIS on board of Mars Express ESA mission; the other is SHARAD for the Mars Reconnaissance Orbiter NASA mission. The SORA experiment will be dedicated to testing SHARAD. MARSIS has a strong penetration power (a few kilometers) and lower vertical resolution, whereas SHARAD will penetrate only several 100s meters but its data will have high-resolution range. SORA will consist of a stratospheric balloon flying at about 35 km above sea level will carry the experiment. The balloon will carry a model of SHARAD with the electronics scaled to the experiment parameters. The balloon will be launched from Svalbard where the facility of the Italian base will be used. Simulations of the balloon trajectory show a circular shape with a landing area within 100 km from the launch pad. During the flight the balloon will get data from northern Greenland the Canadian Archipelago and part of northern Siberia and adjoining islands. The experiment will be able to investigate thick ice sheets, permafrost areas, seasonally snow covered zones and sea ice. This experiment will support the analysis of the SHARAD data and will provide some clues on the use of a similar instrument on the icy satellites.

P51A-04 0920h

Ground Penetrating Radar Measurements of Ice and Frozen Ground in the Mackenzie Delta, NWT, Canada

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Ground Penetrating Radar (GPR) is an efficient, non-invasive tool for subsurface investigations. Whereas low frequency orbital and airborne radar sounders can penetrate hundreds of meters or even a few kilometers, ground-coupled GPR operating between 100 and 1000 MHz can penetrate 10 to 20 m below the surface. GPR data from the top 10s of meters provide high-resolution information about the electrical properties and geologic structure of the shallow subsurface. On Earth, geologic GPR surveys have been used to study the third dimension (depth) of geologic relationships observed at the surface. Depth information is a significant addition to understanding the geologic setting and history of a field site. In recognition of the potential for a rover-deployed Mars GPR to help characterize future landing sites, fieldwork is being conducted at martian analog sites to demonstrate and assess the capabilities of GPR in those environments. Data are collected using commercial antennas at several frequencies as well as a prototype Mars GPR antenna currently under development. To complement past GPR measurements from arid environments in Arizona, California, and Egypt, fieldwork is planned to collect data in areas with ground ice and frozen ground. Data collection is planned in the Mackenzie Delta region of Northwest Territories, Canada, for late March when the average air temperature is -14°C and the ground has been constantly frozen for more than five months. The Mackenzie Delta offers analogs for various terrains and features that may exist at mid- to high-latitudes on Mars. This area has been the focus of previous studies of ground ice, and the GPR measurements will be coordinated with a study using resistivity measurements to map ice. In addition, shallow seismic data will be collected, and existing bore hole data will be used to tie geophysical measurements to the local geology. Data will be collected over ice wedges, a pingo, snow-covered gullies, the transition from ice-poor to ice-rich ground, and over ground ice overlain by sand and by gravel. If weather conditions permit, data will also be collected on frozen lake and sea ice.

P51A-05 0935h

The Potential of Low-Frequency (16-80 MHz) Ground Penetrating Radar to Investigate the Shallow Subsurface in the Arid, Volcanic, and Conductive Soils Near Yucca Mountain: Implications for MARSIS and SHARAD

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In March 2004, the MARSIS radar sounder aboard the Mars Express spacecraft will begin acquiring the first of what will eventually be a global data set of the radar properties of the Martian subsurface within the frequency range of 0.5-5 MHz. Because no MARSIS prototype was ever built, and only limited GPR investigations of the Earth have been made within this frequency range, we plan to conduct a comprehensive radar investigation of a number of well-characterized terrestrial analog sites over the range of frequencies that will be employed by MARSIS and future Mars radars. The ability of these radars to determine the subsurface stratigraphy, structure, and distribution and aqueous history of water on Mars will be strongly dependent on the physical properties, mineralogy, and thermal structure of the subsurface properties that will define the electrical and magnetic characteristics and ultimately determine the propagation, scattering and reflective properties of the crust. The arid volcanic environment around Yucca Mountain, Nevada has many similarities to the geologic environment of Mars. For example, the soil mineralogy is dominated by the presence of iron oxides, materials that can result in significant electrical and magnetic losses to the radar signal, thus affecting the maximum sounding depth and depth at which any subsurface feature can be identified. In order to evaluate and quantify the magnitude of these losses, we performed a 16 - 80 MHz GPR survey at several well-characterized areas in a region to the southwest of Yucca Mountain. A principal goal of this survey is to determine the extent to which these adverse soil properties influence the identification of subsurface stratigraphy, structure, and a water table at depths ranging from several tens to hundreds of meters. We will present a summary of the field and laboratory data acquired during this survey and discuss its implications for radar sounding investigations of Mars

P51A-06 0950h

Specular Reflection of Mars Odyssey's UHF Beacon from H2-Enriched Northern Martian Latitudes

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On August 29th, 2003, the Mars Odyssey UHF beacon and its specular reflection off the Vastitas Borealis surface of Mars was detected with the SRI/Stanford 46-m dish antenna. The specular reflection at Doppler compensated frequencies near 437.1 MHz had an SNR of 6 dB/Hz, and the specular point traversed an arc from Martian latitudes and longitudes starting at [58,280], up to [68,272], and ending at [53,326]. Although weak, the signal incurred an abrupt transition in intensity and bandwidth near [66,300], which interestingly is where the Odyssey GRS H2 maps indicate the H2 concentration itself transitions from high to low. Because the UHF signal's wavelength is 0.686 m, the specular reflection's ability to sense subsurface conditions, particularly the regularity and depth of the scattering interface, may be evident in the intensity and bandwidth profile of the reflection.

P52A CC: 519 B Friday 1030h

Subsurface Radar Investigations of Terrestrial Martian Analogues II

(joint with GP, H, V, NS)

Presiding: E Heggy, Lunar and Planetary Institute; S Arcone, Cold Regions Research and Engineering Laboratory (CRREL); S Clifford, Lunar and Planetary Institute

P52A-01 1035h

Exploring Subsurface Geology Using Radar Techniques: Experiments in Sahara and Consequences for Mars Exploration

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For several years, we have conducted a quantitative study of radar penetration performances in various desert arid environments. This study combines both SAR (Synthetic Aperture Radar) imaging from orbital and airborne platforms and in situ GPR (Ground Penetrating Radar) measurements. Laboratory characterization of various minerals and rocks are used as input to electromagnetic models such as IEM (Integral Equation Model) and FDTD (Finite Difference Time Domain) that describe the subsurface scattering process for inversion purposes. Several test sites were explored, mainly the Sahara. Our first experiment was realized in Republic of Djibouti, an arid volcanic area which is a good analog to Mars. We observed a very little radar penetration there because of the presence of iron oxides and salts in the subsurface that make the soil conductive [Paillou et al., GRL, 2001]. A more favorable site for radar penetration was then explored in southern Egypt: the Bir Safsaf area where buried river channels were discovered using orbital SAR images. We showed how to combine SAR and GPR in order to obtain a complete description of subsurface geology down to several meters [Paillou et al., IEEE TGRS, 2003]. Such field experiments were the basis for more systematic laboratory measurements of the electromagnetic properties of various rocks and minerals which were used in numerical models in order to simulate the performances of future Martian radars, e.g. MARSIS and NETLANDER low frequency radars [Heggy et al., Icarus, 2001; Berthelier et al., JGR, 2003; Heggy et al., JGR, 2003]. More recently, new explorations were conducted in Mauritania in order to demonstrate radar capacities for geologic mapping [Grandjean et al., Coll. Afr. Geol., 2004] and in Libya where radar discovered a double impact crater in the southern desert [Paillou et al., C.R. Geoscience, 2003]. More local radar experiments were also conducted on a test site located in France, the Pyla sand dune, where we observed and modeled a radar signature of subsurface water [Grandjean et al., IEEE TGRS, 2001; Paillou et al., IGARSS'03, 2003]. All of these results shall be used in the context of "terrestrial analogs to Mars" studies in order to prepare for future Mars exploration using radars [Farr et al., Planet. Dec. Study, 2002; Paillou et al., 35th LPSC, 2004]: it concerns both GPR instruments onboard rovers and landers devoted to the exploration of the deep subsurface [Berthelier et al., ESA Paster, 2003] and SAR imaging systems onboard orbital platforms for global mapping of the shallow subsurface geology [Paillou et al., Conf. Water Mars, 2001].

P52A-02 1050h

Mars Orbital SAR: Obtaining Geologic Information from Radar Polarimetry

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Radar penetration of mantling layers, and scattering from buried objects or interfaces, is a topic of current interest in both terrestrial and planetary remote sensing. We examine the behavior of surface and subsurface scattering interfaces, and the types of information that may be obtained from observations in different polarizations and wavelengths. These theoretical results are compared with AIRSAR and SIR-C data for terrestrial arid environments. Our results are also applied to the basic design of a Mars orbital synthetic aperture radar (SAR) system, for which we draw the following conclusions. (1) Mapping of buried geologic features is best accomplished using VV polarization, at an optimal wavelength determined by the competing effects of antenna gain, attenuation in the dust, and the reduction in effective surface roughness with wavelength. For reasonable values of dust depth and loss properties, P-band frequencies offer the best opportunity for detection of moderately rough, buried features. (2) The relative roles of surface and sub-surface scattering may be determined using measurements in HH and VV polarization, with a requisite channel gain calibration better than 0.5 dB. (3) The depth of a mantling layer (or ice mass) cannot be directly inferred from multi-wavelength observations; even for HH and VV measurements in two wavelengths, we only obtain an estimate of the combined effects of dust depth and loss tangent. Mantle or ice layer depth may be inferred from the interferometric correlation of backscatter measurements collected on suitably spaced orbital passes. While additional information may be gained by collecting scattering data in more polarizations or wavelengths, we suggest that the primary science goals of a Mars orbital radar could be accomplished by a single-wavelength, P-band system capable of collecting VV and HH polarizations with the calibration and orbit control needed to permit interferometric analysis.

P52A-03 1105h

Airborne Synthetic Aperture Radar Study of Soil Moisture at Mars Analogs

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Hypotheses involving water have been proposed for Martian surface processes such as gullies, duracrust cementation and dark slope streaks. Future SAR missions capable of detecting soil moisture could test these hypotheses, but standard soil moisture retrieval techniques for SAR data such as the Integral Equation Method (IEM) are not applicable to Mars due to the current lack of high resolution surface roughness data. Another approach would be to conduct repeat passes, where surface roughness is assumed to be constant and changes in backscatter are related to changes in soil moisture. This study was undertaken to determine optimal parameters for detecting soil moisture at Mars analog sites. Quad-polarized C, L and P band AIRSAR data at 11m slant resolution were collected at four sites: a fluvial plain near Cameron, AZ; artificial recharge basins near Tucson, AZ and gullies in San Juan Mountains, CO and Death Valley, CA. Soil moisture was measured at a range of depths (0-40cm) with gravimetric sampling and over a large spatial extent with Time Domain Reflectometry (TDR). For a homogenous unvegetated sand bar at Cameron, a significant correlation (< 0.025 level of significance in a t-distribution test) was found for L-VV and L-TP with soil moisture at 0 cm depth. C-HV had a weaker correlation (< 0.05 level of significance) to 0 cm moisture on both the sand bar and the unvegetated surface of a recharge basin. The lack of response to deeper moisture in this study cannot discount the potential for detecting deeper moisture on Mars if the radar wavelength is long enough to penetrate a desiccated upper layer. Further analysis of the gully sites and TDR data will also be presented.

P52A-04 1120h

Electromagnetic Characterization of Terrestrial Analogues To the Martian Volcanic Sediments in the Frequency Band 1 kHz to 500 MHz: Toward a Dielectric Map of Mars

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We have undertaken a laboratory electromagnetic characterization of minerals identified by the Mars Global Surveyor's Thermal Emission Spectrometer (TES) to determine their dielectric properties over the frequency range from 1 kHz to 500 MHz. The study includes the same sample library used for the calibration of TES, volcanic rocks from potential terrestrial analogues sites, as well as some achondrite and SNC meteorite samples. Samples have been measured in two forms: powder and compacted pellets, reflecting the different extremes in soil density and lithology that are found on the Martian surface (the in-situ density of these materials has been estimated from the TES thermal inertia data). The primary objective of this work is to evaluate the range of the surface electrical and magnetic losses that may be encountered by radar sounding investigations that are conducted to identify the state and distribution of subsurface water on Mars. The electromagnetic properties of these Mars-like materials are being investigated as a function of various geophysical parameters, such as porosity, bulk density and grain size. This information will help to locate regions on Mars where surface dielectric conditions are optimal for orbital subsurface sounding. Preliminary results indicate that for low-density dust, the dielectric contrast between different iron-poor minerals is not very relevant while for consolidated materials with equal densities the contrast is more important. In contrast, iron-rich minerals, such as hematite and magnetite, have both a complex dielectric behavior and yield a strong contrast with other minerals detected on the surface of Mars. Even in minor amounts, iron oxides can have a strong impact on the strength of the backscattered radar signal in the frequency band 1 to 30 MHz. We discuss the potential implications of these findings on the maximum penetration depth and effect of surface clutter at the frequencies utilized by the MARSIS and SHARAD orbital radar sounding instruments.

P52A-05 1135h

Determination of Sub-Ice Topography in a Valley Glacier Environment Using Airborne Radar Sounding with Echo Discrimination Techniques

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The identification of subsurface radar echoes on Mars in areas where significant surface topography exists will require careful echo source discrimination to avoid misinterpretation. We have developed these techniques for airborne radar sounding data in the Dry Valleys of Antarctica. This effort includes a radar data simulator that utilizes a lidar-generated digital elevation model (DEM) of nearby surface topography to predict the location and shape of surface echoes in the radar data. This is combined with the superposition of horizontally migrated radar echoes on optical imagery and a DEM in order to locate the sources of off-nadir surface reflections. Employing these techniques, we are able to both discriminate subsurface echoes and determine accurate subglacial topography in a mountainous area. The airborne radar sounding data were collected primarily in Taylor Valley and over Taylor Glacier in the McMurdo Dry Valleys, Antarctica. Two different airborne radar systems were used, both with an 8 kW transmitter. The first was incoherent, log-detected and pulsed at 60 MHz with a 60 ns pulse duration. The second was coherent, dual channel and chirped from 52.5 - 67.5 MHz with a pulse duration of 1 microsecond. The latter data set has been processed with pulse compression and SAR processing. Surface-based radar sounding data were also collected on Taylor Glacier using a 4 kV (p-p) system centered at 7 MHz and towed behind a skidoo. A single, continuous reflector under the main trunk of Taylor Glacier and multiple reflectors

beneath the toe of Taylor Glacier have been identified as subsurface reflectors in the airborne data. These represent subglacial topography and possible incipient thrust moraines, respectively. Surface-based radar is the least affected by nearby topography and confirms the thickness of the glacier. The determination of subice topography for active valley glaciers is important for understanding remnant glacial topography, and hence, past glacial episodes on Mars. The echo discrimination techniques applied here are applicable to the identification of any subsurface reflectors.

P52A-06 1150h

Orbital Radar Response of Near Surface Materials in Southern Egypt and Implications for Cenozoic History

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Although the existence of "trunk" and tributary drainage channels beneath the sand in the northeast Sahara has been known for two decades, data from the SIR-C mission continues to be useful in solving geologic problems and understanding the radar response from specific types of near surface materials. In the Kiseiba Oasis region of southwest Egypt, SIR-C data revealed a complex tributary pattern of varying brightness that indicated the presence of paleodrainage not noted in the field. The orbital imaging radar uniquely specified key areas for detailed field studies that were not apparent in visible wavelengths. Twenty-two trenches up to 3 m deep, hundreds of shallow pits, several auger holes, and ground penetrating radar reveal that this area has had a history of fluctuating climatic conditions responsible for excavation and enlargement of the local depression by fluvial erosion and preservation of relict surfaces by aeolian blanketing of sand sheet deposits. The resulting near-surface stratigraphy is a complex mixture of fluvial pebble lags in the subsurface and on the surface, where aeolian mixing and local transport have modified the original geometry. In L-band (23 cm wavelength) SIR-C data, a hierarchy of returned signal strength and geometric patterns enables us to predict the type of surface and near-surface materials, sequentially from shallow bedrock to subsurface and surficial lags to sand sheet-veneered weathered anhydrite. Integrating the pattern of sedimentary deposits with relict channels and interflues enables a better understanding of the origin of the Kiseiba-Dungul depression and its Cenozoic history. What was once thought to be a continuous deposit of Eocene limestone from southern Egypt into northern Sudan is cast in doubt as even the most optimistic estimates of scarp retreat don't permit hundred's of kms of retreat to the present position. Instead, the E-W pattern of the depression, the relict hills, and fracture zones all suggest structural control and erosion patterns that started with N-S compression in the latest Cretaceous. A humid climate during the Tertiary aided fluvial dissection of the broken surface, with drainage leading to the north into the present Kharga depression. The drainage patterns of the Quaternary seen now in orbital radar result from remnants of large-scale structural patterns and Tertiary drainage, confused by alternating hyperarid and semi-arid climatic cycles that inverted topography, protected former erosion surfaces, and reversed drainage.

P53A CC: 220 C-E Friday 1330h

Subsurface Radar Investigations of Terrestrial Martian Analogues III Posters (joint with GP, H, V, NS)

Presiding: E Heggy, Lunar and Planetary Institute; **S Arcone**, Cold Regions Research and Engineering Laboratory (CRREL); **S Clifford**, Lunar and Planetary Institute

P53A-01 1330h POSTER

Sounding of Groundwater Through Conductive Media in Mars Analog Environments Using Transient Electromagnetics and Low Frequency GPR.

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