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Long Island Sound is a eutrophied urban estuary that suffers from anoxia during the late summer months. Is the narrow western part of the estuary prone to anoxia as a result of poor circulation during warm periods or is the anthropogenic eutrophication the main driver for the seasonal anoxia? We have reconstructed the history of bottom water oxygenation through the use of stable isotope studies of foraminifera in sediment core samples. The paleo water temperature was approximated from Mg/Ca measurements in shells of the foraminifer Elphidium excavatum and the paleo salinity was calculated from the foram shell's delta 18O values and the temperature estimates. The measured delta 13C values of the shells were corrected for salinity, using our river-seawater mixing model, and the excess delta 13C values were recast into additions of milligrams of algal carbon per liter of water through an isotopic mass balance statement. The equivalent oxygen consumption was then used to calculate the water oxygen contents, which was divided by the saturated oxygen contents of the waters at the calculated temperature and salinity. The resulting percent oxygen saturation values for 5-10 year average values (time in a sediment slice) were plotted as a function of time (cores were dated with a variety of isotopic and pollen techniques). The results show that from 1000 AD to about 1850 AD, mean levels of oxygen saturation were about 70-80 percent; these values started dropping in the mid 19 and 20 century, reaching 30-40 percent saturation values over the last 50 years. The temperature record shows evidence for the warm Mediaeval period, but there is no evidence that the Sound suffered from anoxia at that time. Organic carbon contents of the sediment increased over the last 250 years and organic carbon accumulation rates increased almost 5 fold. Both the amount of sediment-stored organic carbon and the oxidized organic carbon fraction of the total primary productivity increased during the gradual eutrophication of the Sound. We conclude that the main driver of the seasonal anoxia in western Long Island Sound is the release of nutrients (mainly nitrogen compounds) from sewage and run-off, which leads to eutrophication and excess algal carbon production. Modern global warming may provide an additional effect by enhancing water column stratification.

B51G MCC: 2002-2004 Friday 1020h

Astrobiology as a Unifying Theme for Solar System Exploration I *(joint with P)*

Presiding: **D Morrison,** NASA Astrobiology Institute**; B Runnegar,** University of California, Los Angeles

B51G-01 1020h INVITED

Astrobiology as an Integrating Theme in Solar System Exploration

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The discipline of astrobiology examines (i) the origin and evolution of life on Earth and the detailed interplay between biological and planetary evolution, (ii) the evolution of our solar system and the potential and actual distribution of life within it, (iii) the occurrence of planets around other stars and their potential for life, and (iv) the interplay between each of these areas. In our own solar system, astrobiology encompasses much more than just the search for life on Mars or Europa. Our goal is to understand the nature of planetary habitability–which planets have evolved to have environments that are habitable by microorganisms, and which have not. By understanding the processes that control the architecture of our solar system, we can extrapolate how these same processes might have played out in other planetary systems and what the distribution of habitability might be beyond our own system. In this context, Mars and Europa appear as potentially habitable worlds either today or in the past, Ganymede and Callisto might have deep subsurface oceans and be habitable, Venus might have been habitable early on but does not appear to be today, and Titan probably has had intermittent liquid water as well as ongoing chemical evolution involving organic molecules. Looking more broadly, the origin and the evolution of the gas-giant planets and their dynamical effects have had a major influence on the terrestrial planets; the characteristics of the Kuiper belt and Oort cloud influence our understanding of early chemical and volatile processes that affect habitability; and asteroids have had a tremendous impact on the terrestrial planets throughout their history. In order to understand planetary habitability in general, and the implications of a discovery of the presence or absence of life on any given object, we need to understand the detailed origin and evolution of our solar system as a whole and of the individual bodies within it. A broad program of planetary exploration is the best way to investigate the astrobiology of our solar system.

B51G-02 1040h

Planetary Protection: A Major Challenge in the Exploration of Life in the Solar System

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The picture of Mars that is now emerging from the Mars Global Surveyor and Odyssey results stands in marked contrast from that portrayed shortly after the Viking missions of the mid-1970s. The abundance of water ice seen both in the polar caps themselves, and in lower latitudes outside of the polar regions is particularly intriguing, and adds to the heightened consideration Mars as a planet that might support life–either Mars life or life brought from Earth. Elsewhere in the Solar System the situation also intrigues those looking for habitable niches. The tides of Europa are thought to keep its icy shell melted, thus providing ample liquid water in an ocean that may be on the order of 100 km deep. Other icy bodies may also be as interesting, whether they orbit Jupiter or are found around Saturn or the other outer planets. The intriguing nature of these bodies, and their potential niches for life, highlight the problems involved with possible biological contamination that may be carried by future missions, and its possible effects. A particular challenge are missions carrying perennial heat sources of high capacity and longevity (e.g., Radioisotope Thermoelectric Generators) which could, by non-nominal landings or other mission operations, be introduced to close contact with water ice–potentially forming Earthlike environments that could accommodate the growth of contaminant organisms. Maintaining the cleanliness of solar system bodies from biological growth is of critical importance to the future success of NASA's science and exploration missions, as is protecting the Earth from the importation of life from elsewhere, if it exists. Recently, the ICSU Committee on Space Research (COSPAR) has published an international consensus planetary protection policy that provides a standard to address the prevention of biological contamination in sensitive areas on Mars, and in the Jovian moons.. Furthermore, as our array of missions grow, new data will drive future planetary protection concerns. A framework for assessing required contamination control measures must be developed.

B51G-03 1055h INVITED

Exploring for Biosignatures of Extant Life in Martian Ground Ice

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The strategy for the next decade of Mars exploration emphasizes the discovery of favorable sites for sampling ancient, aqueously-formed sedimentary rocks, especially those capable of capturing and preserving fossil biosignatures. Nevertheless, it is widely accepted that habitable zones of deep groundwater, able to support extant Martian life, could also be present in the subsurface today. Generally speaking, access to subsurface groundwater habitats could require drilling to depths of several km, far deeper than could be accomplished with the current generation of robotic landers and rovers. But, in the absence of advanced drilling technologies and perhaps human explorers needed to operate them, is it still possible, with present capabilities, to gain access to a deep subsurface hydrosphere on Mars during the robotic phase of exploration? Subsurface cryosphere-magma interactions appear to have been active throughout Martian history. Magma bodies emplaced into the shallow cryosphere would set up deeply convecting hydrothermal systems that would, in turn, carry subsurface organic chemistry and any organisms present in subsurface groundwater, upward into the shallow crust. Upon cooling, these materials could be incorporated into shallow ground ice. Such ice deposits may be accessible to future surface robotic missions via shallow drilling (tens to hundreds of meters depth) of recently active igneous/volcanic areas. Discoveries from the Mars Global Surveyor and Odyssey missions have already discovered several geological environments on Mars favorable for such magma-cryosphere processes. These include numerous small gully systems ("seeps"), mostly found on steep, poleward-facing slopes at high latitudes (Malin and Edgett 2000; Christensen 2003), sites marginal to the Martian polar caps where periodic outflooding events appear to have occurred (Clifford 1987) and recent volcanic constructs situated in ground ice-rich regions at high latitudes. While the strategy for exploring for cryopreserved biosignatures of extant life in near surface ice deposits needs additional study, it appears that the shallow cryosphere of Mars offers many tantalizing opportunities for future astrobiological exploration.

B51G-04 1110h

Past Habitability of Mars: Interpretations of Mars Global Surveyor TES

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A primary question in habitability studies of Mars is whether significant surface water was present in the past. If large water deposits were present, then carbonate deposits likely would have formed. Thus, much debate about the past climate and habitability centers on whether carbonate deposits have been detected. Here we discuss relevant infrared spectral evidence; implications for astrobiology; and the unifying research needed to address astrobiology concerns. Under specific conditions, carbonates exhibit spectral features near 6.5, 11, and 33 microns. Several past studies proposed detection of carbonates on Mars (reviewed Roush et al. [1993]). The detections have not widely been perceived as conclusive. Two recent orbited instruments (1996 Global Surveyor TES; 2001 Odyssey THEMIS) were intended to resolve the question. However, no 11 or 33 micron band detections have been reported. Complexities in atmospheric unmixing significantly delayed and complicated analysis of the 6.5 micron region. Bandfield et al. [2003] recently proposed detection of a 6.5 micron carbonate feature in the surface dust. However, TES did not detect the 11 and 33 micron bands, placing the interpretation again in the debated category. Christensen et al. [2001] concluded that TES detected no carbonate to the 10 percent per pixel level, and Bandfield et al. [2003] in selected dark regions to 5 percent. The 2003 rover Mini-TES is comparable to TES, and is similarly intended to resolve the minerals present. One interpretation of those results is that the types of carbonate deposits expected from large bodies of water are not present. One inference is that no large, standing bodies of water on Mars existed. However, discussion of a key issue to the debate has been missing: What impacts whether a mineral deposit is detectable by these instruments? We will demonstrate that rough surface texture can cause large mineral deposits, including rocks, to have subdued spectral signatures [Kirkland et al. 2001, 2002, 2003]. Subdued signatures can make a mineral undetectable ("infrared stealthy"). For example, the Mars "White Rock" deposit exhibits no detectable TES bands [Ruff et al. 2001]. Yet White Rock certainly is made of something. Grain scale roughness can be a primary cause of infrared stealthy behavior. The astrobiology community should be alerted to the following: 1. Accurate interpretations of these data sets require knowledge of the expected target texture. The textures are poorly known for the formation and weathering conditions on Mars. 2. An assessment of texture and dectectability will require collaboration between scientists who research astrobiology, geology of Mars, and the physics of spectral behavior. The unifying theme is identification of materials of interest to the astrobiology community on Mars by an infrared spectrometer, and conversely, defining when such materials will remain undetected. 3. Interpretations based on non-detection need to be revisited based on improved understanding of the true detection capabilities. 4. Interpretations founded on detection of a single spectral feature when more than one feature is expected should be viewed cautiously. References. Bandfield et al. Science 301, 1084 (2003); Christensen et al. JGR 106, 23823 (2001); Kirkland et al. Appl. Opt., 40, 4852 (2001); Kirkland et al. Remote Sens. Env., 80, 447 (2002); Kirkland et al., JGR in press, preprint www.lpi.usra.edu/science/kirkland (2003); Roush et al. Ch. 16 Remote Geochem. Analysis (1993); Ruff et al. JGR 106, 23921 (2001).

URL: http://www.lpi.usra.edu/science/kirkland

B51G-05 1125h

A Search for Life in the Subsurface At Rio Tinto Spain, An Analog To Searching For Life On Mars.

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Most familiar life forms on Earth live in the surface biosphere where liquid water, sunlight, and the essential chemical elements for life are abundant. However, such environments are not found on Mars or anywhere else in the solar system. On Mars, the surface environmental conditions of pressure and temperature prevent formation of liquid water. Furthermore, conditions at the Martian surface are unfavorable to life due to intense ultraviolet radiation and strong oxidizing compounds that destroy organic compounds. However, subsurface liquid water on Mars has been predicted on theoretical grounds. The recent discovery of near surface ground ice by the Mars Odyssey mission, and the abundant evidence for recent Gully features observed by the Mars Global Surveyor mission strengthen the case for subsurface liquid water on Mars. Thus, the strategy for searching for life on Mars points to drilling to the depth of liquid water, bringing samples to the surface and analyzing them with instrumentation to detect in situ organisms and biomarker compounds. The MARTE (Mars Astrobiology Research and Technology Experiment) project is a field experiment focused on searching for a hypothesized subsurface anaerobic chemoautotrophic biosphere in the region of the Rio Tinto, a river in southwestern Spain while also demonstrating technology relevant to searching for a subsurface biosphere on Mars. The Tinto river is located in the Iberian Pyrite belt, one of the largest deposits of sulfide minerals in the world. The surface (river) system is an acidic extreme environment produced and maintained by microbes that metabolize sulfide minerals and produce sulfuric acid as a byproduct. Evidence suggests that the river is a surface manifestation of an underground biochemical reactor. Organisms found in the river are capable of chemoautotrophic metabolism using sulfide and ferric iron mineral substrates, suggesting these organisms could thrive in groundwater which is the source of the Rio Tinto. The MARTE project will simulate the search for subsurface life on Mars using a drilling system developed for future Mars flight to accomplish subsurface access. Augmenting the drill are robotic systems for extracting the cores from the drill head and performing analysis using a suite of instruments to understand the composition, mineralogy, presence of organics, and to search for life signatures in subsurface samples. A robotic bore-hole inspection system will characterize borehole properties in situ. A Mars drilling mission simulation including remote operation of the drilling, sample handling, and instruments and interpretation of results by a remote science team will be performed. This simulated mission will be augmented by manual methods of drilling, sample handling, and sample analysis to fully document the subsurface, prevent surface microbial contamination, identify subsurface biota, and compare what can be learned with robotically-operated instruments. The first drilling campaign in the MARTE project takes place in September 2003 and is focused on characterizing the microbiology of the subsurface at Rio Tinto using conventional drilling, sample handling and laboratory analysis techniques. Lessons learned from this "ground truth" drilling campaign will guide the development of robotic systems and instruments needed for searching for life underground on Mars.

B51G-06 1140h INVITED

Records of our Early Biosphere Illuminate our Origins and Guide our Search for Life beyond Earth

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A scientific "mission of exploration to early Earth" will help us chart the distribution of life elsewhere. We must discriminate between attributes of biospheres that are universal versus those attributes that represent principally the outcomes of long-term survival specifically on Earth. In addition to the basic physics and chemistry of matter, the geologic evolution of rocky habitable planets and their climates might be similar elsewhere in the Universe. Certain key agents that drive long-term environmental change (e.g., stellar evolution, impacts, geothermal heat flow, tectonics, etc.) can help us to reconstruct ancient climates and to compare their evolution among populations of Earth-like planets. Early Earth was tectonically more active than today and therefore it exhaled reduced chemical species into the more oxidized surface environment at greater rates. This tectonic activity thus sustained oxidation-reduction reactions that provided the basis for the development of biochemical pathways that harvest chemical energy ("bioenergetics"). Most examples of bioenergetics today that extract energy by reacting oxidized and reduced chemicals in the environment were likely more pervasive among our microbial ancestors than are the presently known examples of photosynthesis. The geologic rock record indicates that, as early as 3.5 billion years ago (3.5 Ga), microbial biofilms were widespread within the coastal environments of small continents and tectonically unstable volcanic islands. Non oxygen-producing (non-oxygenic) photosynthesis preceded oxygenic photosynthesis, but all types of photosynthesis contributed substantially to the long-term increase in global primary biological productivity. Evidence of photosynthesis is tentative by 3.5 Ga and compelling by 2.7 Ga. Evidence of oxygenic photosynthesis is strong by 2.7 Ga and compelling by 2.3 Ga. These successive innovations transformed life from local communities that survived principally by catalyzing chemical equilibration to a globally dominant agent that created and sustained widespread chemical disequilibria in the environment and shallow crust. Major biogeochemical perturbations ca. 2.3 to 2.0 Ga, 1.3 Ga, and also 0.8 to 0.6 Ga, contributed to the irreversible oxidation of the global environment and perhaps also triggered evolutionary innovations (e.g., the development of multi-cellular biota) that became the foundations of our modern biosphere. Understanding the nature and timing of this ascent of life is crucial for discerning our own beginnings. This understanding also empowers our search for the origins, evolution and distribution of life elsewhere in our solar system and beyond. (This work was supported by the NASA Astrobiology Institute.)

B51G-07 1155h

Evolutionary and Ecological Sequelae of Mass Extinctions: Examples From the Continental Triassic-Jurassic Boundary

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The Triassic-Jurassic boundary at ~200 Ma marks one of the five major mass-extinctions of the Phanerozoic and, depending on the metrics used, was similar in magnitude to the K-T mass extinction. In continental environments about 50% of all tetrapod families are eliminated and although floral diversity change is difficult to gauge, a similar proportion of palynomorph taxa disappear at the boundary. The extinction event appears to have been very abrupt, followed by a roughly 900 ky super-greenhouse period characterized by increased precipitation. We hypothesize a series of biological consequences of the drop in diversity and associated super-greenhouse based on observations of the earliest Jurassic assemblages, largely from eastern North America. 1) The drop in diversity results in a collapse of ecological interactions that tend to stabilize the composition of regional biotas and buffer them from invading forms. Triassic assemblages show considerable biogeographic provinciality despite the existence of Pangea, but the earliest Jurassic assemblages were extraordinarily homogenous with many vertebrate genera being essentially global in distribution. 2) Initially the post-boundary terrestrial assemblages were comprised of eurytopic trophic generalists, with animal communities with few herbivores, but abundant carnivores and detritivores subsisting on aquatic-based food webs. The earliest Jurassic tetrapod footprint record is overwhelmingly dominated by the footprints of ceratosaurian theropod dinosaurs, the latter having skull characteristics usually associated at least in part with piscivory. 3) The dramatic size changes over very short periods of time were likely due to an absence of competition (i.e., ecological release). The maximum size of theropod dinosaur footprints increased by about 25% within 10 ky following the boundary, corresponding to a doubling of mass. 4) Representatives of clades with intrinsically high rates of speciation tend to form species flocks after the boundary. Species flocks of semionotid fishes dominated earliest Jurassic giant rift lakes in eastern North America, but not Triassic or later Early Jurassic lakes in the same basins. Based on footprint data, it is quite possible that there were also species flocks of morphologically similar ceratosaurian theropod dinosaurs in the Early Jurassic.

B51G-08 1210h INVITED

The astrobiology of Titan

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The known organic environments in the solar system other than the Earth and certain meteorites are in the outer solar system. Those of astrobiological potential are Europa, Titan, and comets. Titan is of interest because its nitrogen-methane atmosphere generates hydrocarbons and nitriles which fall to the surface and are protected from damaging particle and UV radiation by a thick atmosphere. Further chemistry, including in the presence of transient and localized areas of cryovolcanic- or impact-generated liquid water, may proceed on the surface in staccato fashion over geologic time. The Cassini-Huygens mission will initiate the detailed exploration of Titan in 2004, and this fall NASA solicited mission concepts for post Cassini-Huygens missions to Titan. A focus group on the astrobiological exploration of Titan has been founded by the NASA Astrobiology Institute under the leadership of the author. It will provide science rationales from an astrobiological perspective on the future exploration of Titan, i.e. beyond Cassini-Huygens, through electronic discussions and workshops. Early results of the Focus Group will be described in this talk.

URL: http://www.nai.arc.nasa.gov/institute/focus_groups.cfm

B52A MCC: Level 2 Friday 1330h

An Ecohydrological Perspective on Woody Plant Encroachment in Semiarid Regions II Posters *(joint with H)*

Presiding: **R L Scott,** USDA Agricultural Research Service**; D Breshears,** Los Alamos National Laboratory

B

B52A-1021 1330h POSTER

The Progression of Shrub Encroachment Into a Desert Grassland in Southern New Mexico from 1936-2003

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Woody plant encroachment into arid and semiarid grass-dominated landscapes has been noted in many parts of the Southwestern United States. This shrub advance has been observed on both the USDA-ARS Jornada Experimental Range (JER) and the adjacent New Mexico State University Chihuahuan Desert Rangeland Research Center (CDRRC) in southern New Mexico using varying ground survey techniques extending back to 1858. These two experimental ranges have also been imaged numerous times using aerial photography (and recently with high resolution commercial satellites) starting with USDA flights in the 1930's. Since 1936, thirty-seven separate aerial photography missions have been flown over parts of JER/CDRRC. Because rangeland remediation treatments are common in the Jornada Basin, it is difficult to find areas where no treatments, especially herbicide applications, have been employed to arrest the shrub advance. Aerial photographs were analyzed over Pasture 2 on the CDRRC where no herbicides or other treatments had been applied. There are 22 separate overflight dates covering Pasture 2 from 1936 to 2003. The aerial photos were scanned and digitized to analyze the amount of grass cover and its change over 60+ years. Despite encountering numerous difficulties in analyzing a greatly varying aerial photo data set (including varying resolutions, spectral intervals, moisture conditions, time of year of observation, and appearance of grass cover), the aerial photos provide an invaluable historic record. The grass cover obtained from remote sensing data in Pasture 2 is compared with the less frequent conventional vegetation ground surveys. The changing amounts of grass cover with time are related to various outside factors such as persistent drought periods. The rate of shrub advance across Pasture 2 has a direct influence on changes in the water, carbon, and energy cycles of these arid lands.

B52A-1022 1330h POSTER

Bush Encroachment and Soil Biochemistry: Controls and Feedbacks in Kalahari Rangelands

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