marsh, and lacustrine. Periodic floods remobilize primary ore minerals and secondary minerals from upstream tailings (primarily oxyhydroxides, sulfides and carbonates). The bedload in the lower valley is a reducing environment and acts as a sink for detrital carbonates and sulfides moving downstream. In addition, authigenic/biogenic Fe, Pb and Zn sulfides and phosphates are common in bedload sediments near the sediment/water interface. Flood redistribution of oxide, sulfide and carbonate phases results in periodic contaminant recharge generating a complex system of metal dissolution, mobilization, migration and precipitation. In levee environments, authigenic sulfides from flood scouring are quickly oxidized resulting in development of oxide coated grain surfaces. Stability of detrital minerals on the levee is variable depending on sediment permeability, grain size and mineralogy resulting in a complex stratigraphy of oxide zones mottled with zones dominated by detrital and authigenic carbonate and sulfide phases. Marshes subjected to periodic subaerial exposure/flooding are even more complex and dominated by authigenic and biogenic mineralization. Lacustrine environments are dominated by nanocrystalline inorganic and biogenic sulfide minerals in the upper third of the contaminated sediment column with increasing amounts of silt sized detrital sulfides (especially sphalerite) closer to the premining surface.

In pH-neutral subenvironments within the wetlands and lateral lakes of the lower Coeur d'Alene River Valley, microbial fixation plays a critical role in sequestering metals. Complex metal oxyhydroxide phases provided via flood recharge to river edge, marsh and lacustrine environments rapidly dissolve upon encountering anoxic conditions. Microbial activity is extremely effective in removing heavy metals from the water column, producing a nanocrystalline biofilm substrate characterized by ZnS (sphalerite) and non-stoichiometric PbS, FeS, and mixed metal sulfides. These solid phases are inherently unstable, and the sequestered metals become readily available through changes in redox or pH conditions, particularly dam-controlled annual fluctuations in base level, or during removal by bottom-feeding aquatic water fowl. The recognition of the inherent complexity and instability of microbially produced sulfidic material in a pH-neutral environment has important implications for remediation efforts utilizing wetland filtration methods.

B32C MC: 135 Wednesday 1330h

Biological Mineralization: Early and Extreme Environments II *(joint with OS, P, PP, MR)*

Presiding: **P M Dove,** Virginia Polytechnic Institute and State University**; J J DeYoreo,** Lawrence Livermore National Laboratory

B32C-01 1330h INVITED

Detection of Bacterial Magnetofossils with Ferromagnetic Resonance and Rock Magnetic Techniques

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Intracellular biomineralization of magnetite is a biochemical process used by members of the Bacteria, Protist, and Animal kingdoms, and the fossil remains of this process on Earth (termed magnetofossils) have been documented in sediments as old as the 2 Byr Gunflint Chert. Magnetofossils 4 Byr old have also been reported from carbonates in the Martian meteorite ALH84001; if this interpretation is correct, they represent the oldest evidence for life yet found.

Past techniques for identification of bacterial magnetofossils have relied on the use of particle extraction and high-resolution electron microscopy (HRTEM). Because these techniques are time-consuming and fairly complex, they are not appropriate for screening large volumes of sediments on Earth and could not be used remotely on a Martian lander. For this reason, we have been testing a variety of ferromagnetic resonance and low-temperature rock magnetic techniques to determine if they are capable of identifying correctly rock samples known to contain abundant magnetofossils. An instrument capable of making such a determination, if deployed on the Martian surface, could be extraordinarily valuable for selecting samples for return to Earth. Several features of the ferromagnetic resonance (FMR) spectra have signatures only displayed by pure samples of magnetite from the magnetotactic bacteria, and from samples known to contain abundant magnetofossils. These unique features apparently arise from the elongated shape and narrow size distribution of the single-domain magnetite produced by these bacteria. Preliminary results from ALH84001 carbonates also have these features. We are also currently obtaining FMR spectra and low-temperature rock magnetic data on samples of Archean and Early Proterozoic sediments from Australia to search for older evidence of intracellular magnetite biomineralization on Earth.

B32C-02 1345h

MINERAL BIONIZATION - SURFACE CHEMICAL MODELING OF THE EMERGENCE OF LIFE

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The earliest stages in entering an RNA-world require natural mechanisms that are capable of selective concentration of simple aldehydes from dilute solution in the environment (4), furthermore phosphorylation of the sequestered aldehydes (2) and their catalytic condensation to form, selectively, tetrose- (threose) or pentose- (ribose) phosphate (3); the latter representing the R in RNA.

A variety of common positively charged sheet structure minerals (mixed valence double layer metal hydroxide minerals such as hydrotalcite and green rust) have proven to be remarkably capable of performing these crucial tasks under simplified natural conditions (1). These prebiotic model reactions have demonstrated plausible closure of the gap, previously thought to preclude the natural formation of nucleoside phosphates, the backbone components of the information carrying genetic material.

Pioneering research by other workers (5) has demonstrated the feasibility of necessary further steps in the chain toward functional RNA; mineral (montmorillonite) catalyzed oligomerization of nucleotides, the formation of complementary RNA strands (6) and the enzymatic activity of RNA (ribozymes). These contributions have placed the initially conjectural concept of an initial RNA-world on an experimental footing.

Remaining problems include the initial transfer of information to spontaneously forming RNA, sufficient to convey biofunctionallity (7). Also in this central problem mineral surface interactions may be speculated to play a natural role; a question that is open to experimental verification.

References.

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B32C-03 1400h

Genomic Analysis of the Archaeon Ferroplasma acidarmanus: New Insights Into the Evolution of Arsenic Resistance

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Arsenic resistance allows microbes to live in As-rich solutions and in proximity to As-bearing minerals and thus, to impact dissolution and precipitation reactions. As-resistance is a characteristic of both Bacteria and Archaea. In some cases, it is conferred by the acquisition of a plasmid, in other instances the genes are located on the chromosome. Through analysis of newly acquired genomic data for the highly arsenic-resistant, iron-oxidizing extreme acidophile Ferroplasma acidarmanus and genomic data for other organisms we can gain insight into the mechanisms, origin, and evolution of genes that confer arsenic resistance. The deduced protein sequences of all known arsenic resistance genes were compiled from genomic and protein databases. Sequence alignments and phylogenic analyses were performed. Comparisons of arsenite efflux pump (ArsB) and 16S rDNA phylogenies indicated a parallel evolutionary history for the two genes. Results indicate that the As(III) efflux pump was present in the ancestor common to the Bacterial and Archaeal domains. This pump, conferring resistance to arsenite, was probably important to early life living in metal-rich environments. Previous work has shown that the gene encoding for ArsA, an ATPase that increases the efficiency of arsenic efflux, clearly arose via gene duplication. Ferroplasma and related Thermoplasmales group organisms contain a pre-duplication subunit of uncertain function. ArsA phylogeny shows two separate and distinct lines of evolution for the chromosomal- and plasmid-based proteins. This study provides the first evidence of metal resistance developing early in the evolution of life and gives new insights into the evolutionary history of the arsenic resistance proteins.

B32C-04 1415h

Ancient bacterial diversity in mid-Cretaceous black shale: DNA records of oceanic euxinic paleoenvironmnets

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A record of the history of the planet Earth is hidden in the subsurface biosphere, like the annual rings of an old tree. From limited evidences retrieved from underground, one can infer the geographical, geological and biological events that occurred throughout Earthś history. Biosphere in oceanic subseafloor and terrestrial subsurface environment has been already recognized as the biggest microbial world. Recent progress in approaching deep biosphere revealed that numerable microbial populations were consistently present in the drilling core samples and aquifers recovered from deep subsurface environment. However, the microbial community structures and the relationship between their habitats and geological events have been poorly proved. Molecular phylogenetic analyses have been becoming powerful tool for investigating the naturally occurring microbial communities. Using a combination of culture independent molecular phylogenetic analyses, we sought to recapture the indigenous microbial community of ancient oceanic habitats recovered from a continental drilled core of black shale deposited 100 million years ago.
We recovered the drilled core sample of black shale from the continental margin at Serre des Castets, the southern part of France. The recovered black shale contained one phosphate-accumulated strata, defined as a part of the mid-Cretaceous OAE (Oceanic Anoxic Evnets). Indigenous DNA was extracted from the several axis parts of the core, then bacterial ribosomal RNA genes (rDNA) was amplified by PCR. The molecular approaches such as the terminal-restriction fragment length polymorphism (T-RFLP) fingerprinting analysis, phylotype analysis of rDNA clone libraries and the phylogenetic analysis of representative rDNA sequences revealed that the genetic signals from mid-Cretaceous black shale were almost similar to bacterial habitats at deep-seafloor sediments. Furthermore, a number of rDNA clone within the delta-subclass (sulfur-reducing bacteria) and epsilon subclass (sulfur-oxidizing bacteria) of Proteobacteria class was prominent at the phosphate rich OAE strata. The redox-front type rDNA structure of oceanic bacterial habitats are observed at the euxinic water discharging sites such as the deep-sea cold seep and hydrothermal vent in present oceanic environments. These genetic rDNA signatures probably associated with the microbial habitats occurring at 100 million years ago, serves as potential geomicrobiological evidence reflecting novel records of the oceanic paleoenvironment in the Cretaceous period.

URL: http://www.jamstec.go.jp

B32C-05 1430h

Ubiquity of Deep-Sea Hydrothermal Vent Archaea in the Global Subsurface Biosphere

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Recent microbiological surveys of terrestrial and oceanic subsurface biosphere have revealed that sizable microbial populations are present in the global subsurface environments. However, little is known about the community structure, the genetic diversity and the distribution pattern of the subsurface bacteria and archaea since these surveys are mainly dependent on microscopic observations and conventional cultivation techniques. Culture-independent, molecular phylogenetic techniques are now applied to explore microbial communities in various subsurface environments such as underground mines, subterrestrial rocks, continental and ocean oil reservoirs, subseafloor pelagic sediments and methane hydrates, and subvent microbial ecosystems. It becomes apparent that unique archaeal components are commonly present in these subsurface microbial habitats whereas archaea are always less abundant than bacteria. Most frequently recovered genetic signatures are of hyperthermophiles Thermococcus and extreme halophiles Haloarcula members. Unexpected ubiquity of them even in non-extreme, subsurface environments may represent the great mass potential of probably dormant extremophilic archaea in the global subsurface biosphere. Archaeal populations in deep-sea hydrothermal vents and the subvent environments might serve as sources of the dormant extremophiles, the silent majority of archaea. It seems likely therefore that the global and local ocean hydrothermal activities persistently have a great impact on the formation of subsurface microbial communities and the distribution of subsurface microorganisms. In the KR01-09 cruise which was named ?geomicrobiological investigation of subseafloor biosphere associated with deep-sea hydrothermal activity in the Okinawa Trough?, active populations of hyperthermophilic archaea Thermococcus were detected from non-hydrothermal subseafloor sediments. Their viability was likely correlated with the distance and the duration from the deep-sea hydrothermal vent activities. It will be discussed how the extremophilic archaea are propagated in the global subsurface biosphere.

B32C-06 1445h

Biological Origin of Micro-laminated Calcium Carbonate Deposits on Antarctic Rock Surfaces

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We have observed and sampled patchy encrustations of calcium carbonate on rock surfaces in East and West Antarctica. Individual disk-like deposits are up to 1 cm across and a few mm thick, but in places coalesce to form more extensive, colloform coatings. We have observed these deposits on substrates of granite, sandstone, and schist. Their distribution appears similar to that of Antarctic lichens and endolithic algae, extending up to ca. 1000m elevation, but has no consistent relationship to snow drifts, solar radiation, or prevailing winds. The morphology and position of the deposits are distinct from sub-glacial carbonate precipitates. In Marie Byrd Land, the encrustations occur on the surfaces exposed by deglaciation within the past 5000 yrs, and the sample from East Antarctica contains live C-14 (M. Mabin, pers. comm.), suggesting a possible biological origin

Electron microprobe and SEM examination of cross-sectioned specimens reveals micron-scale layering of predominantly calcium carbonate, but with a number of bright laminae in SEM images, believed to be calcium fluoride. Sections closely resemble desert varnish in micro-morphology, though not in mineralogy. Isotopic analysis of an organic carbon extract (as opposed to C from the CaCO3 itself) gave a delta C-13 PDB value of -23.3 per mil, similar to values expected in carbon of biological origin. However, we have no proof yet that the carbon analyzed was produced by organisms within the encrustation, rather than being entrapped during an inorganic precipitation process. To investigate the possible biological origin of this material, we attempted to sequence the 16S segment of rRNA in the organic extract, but have not yet completed successful PCR replication. We are continuing attempts to isolate and analyze the pertinent genetic material.

The micro-morphology, strongly negative delta C-13 and presence of live C-14 suggest a biological process for precipitation of these calcium carbonate deposits. We hope to be able to test this in future by comparing extracted genetic material with that from known psychrophilic bacteria. If this Antarctic material proves to be biological in origin, it may yield insights into the adaptation of organisms to conditions of extreme cold, aridity and UV exposure on Earth, or elsewhere in the Solar System.

B32C-07 1500h

Biologically-Induced Mineralization by the Endolithic Lichen *Verrucaria rubrocincta* Breuss in the Sonoran Desert

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Verrucaria rubrocincta is an endolithic lichen that inhabits exposed caliche in southwestern Arizona. It has developed a survival strategy against the high photon fluxes, aridity, and temperature extremes of the Sonoran Desert. The lichen occurs within the surface of caliche plates. *Verrucaria rubrocincta* -inhabited caliche can be distinguished from uninhabited substrate by the abundance of reddish-black fruiting bodies protruding through the rock surface. The lichen invades the rock from the edges. It grows beneath a 50 to 150 μmsurface precipitate of fine-grained calcite (micrite). Below the micrite is the upper medulla, ca. 120 μmthick, characterized by an abundance of algal cells. Fungal hyphae penetrate up to 1 cm into the caliche. The micrite layer is dominated by calcite with minor quantities of weddellite ($CaC_2O_4.H_2O$), and detrital quartz. Ca-oxalates are absent in the unaltered caliche. The micrite is enriched in ^{13}C ($\delta^{13}C = 8.1$) relative to the underlying caliche ($\delta^{13}C = 0.0$). It is therefore ca. 5 per mil enriched in ^{13}C relative to calcite in isotopic equilibrium with atmospheric CO_2, indicating that the light carbon is fractionated into organic material hence leaving heavy CO_2 to form carbonate. The heavy ^{13}C enrichment suggests that the micrite layer is not strictly a biological precipitate but a biologically-induced fractionation with light CO_2 extracted by the organism leaving a residual heavy CO_2 to form the micrite. Our observations suggest that the endolithic growth of the lichen results from two different processes: 1) Dissolution and mechanical weathering of the caliche by the fungal hyphae, and 2) precipitation of a protective surface layer of micrite. The lichen thus simultaneously dissolves the caliche substrate and biomineralizes a micrite surface. Our field observations suggest the *Verrucaria*-inhabited substrate weathers at a similar rate as uninhabited caliche.

B32C-08 1515h

Organic Sulfur Gas Production in Sulfidic Caves

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Lower Kane Cave, Big Horn Basin, WY, permits access to an environment where anaerobic sulfide-rich groundwater meets the aerobic vadose zone. At this interface microorganisms thrive on diverse metabolic pathways including autotrophic sulfur oxidation, sulfate reduction, and aerobic heterotrophy. Springs introduce groundwater rich in H_2S to the cave where it both degasses into the cave atmosphere and is used by chemautotrophic sulfur oxidizing bacteria in the cave spring and stream habitat. The cave atmosphere in the immediate vicinity of the springs has elevated levels of CO_2, H_2S and methane, mirroring the higher concentration of H_2S and methane in the spring water. The high CO_2 concentrations are attenuated toward the two main sources of fresh air, the cave entrance and breathing holes at the rear of the cave.

Conventional toxic gas monitors permit estimations of H_2S concentrations, but they have severe cross sensitivity with other reduced sulfur gases, and thus are inadequate for characterization of sulfur cave gases. However employment of a field-based GC revealed elevated concentrations of carbonyl sulfide in cave atmosphere. Cultures of microorganisms collected from the cave optimized for enriching fermenters and autotrophic and heterophic sulfate reducing bacteria each produced carbonyl sulfide suggesting a biogenic in origin of the COS in addition to H_2S. Enrichment cultures also produced methanethiol (methyl mercaptan) and an additional as yet undetermined volatile organic sulfur compound. In culture, the organo-sulfur compounds were less abundant than H_2S, whereas in the cave atmosphere the organo-sulfur compounds were the dominant sulfur gases. Thus, these organo-sulfur gases may prove to be important sources of both reduced sulfur and organic carbon to microorganisms living on the cave wall in a subaerial habitat. Moreover groundwater has not yet been recognized as a source of sulfur gases to the atmosphere, but with the abundance of sulfidic groundwater, this environment may prove to be important to the global sulfur cycle and its influence of the global radiation budget.

B32D MC: 135 Wednesday 1600h

Carl Sagan Lecture

Presiding: **D M McKnight,** INSTAAR, Univ of Colorado

B32D-01 1600h

Mars, Panspermia, and the Origin of Life: Did it begin on Earth, Mars, or Somewhere Else?

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There is no abstract available for this presentation.

B41A MC: 122 Thursday 0830h

Water, Energy, and Carbon Cycles in Terrestrial Systems: Local-Scale Observations Through Fluxnet and Other Micrometeorological Tower Sites I *(joint with H)*

Presiding: **L Gu,** University of California at Berkeley**; D Baldocchi,** University of California, Berkeley**; S W Running,** University of Montana**; R Leuning,** CSIRO Land and Water**; R Valentini,** University of Tuscia

B41A-01 0830h

FLUXNET: Distribution of a Global Network of Eddy-Covariance Flux Towers and their Role in Validating Models and Remote Sensing Products

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Currently the global network called FLUXNET consists of over 150 eddy-covariance flux-tower systems, with most flux towers operating continuously for 4 years or longer. FLUXNET (see http://daac.ornl.gov/fluxnet/) provides scientific coordination and access to consistent flux data to support global carbon cycle science. The FLUXNET database contains carbon, water vapor, sensible heat, momentum, and radiation flux measurements with associated ancillary and value-added data products. Towers are located in temperate conifer and broadleaf forests, tropical and boreal forests, crops, grasslands, chaparral, wetlands, and tundra on five continents. An analysis of the distribution of towers in the conterminous United States shows that most environmental conditions are well represented by the set of 35 towers. The combined climate, soils, and topography for each tower was compared to clusters representing groupings of similar climate, soils, and topography across the United States. The comparison identified a few combinations that were not well represented. Flux data are being used to validate ecosystem model outputs and to provide information for validating remote sensing based products, including surface temperature, reflectance, vegetation indices, LAI, FPAR, and PSN (photosynthesis) derived from the MODIS sensor on the Terra satellite. Estimates of the selected products for 8-day periods for 1-km pixels in the immediate vicinity of the flux tower are being posted on the FLUXNET Web site