insight into the stratospheric chemical perturbation induced by large volcanic eruptions. Three events with very different dynamics that are well preserved in South Poles snow and ice have been sampled. The total isotopic analysis of the volcanic sulfate (δ^{18}O, δ^{17}O, δ^{34}S, δ^{33}S, and δ^{36}S) of Mount Pinatubo (June 1991, 15Tg SO_2), Cerro Hudson (August 1991, 2 Tg SO_2) and the 1259 AD unknown event (320 Tg SO_2), along with the backgrounds surrounding these events have been carried out.

No $\Delta\ ^{33}$S was found for the background and Cerro Hudson sulfate samples, but they both show similar $\Delta\ ^{17}$O of 2.7 and 2.2 $^{o}/_{oo}$, respectively. In contrast, both the Pinatubo and the 1259 AD produced sulfate with a $\Delta\ ^{33}$S (0.60 and – 0.42 $^{o}/_{oo}$, respectively). However and surprisingly, sulfate generated by the Pinatubo eruption have a much higher $\Delta\ ^{17}$O (4.7 $^{o}/_{oo}$) relative to the 1259 AD, (0.8 $^{o}/_{oo}$) despite the fact that both were well injected into the stratosphere. A tentative explanation on how similar eruptions can induce a sulfur MIF, and $\Delta\ ^{17}$O with such differing values will be given in the currently accepted isotope theoretical framework and the use of a photochemical model.

B62A MCC: 134 Saturday 1330h

Terran and Synthetic Environments: Where in the Solar System Can They Take Us? *(joint with OS, P)*

Presiding: **J Baross,** University of Washington**; M Meyer,** NASA Office of Space Science

B62A-01 1335h INVITED

Titan and the Origin of Life

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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 interest or potential are Europa, Titan, and comets. Europa may contain organic compounds in a subcrustal liquid water environment, but this assumption will not be tested until after 2010. Titan is of interest because it is known to generate suites of hydrocarbons and nitriles in its stratosphere, which then 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 liquid water, may proceed on the surface in staccato fashion over geologic time. Titan, in summary, provides us with a planet-sized laboratory for testing the synthesis of organic compounds in a nearly neutral redox environment, over large spatial scales, both with and without liquid water. These natural chemical experiments could be ongoing today, and the products of such experiments in localized regions of elevated temperatures would be well preserved under the ambient 95 K temperatures and high atmospheric densities that shield the surface from destructive radiation. The Cassini-Huygens mission will make a complete inventory of the surface from a variety of remote sensing and in situ techniques, over the time period late 2004 through late 2008. In support of future exploration of Titan beyond Cassini-Huygens, the NASA Astrobiology Institute has initiated a Titan Focus Group, whose operation and initial results will be discussed.

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

B62A-02 1350h INVITED

Alternative Life Styles for Extraterrestrial Chemists

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Life is no more (and no less) than a special type of organic chemistry, one that combines a frequently encountered property of organic molecules (the ability to undergo spontaneous chemical transformation) with an uncommon property (the ability to direct the synthesis of self-copies) in a way that allows new molecular features arising through spontaneous transformation to themselves be copied. Any chemical system having this combination will undergo natural selection, evolving in structure to replicate faster through more efficient use of molecular resources and energy. Axiomatically, life cannot exist in an environment at thermodynamic equilibrium. If it were, by the second law of thermodynamics, no net chemical transformation would be possible. Beyond this constraint, it is difficult to define environmental conditions or chemical structures necessary for life. Water is certainly not required for a chemical system to copy itself; in the laboratory, nonaqueous environments appear to support this behavior better. Chemical transformations that might support energy and chemical metabolisms are known in environments as acidic as the aerosols in the atmosphere of Venus, or as basic as the atmosphere of Jupiter. Laboratory experiments with analogs of the nucleic acids, proteins, sugars, and lipids show that the particular molecular structures found in terrean life need not be universal, even those life in water near neutral pH. Indeed, while both water and biological macromolecules are commonly regarded as essential for terrean-like life, water destroys terrean biological macromolecules.

These chemical realities create a complex decision environment as NASA attempts to design instrumentation carried by missions, select places in the solar system to send them, and chose laboratory studies on Earth to provide their scientific support. This talk will review a hierarchy of chemical possibilities and constraints that start with the chemistry of terrean life, and takes steps towards weird life. We shall consider alternative amino acid building blocks for proteins, alternative building blocks for nucleic acids, alternative structural features of genetic and catalytic molecules, alternative nucleophile-electrophile pairs to support metabolism, non-polar reaction modes that might support metabolism, non-terrean pH (< 0, > 14) and solvent environments for life, extreme temperature ranges (especially sub zero Celsius) low temperature ranges, alternative thermodynamic design for metabolic pathways, alternative dimensionalities of genetic and catalytic molecules, and approaches for isolating life other than conventional cell structures. Each of these discussions will combine experimental and theoretical information. The first involves organic chemical synthesis that creates new forms of chemical matter to ask "What if?" and "Why not?" questions. The second draws on a century of literature in physical organic chemistry to formulate general constraints on the structure and transformation of organic matter to provide constraints on possible Darwinian chemistries in the galaxy.

B62A-03 1405h INVITED

The Ultramafic-Hosted Lost City Hydrothermal Field: Clues in the Search for Life Elsewhere in the Solar System?

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The recent discovery of the peridotite-hosted Lost City Hydrothermal Field (LCHF) raises the possibility that such systems are prevalent not only on Earth, but that similar systems may have existed, or currently exist, elsewhere in the solar system. The LCHF, which rests atop the Atlantis massif at 30N on the Mid-Atlantic Ridge, is unlike any previously known hydrothermal field: 1) it is located on 1.5 my-old crust, nearly 15 km west of the spreading axis; 2) it hosts at least 30 active and inactive carbonate-brucite chimneys that tower up to 60 m above the seafloor; 3) the venting pinnacles appear to be the surface expression of warm (40-75C), high pH (9-10) fluids emanating from fault zones that tap a region of active serpentinization in the underlying peridotites; and 5) hydrothermal flow is facilitated by exothermic serpentinization reactions at depth. The diffusely venting fluids support dense and diverse communities of mesophilic to hyperthermophilic organisms that may include sulfur-, methane- and hydrogen-oxidizers.

The Lost City Field may represent our closest analogue to hydrothermal systems operative during early Earth where ultramafic rocks were predominant. The reducing conditions associated with serpentinization of ultramafic material may be similar to those present in the Hadean ocean (4.5-3.9 Gyr) and it has been suggested that such high-pH systems were a requirement for the emergence of life on the seafloor. Model calculations based on thermodynamic considerations and experimental studies suggest that synthesis of numerous organic compounds is favored during mixing of warm, serpentinite-derived, high-pH, reducing fluids with cool, oxygenated seawater. Dissolved hydrogen, present in hydrothermal fluids due to reaction of olivine and other iron-bearing minerals with fluids, provides the reduction potential and the thermodynamic drive for organic synthesis. Significant quantities of methane and hydrogen produced during serpentinization reactions form critical nutrients for microbial communities within submarine systems.

Many of the carbonate-veined serpentinites (ophicalcites) and breccias that underlie the LCVF are similar to those known from ancient ophiolites, including Archean (>3000 m.y. old) examples. These types of assemblages may represent a linkage to hydrothermal and possibly biological activity at the time of the oldest known life on Earth. The warm, organic- and volatile-enriched environment present within the porous interior of ancient hydrothermal deposits may have been extremely suitable habitats for the emergence of thermophilic or hyperthermophilic anaerobic organisms capable of utilizing methane and hydrogen.

The LCVF may provide new insights into the search for life elsewhere in the solar system. This hydrothermal field highlights the fact that volcanic heat is not a requirement for fluid flow, but that a large component of energy to drive flow may come directly from exothermic reactions as fluids interact with ultramafic material. It also shows that hydrothermal systems, and the life that they support, can exist far away from major spreading centers. Collectively, these observations indicate that water-bearing planets, chondritic in composition, that have experienced tectonic processes are potential sites for Lost City type systems and life.

B62A-04 1420h

Direct Observations Of Microbial Activity At Extreme Pressures

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Microbial communities adapt to a wide range of pressures, temperatures, salinities, pH, and oxidation states. Although, significant attention has been focused on the effects of high and low temperature on physiology, there is some evidence that elevated pressure may also manifest interesting effects on cellular physiology, such as enzyme inactivation, cell-membrane breach, and suppression of protein interactions with various substrates. However, exactly how these factors affect intact cells is not well understood. In this study, we have adapted diamond anvil cells to explore the effects of high pressure on microbial life. We used the rate of microbial formate oxidation as a probe of metabolic viability. The utilization of formate by microorganisms is a fundamental metabolic process in anaerobic environments. We monitored in-situ microbial formate oxidation via molecular spectroscopy for *Shewanella oneidensis* strain MR1 and *Escherichia coli* strain MG1655 at high pressures (68 to 1060 MPa). At pressures of 1200 to 1600 MPa, living bacteria resided in fluid inclusions in ice-VI crystals and continued to be viable upon subsequent release to ambient pressures (0.1 MPa). Furthermore, direct microscopic observations indicate that these cells maintain their ability for cellular division upon decompression from such high pressures. Evidence of microbial viability and activity at these extreme pressures expands by an order of magnitude the range of conditions representing the habitable zone in the solar system. These results imply that pressure may not be a significant impediment to life. The maximum pressure explored in this work is equivalent to a depth of ~ 50 km below Earths crust, or ~ 160 km in a hypothetical ocean. The pressures encountered at the depths of thick ice caps and deep crustal subsurface may not be a limiting factor for the existence of life. This suggests that deep (water/ice) layers of Europa, Callisto, or Ganymede, subduction zones on Earth, and the polar ice caps of Mars might provide viable settings for life unhindered by the high pressures.

B62A-05 1455h

The Witwatersrand Deep Microbiology Project: Observations Pertaining to Hypothetical Microbial Ecosytems Beneath the Surface of Mars

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The geochemical, isotopic and microbial attributes of over 100 water and gas samples taken from South African deep mines in at 0.8 to 3.3 km depth, temperatures up to 60oC and over 40,000 km2 area have been analyzed. Noble gas isotopic estimates of the subsurface residence times for some of the deepest, most saline water samples from the 2.7 Ga Ventersdorp Group volcanics range up to 400 Myr. H2 and hydrocarbon concentrations are quite high in these samples and cellular concentrations quite low (1000 cells/ml). SO4 concentrations can also be quite high and are isotopically enriched by microbial fractionation. Mass balance considerations and theoretical arguments suggest that H2 and sulfate may have originated from radiolytic reactions with water and sulfide. Isotopic data indicate that the hydrocarbons formed by abiotic reduction of inorganic carbon. The 16SrDNA sequences of environmental samples and the microbial enrichments are dominated by heterotrophic, sulfate and metal reducing bacteria with few autotrophs. These results suggest that: 1) abiogenic synthesis or organic carbon may obviate the need for an autotrophic community supporting a heterotrophic one; 2) H2, He and CH4 may be abundant in the Martian cryosphere; and 3) radiolysis can lower the freezing point of brines by increasing their salinity and bivalent anion concentration.

B62A-06 1510h

Dress Warm, Focus on the Fluids and Be Patient: Studying Ice Habitats and Constraints on Microbial Life at Low Temperatures

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Studies of low-temperature environments on Earth can help guide exploration of other planetary environments that are of interest in the search for potential traces of life (or absence thereof) elsewhere in the solar system. Ice environments and habitats on Earth range from terrestrial permafrost to the polar ice caps or floating sea and lake ice. Despite the complexity of these different environments, the physical chemistry of unfrozen water - generally deemed a prerequisite for active life - and the pore microstructure can help in describing and categorizing different types of ice from an astrobiological perspective.

In northern Alaska, we have studied constraints on microbial life in two types of ice, sea and lake ice, that bracket the range of availability of liquid water and solid surfaces. The latter have been found to be important for bacterial activity at very low temperatures, with active bacterial cells in sea ice documented down to temperatures of -20 C. Standard and epi-fluorescence microscopy adapted to studies at very low in-situ temperatures can help in locating individual cells and yield insight into the distribution of liquids, organisms and potential biomarkers in icy habitats. As the distribution of fluids, organisms and impurities is governed by segregation processes on different spatial scales, such work can aid in the planning of exploration campaigns (e.g., on Mars and Europa) and help guide the identification of intensive-study sites or the design of sampling equipment.

Apart from such specific lessons, three major conclusions emerge: (1) The use of improved or new methods continues to push the envelope for activity of microbial life to lower temperatures, boding well for planetary exploration campaigns. (2) While the thermodynamics of water activity in ice may constitute an ultimate boundary, the low-temperature kinetic constraints currently present a significant challenge for the study of low-temperature life processes. This may call for dedicated laboratory studies of cells maintained in vitro or in synthetic low-temperature ice environments. (3) Ice-fluid systems lend themselves readily to studies of synthetic environments, extending all the way out to conditions likely to be encountered in Martian or Europan settings.

B62A-07 1525h INVITED

Europa: Prospects for Life and for the Origin of Life

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Life as we know it could exist on Europa as we know it. That is, our current understanding of Europa seems to allow the existence of certain microorganisms that we know on Earth. Europa almost certainly has an ocean of liquid water and a supply of biogenic elements sufficient for a biosphere. Potential sources of free energy that could fuel a europan microbial ecosystem can be identified, but several of them depend on the extent to which Europas crust communicates with its ocean (Chyba and Hand, Science 292, 2026-2027 (2001); Chyba and Phillips, Origins of Life 32, 47-68 (2002)). This communication seems possible in both thin-ice and thick-ice scenarios, but it may require another mission before we are confident about which geophysical models are in fact correct.

The prospects for the origin of life on Europa are much trickier to evaluate. If the origin of life had to occur under the present ice cover, the abundant energy of the Suns ultraviolet light would not have been available to drive prebiotic chemistry. Some current models for the origin of life on Earth would seem not to be troubled by this, but recent experimental results suggest that the concentration of salts in the early terrestrial ocean could have been an important impediment to the polymerization of early organic monomers and the formation of prebiotic vesiclesimplying that life may have originated in freshwater environments on early Earth. The implications of these results for the origin of life in Europas ocean will be discussed.

URL: http://www.seti.org

B62B MCC: 134 Saturday 1600h

Sagan Lecture *(joint with P)*

Presiding: **S Trumbore,** University of California, Irvine

B62B-01 1600h

From Genomes to Life to the Planet and the Cosmos: In Appreciation of Carl Sagan

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The Earth and life have evolved in tandem; It is impossible to separate the two over most of geologic time. Geological and geochemical processes create and define the conditions necessary for life. In turn, life has shaped geological processes in ways that are understood, and ways that are not yet understood.

The reciprocal interaction between the planet and its inhabitants has driven changes in the molecules, metabolisms, and morphologies of terrean organisms. Today, with the emergence of complete genome sequences and tools from molecular biology, we are now better able, more than ever before, to tell stories of how we came to be, on a planet and in a cosmos that has both nourished us and (from time to time) threatened to extinguish us.

The stories to be told in this talk combine information from the geological and paleontological records, analysis of genome sequence data, and experiments that resurrect ancient, extinct life forms for study in the laboratory. The talk will emphasize the non-recurring, progressive feature of the dance between Earth and Life. We will show how the emergence of humans was influenced by the environment, and how humans placed their irreversible mark on the genes of organisms that they touched. We will show how the global environmental crisis that began in the Oligocene irreversibly transformed the plant and animal kingdoms. We will proceed back to the Cretaceous, to explore how plants and dinosaurs influenced each other, and the genomes of surviving fungus and flies. From there we will go to the Jurassic, as the first placental mammals reconstructed their reproductive systems in response to the planetary changes. We will ask how cosmic events, from asteroids to supernova, may have influenced life on Earth. We will ask what consequential features of life that we see around us might be unique to Earth, and what features might be found universally in life elsewhere.

The talk will also review some of the methodological issues associated with converting just-so stories into experimentally testable hypotheses. We will emphasize the "present day backwards" strategy, where tools developed for the recent past can be tested in a regime where testing is possible, and then applied to more ancient events. We also will show how a natural history approach to the analysis of human biology has practical value, offering approaches to treating human diseases as diverse as obesity and cancer, by understanding these diseases in the context of the history through which they have passed.