B22A-0145 1330h POSTER

The Biological Nature of Geochemical Proxies: algal symbionts affect coral skeletal chemistry

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The strontium-calcium ratio (Sr/Ca) of reef coral skeleton is an important ocean temperature proxy that has been used to address some particularly controversial climate change issues. However, the paleothermometer has sometimes proven unreliable and there are indications that the temperature-dependence of Sr/Ca in coral aragonite is linked to the photosynthetic activity of algal symbionts (zooxanthellae) in coral tissue. We examined the effect of algal symbiosis on skeletal chemistry using Astrangia danae, a small colonial temperate scleractinian that occurs naturally with and without zooxanthellae. Live symbiotic (deep brown) and asymbiotic (white) colonies of similar size were collected in Woods Hole where water temperatures fluctuate seasonally between -2°C and 23°C. We used a microbeam technique (Secondary Ion Mass Spectrometry) and a 30 micron diameter sampling beam to construct high-resolution Sr/Ca profiles, 2500 microns long, down the growth axes of the outer calical (thecal) walls. Profiles generated from co-occuring symbiotic and asymbiotic colonies are remarkably different despite their exposure to identical water temperatures. Symbiotic coral Sr/Ca displays four large-amplitude annual cycles with high values in the winter, low values in the summer and a temperature dependence similar to that of tropical reef corals. By comparison, Sr/Ca profiles constructed from asymbiotic coral skeleton display little variability over the same time period. Asymbiont Sr/Ca is relatively insensitive to the enormous temperature changes experienced over the year; the temperature dependence is similar to that of nighttime skeletal deposits in tropical reef corals and non-biological aragonite precipitates. We propose that the large variations in skeletal Sr/Ca observed in all symbiont-hosting coral species are not related to SST variability per se but are driven primarily by large seasonal variations in skeletal calcification rate associated with symbiont photosynthesis. Our model provides a framework for understanding the role of biology in determining coral skeletal chemistry and an explanation for anomalous Sr/Ca-based paleotemperature derivations.

B22B MC: Hall D Tuesday 1330h

Long Term Survival of Geologically Sequestered Microorganisms: Biogeological Conditions and Implications *(joint with P)*

Presiding: **R Holt,** The University of Mississippi**; T Kieft,** New Mexico Tech**; D Powers,** Consulting Geologist

B22B-0146 1330h POSTER

Limit for the Survivability from Potassium Decay of Bacterial Spores in Halite Fluid Inclusions

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Vreeland *et al.*[1] recently claimed to have isolated and cultured a viable spore forming halotolerant bacterium from a 250 million year old brine inclusion present in a salt crystal from the Salado formation. An earlier report suggested that viable bacterial spores could be revived from samples obtained from insects entombed in 25-40 million year old Dominican amber[2]. On the bases of these reports, Parkes[3] raised the question of whether bacterial spores under some conditions might be effectively immortal.

Sporulation, induced by an adverse change in the environmental conditions, is able to stabilize the DNA primarily against hydrolytic depurination for extended periods of time[4]. However, the organism is still exposed to ionizing radiation from the environment. Dormant spores have a reduced sensitivity to ionizing radiation per se, but unlike active organisms are unable to repair DNA damage encountered during long-term exposure to ionizing radiation. The accumulated damage may overwhelm any repair mechanism that starts in the early stage of spore germination[5].

The main radionuclide in a halite fluid inclusion is ^{40}K, which accounts for 0.0117% of natural potassium. ^{40}K decays via beta decay to ^{40}Ca and via electron capture to ^{40}Ar, releasing a primary gamma-ray. About 83.3 % of the beta's emitted are in the energy range of 0.3-1.3 MeV.

We assume 7 g/l for an average concentration of natural potassium in a halite fluid inclusion, which means that the amount of ^{40}K in a 10 μl fluid inclusion is 8.19 ng. We have chosen a 10 μ l because this volume is typical of that used to obtain chemical data and in the attempts to extract bacteria. Less than a percent of the gamma decay energy is absorbed in a fluid inclusion of 10 μ l. Thus, we will not take the gamma decay energy into account for the further discussion. Almost all the beta energy is absorbed in the fluid inclusion. The total decay energy absorbed in a time period of 250 million years is about 87 kGy.

The most DNA damage-tolerant organism known today is Deinococcus radiodurans. The viability of *D. radiodurans* falls to undetectable levels[6] at about 18 kGy. The survival curve of dry *Bacillus megaterium* spores shows a 4-log reduction at about 8-10 kGy[7,8]. These numbers can be compared to the 87 kGy in the case for a Permian fluid inclusion. The ability to tolerate radiation induced damage lies in the efficient repair mechanism employed by *D. radiodurans*, which is not operative in a dormant spore. It would thus be highly unusual for a bacterial spore to survive intact for 100's of millions of years unless these bacteria are extremely radiation tolerant.

Based on these considerations and without active DNA repair mechanisms, viability of a dormant bacterial spore and the survival of viable genetic material over extended periods of geologic time is probably limited by exposure to natural background radiation.

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B22B-0147 1330h POSTER

Recycling Sequestered Bacteria Through Natural Hydrogeologic Processes

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A report of viable Permian-age bacteria (sp. 2-9-3) preserved in salt has been contested on grounds that the revived bacteria are not genetically different enough from modern bacteria to be that old. Mutation rates are assumed to apply over geologic periods to this bacterium, but this hypothesis is not testable without reference to geologically old organisms. Recycling organisms by natural processes could complicate such schemes.

The Permian Salado Formation at the bacterium-sampling site has been protected well from natural sources of contamination. Elsewhere the unit has been subject to dissolution for at least 10-20 Ma potentially liberating trapped bacteria. Where the formation approaches the surface, it becomes much thinner and develops a solution residue on top of undissolved salt. At Nash Draw, a shallow valley is developing by solution and collapse, brine collects on and in the residue and flows as groundwater toward the Pecos River. Brine springs discharge into the Pecos River, which joins the Rio Grande, and ultimately reaches the Caribbean. Unless the sample from the Salado contained the only viable bacterium in the formation, 2-9-3 has likely been reintroduced into the biosphere frequently, if not nearly continuously, over millions of years. For such situations, unraveling the genetic relationships and mutation history will be more complicated than currently assumed.

B22B-0148 1330h POSTER

Deep-Subterranean Microbial Habitats in the Hishikari Epithermal Gold Mine: Active Thermophilic Microbial Communities and Endolithic Ancient Microbial Relicts.

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Deep subterranean microbial community structures in an epithermal gold-silver deposit, Hishikari gold mine, southern part of Kyusyu Japan, were evaluated through the combined use of enrichment culture methods and culture-independent molecular surveys. The geologic setting of the Hishikari deposit is composed of three lithologies; basement oceanic sediments of the Cretaceous Shimanto Supergroup, Quaternary andesites, and auriferous quartz vein. We studied the drilled core rock of these, and the geothermal hot waters from the basement aquifers collected by means of the dewatering system located at the deepest level in the mining sites. Culture-independent molecular phylogenetic analyses of PCR-amplified ribosomal DNA (rDNA) recovered from drilled cores suggested that the deep-sea oceanic microbial communities were present as ancient indigenous relicts confined in the Shimanto basement. On the other hand, genetic signals of active thermophilic microbial communities, mainly consisting of thermophilic hydrogen-oxidizer within Aquificales, thermophilic methanotroph within g-Proteobacteria and yet-uncultivated bacterium OPB37 within b-Proteobacteria, were detected with these of oceanic relicts from the subterranean geothermal hot aquifers (temp. 70-100C). Successful cultivation and FISH analyses strongly supported that these thermophilic lithotrophic microorganisms could be exactly active and they grew using geochemically produced hydrogen and methane gasses as nutrients. Based on these results, the deep-subsurface biosphere occurring in the Hishikari epithermal gold mine was delineated as endolithic ancient microbial relicts and modern habitats raising active lithotrophic thermophiles associated with the geological and geochemical features of the epithermal gold deposit.

B22B-0149 1330h POSTER

Hydrocarbon Gases in Hydrogeologically Isolated Fractures in Au Mines of the Witwatersrand Basin, South Africa: Potential Substrates for Deep Subsurface Microorganisms

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Deep subsurface microbial communities are the subject of a multi-disciplinary study in the Witwatersrand Basin, of South Africa. Hydrocarbon and H2 gases found in the mines were investigated to determine their origin and role as potential substrates for long-term survival of microorganisms. Large quantities of gas (up to 30L/min/borehole) are released when sealed fracture systems are opened by exploration drilling. Two

compositionally and isotopically distinct types of gases have been identified in the Witwatersrand and Ventersdorp sequences beneath the Transvaal Sequence. Group 1 gases correspond to major fault intersections within the Witwatersrand Supergroup and contain methane that is isotopically depleted in 13C (-43.5 to -59.4 permil), and enriched in 2H (-162 to -214 permil) consistent with either bacteriogenic and/or thermogenic orgins. Group 2 gases discharges in association with saline fissure waters from fractures within the andesitic lava of the Ventersdorp Sequence. They are isotopically depleted in 2H (to -327 permil), and enriched in 13C (to -34.4 permil) falling outside the conventional bacteriogenic or thermogenic isotopic fields. Group 2 gases do however resemble those reported from Precambrian Shield mines in Canada for which an abiogenic origin has been suggested. Differences in the microbial communities associated with these different gas types and geologic strata are under investigation.

B22C MC: Hall D Tuesday 1330h

Carbon, Climate Change, and Disturbance in Northern Forest Ecosystems II *(joint with GC)*

Presiding: **M Apps,** Natural Resources Canada**; A D McGuire,** University of Alaska Fairbanks**; J Caspersen,** Princeton University

B22C-0150 1330h POSTER

Climate-Induced Changes in the Chemical Characteristics of Natural Organic Matter at a Small Freshwater Wetland

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This study investigated the spatiotemporal variability in dissolved organic carbon concentration (DOC), natural organic matter (NOM) weight average molecular weight (Mw), and absorptivity at 280 nm (e280, an estimator of aromaticity) at McDonalds Branch, a first-order stream that is a fen wetland. When ground-water discharge to the stream was predominant, the DOC, the Mw, and the e280 were all relatively low. When soil porewater was more important, not only was the DOC higher, but also the Mw and e280. Hence, the contribution of soil pore water relative to ground water controlled not only the concentration but also the average physicochemical characteristics of the NOM.

Results from this small watershed study provide insight into climatic effects on surface-water NOM characteristics in a small freshwater fen. Low-flow periods resulted in lower Mw, more aliphatic NOM derived primarily from ground-water discharge to the stream whereas higher flow periods resulted in a higher Mw(by 150-500 Da), more aromatic downstream surface-water NOM pool. Hence, during future summer drought periods, as suggested by climate-change models for much of North America, surface-water NOM likely will be lower molecular weight, more aliphatic, and more hydrophilic with lesser metal binding and HOC uptake abilities, along with decreased ability to attenuate UV radiation.

B22C-0151 1330h POSTER

Fire-derived Char-Black Carbon in Siberian Scots Pine Forests - Stocks and Dynamics

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Siberian Scots pine forests comprise the largest part (37 %) of West Siberian forests. Natural fires occur frequently, producing thermally-altered organic matter (char-black carbon, CBC). CBC is considered to resist degradation and accumulate in soils, due to its molecular structure. Thus, CBC may be an important long-term sink for photosynthetically fixed atmospheric carbon dioxide, and play an important role in carbon sequestration of boreal soils. Presently, there are, however, only few studies on CBC stability in soils and none on boreal ecosystems.

To assess the role of CBC in carbon sequestration of boreal forests, we addressed the following questions: How much soil organic carbon (SOC) do natural fires convert to CBC? How do fires (both stand replacing and surface fires) affect SOC and CBC stocks and soil development for 0 to 200 years?

We investigated sandy podzolic soils (Dystrustepts) under monotypic pristine Siberian Scots pine (Pinus sylvestris) forests in Western Siberia near river Yenesei (60 °43'N, 89 °08'E). To measure CBC conversion we sampled five replicates of (un-)burnt forest floor immediately after fire. To assess carbon stocks and soil development, we sampled a chronosequence (0-400 years after stand replacing fire), also including different fire regimes (surface fires every 25-40 years). SOC was quantified with elemental analyzer, CBC via gas-chromatography / atomic emission detector using benzenepolycarboxylic acids as molecular markers, and parameters of soil development via ion coupled plasma mass spectroscopy.

Fire converted 0.7 % of the SOC in the forest floor to CBC. CBC accounted for 1.5 to 3.4 % of SOC stocks (forest floor and 1 m mineral soil), and is mainly located in the forest floor. In the forest floor, SOC stocks increased with time since stand replacing fire, except when surface fires reduced stocks. For CBC, however, no such trend could be observed. Mineral SOC stocks were smaller than those in the forest floor, and followed a typical podzolic pattern 6 and 160 years after fire, but were larger 33 to 96 years after fire. TOC stocks below 0.8 m were always similar, contributing small amounts. As a result, CBC does so not seem to accumulate in soils under boreal forests to a larger extent. The fate of CBC (e.g. chemical degradation, particular or colloidal transport) remains an open question.

B22C-0152 1330h POSTER

The Modeling of Active Layer Thickness and Permafrost Temperature Regime (past, present and future) within East-Siberian Transect, using GIS.

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The active layer is a thin layer, which thaws every summer, stays frozen for the rest of the year and acts like an insulating layer between the permafrost and atmosphere. The active layer is an important component of the northern ecosystem and has a considerable influence on carbon cycle. The contents of free and bounded water and temperature regime within the active layer are primary factors that quantify the magnitudes of summer and winter respiration and carbon fluxes, which are the results of microbial and other biological activities. Any changes in the active layer have a direct impact on the temperature regime and consequently on dynamics of permafrost and permafrost stability. In turn, the active layer thickness and temperature regime depend mostly on combination of climatic parameters such as mean annual air temperature and annual air temperatures amplitude, let alone the mean annual snow cover thickness, soils thermal properties, and moisture content. Our study area encompasses the East-Siberian transect, which is centered on the 135° meridian and expanded from 70 degrees Northern Latitude (N.L.) to 60 degrees N.L. The ecosystem and the permafrost within the transect are especially vulnerable to the positive changes in active layer thickness and temperature. Permafrost in East Siberia contains significant amount of ice in the form of segregated ice, ice wedges and buried layers of ice. If summer thawing will reach the ice horizon, or if the temperature in the permafrost rises, so that the process of permafrost thawing will start, then major changes in the ecosystem may occur; for example, wetlands or grasslands may gradually replace the boreal forest. The purpose of this work is to show the spatial extent and dynamics of the active layer thickness and its influence on permafrost stability for different scenarios of climate changes, with the means of ArcView software. In order to calculate active layer thickness and permafrost temperature, we chose Kudryavtsev's equations. The major parameters in these equations are mean annual air temperature and seasonal air amplitudes. Also, mean annual snow thickness, thermophysical properties of the soils (heat capacity and thermal conductivity) are taking into account. By using different sources, such as: publications, maps and digital maps, the layers representing geology, snow thickness and vegetation have been created. The program for active layer thickness calculations works with a grid of cell dimension 0.5x0.5 degrees, which covers the entire area of the transect. All climatic and thermophysical parameters are set for each grid cell. The program uses GIS Avenue code, which takes input data from all necessary layers, calculates active layer thickness and temperature of permafrost for each grid cell, and then performs the interpolation between grid cells to show the output in the form of digital maps that cover the area of the transect. Several scenarios have been considered: natural dynamics of snow thickness and air temperatures and dynamics with applied trend of global warming. We used data obtained by real-time modeling of air temperatures and snow thickness as input. The results for the natural dynamics case were compared with actual measurements and the results of numerical simulation, for four sites: Chabody3, Chabody8, Yakutsk and Tiksi. For all four sites the detailed information about climate, soil temperature distribution and thermophysical properties is available. Such a comparison will validate the use of Kudryavtsev equations for forecasting the dynamics of the active layer and mean annual temperatures of permafrost.

B22C-0153 1330h POSTER

Boreal Forest Fires and Lightning

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A forest fire experiment called FROSTFIRE (1999) was carried out in the taiga zone of Alaska, U.S.A. in July 8-15, 1999 and was completed successfully.

The first author joined FROSTFIRE as a fire scientist. FROSTFIRE has provided good opportunities to clarify the conditions of boreal forest fires by conducting field research of the vegetation, thunderstorm observations before the fire, and observation of large forest fire areas, etc.

This paper mainly discusses the ignition probability of forest fires by lightning by analyzing lightning data and forest fire data of AFS (Alaska Fire Service) and observation results. Thunderstorm observations by video camera from the Poker Flat top recorded multiple lightning strikes. After the storm, three plumes from forest fires were observed in different directions. The annual, daily, and local ignition probabilities by lightning are calculated and discussed.

Next, the starting mechanism of lightning-caused fires occurring in boreal forests is discussed by considering characteristics of dry thunderstorms.

Finally, a preliminary ignition experiment using impulse voltage generator was carried out to know ignition mechanism by lightning. Experimental results are also briefly discussed.

B22C-0154 1330h POSTER

Interpretation of Remotely Sensed Data in Alaskan tundra-taiga zone based on componential spectral characteristics

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We measured and modeled spectral reflectance factors to the nadir view on an Alaskan north-south transect from tundra to taiga in order to understand possibilities of spectral decomposition of tundra, and forest floors of tundra-taiga transition and forest floors of taiga. Vegetation distribution in tundra zone indicate distribution of methane emission from tundra as well as active layer thickness and vegetation change with climate change. These distributions relate terrestrial carbon budget in tundra. Classification of taiga forest according to forest age after the last fire and to forest viability as well as tree species contributes to carbon, heat, and water budgets. In tundra-taiga transition zone, vegetation classification concerns with both methane emission and forest fire influence. Radiative transfer modeling gives a basis for interpreting remotely sensed data on taiga and tundra vegetation. Tundra vegetation and taiga forest floors are composed by small patch of plant species. Some plant species may be spectrally separated, and others may not. Spectral decomposition of plant species corresponding different methane emission shows usefulness of remote sensing for methane emission distribution mapping. In this research, we showed spectral reflectance characteristics of vegetation components such as leaves, forest floors, and tundra vegetation in Alaskan tundra, Alaskan taiga, and explained the vegetation reflectance characteristics based on the component characteristics and a radiative transfer model.