B12C MC: Hall D Monday 1330h

Geologic Influences on Biogeochemical Cycles I *(joint with H)*

Presiding: **J Neff,** U.S. Geological Survey**; J M Holloway,** U.S. Geological Survey

B12C-0129 1330h POSTER

Plant and Microbial Dynamics Along Gradients in Soil Texture and Eolian Dust Accumulation in the Colorado Plateau.

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The canyonlands region of Southwest Utah is made up of soils with a range of textures and chemistries. We have identified three transects of soils that range from high sand to high silt content in order to examine the effect of soil texture and chemistry on plant and microbial dynamics. We also take advantage of new techniques that allow separation of eolian-derived fine soil particles from in situ weathering and erosion products to evaluate the role that dust deposition plays in the chemistry of desert ecosystems. We present results from several studies along these transects including measurements of hydrologic fluxes and comparisons of soil and plant chemistry. We have also carried out experiments on microbial and plant processes along gradients with the aim of linking biological dynamics to variation in surficial chemistry and hydrology. Our initial results indicate that water holding capacity is substantially higher in silts vs. sandy soils but that increases in water availability in sands have a disproportionate effect on soil respiration rates with a more rapid and prolonged response to wetting in sands vs. silts. Comparisons of plant and soil chemistry suggest that plants and soils show similar increases in Mg and Mn concentrations along our textural transects. In addition, native bunch grasses growing in high eolian silt environments show elevated P content in their tissues and may reflect the input of P in eolian deposition. With these studies, we are beginning to build a mechanistic framework for understanding the relationship between eolian deposition and ecosystem response in arid environments.

B12C-0130 1330h POSTER

Eolian Dust in Colorado Plateau Soils: Linking Landscape and Ecosystem Evolution

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Eolian dust in soils and surficial deposits influences landscape evolution and ecosystem dynamics of drylands. Fundamental knowledge is lacking, however, about the nutrient contributions from eolian dust to arid-land biotic systems compared to those from weathered bedrock. Mineralogic, chemical, textural, and geochronologic investigations of soils and surficial deposits of the semi-arid central Colorado Plateau are designed to (1) recognize eolian dust, (2) ascertain the late Quaternary geomorphic history of the landscape, (3) identify past and modern dust sources, and (4) along with monitoring of climate and wind-erosion parameters, assess land-surface vulnerability to wind erosion in response to climate and land-use history. Sandy soil on isolated surfaces and grasslands in the Canyonlands region of the Colorado Plateau differs greatly in mineralogic and chemical composition from associated bedrock, mainly Paleozoic and Mesozoic eolian sandstone. Moderately high detrital magnetite content, absent in local bedrock, is the primary evidence for the presence of eolian dust in these soils. Magnetic susceptibility (MS, a measure of magnetite content) correlates with the silt content in undisturbed soils and suggests that eolian dust content of the soil is typically 10-30 percent. Relative to detritus from local bedrock, atmospheric inputs have increased many plant-essential nutrients (P, K, Mg, Na, Ca, Fe, Cu, Mn, and Mo) in soils. Both labile and refractory P contents increase with increasing silt content; the increase in labile P indicates that eolian dust has supplied plant-available P to the ecosystem.

Changing landscapes of contemporary grass uplands are recorded by variations (likely spanning the past several thousand yrs) in eolian dust, pollen assemblages, and the presence of buried soils within 2 m of the modern surface. Sr isotopic ratios (0.7092-0.7095) of acetic-acid-leached samples, from OSL-dated and correlative surficial deposits, are dominated by atmospheric Sr inputs. Highest values correspond with a buried soil, suggesting a link between surface stability (wetter climate?) and a slight, temporary enhancement of chemical weathering of detritus, whether eolian dust or derived from local bedrock. Some textural, magnetic, and chemical parameters (e.g., silt content, MS, P) are strongly correlated in samples of sandy soil (0-10 cm depth) from an undisturbed setting. The same parameters in similar deposits of previously and currently grazed settings exhibit more poorly defined relations with lower silt content and MS. Thus, certain land-use activities may have fundamentally altered the distribution of nutrients and other soil characteristics, perhaps by wind erosion of fine-grained soil materials.

B12C-0131 1330h POSTER

Phosphorus in Soils of a Cool-desert Ecosystem: Dust Inputs and Land-use Effects on Erosion, Colorado Plateau, USA.

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Phosphorus (P) contents indicate that aeolian dust is supplying P to soils and vegetation in the Colorado Plateau. We determined P fractions for dust inputs, surface soils, and bedrock at Canyonlands N.P., Utah. Measurement sites were chosen on the basis of livestock grazing history; one site has never been grazed, another site had grazing until 30 years ago, and a third site is grazed currently. Using a modified Hedley sequential fractionation, we partitioned dust, soils, and bedrock into biological and geochemical pools, as well as labile and refractory pools. At the never-grazed site, total P in surface soil (0-10 cm) is half that of dust, whereas total P in bedrock samples is only one third that of dust. The contrast is more striking for labile P and biological P; modern dust samples have 6x and 9x more, respectively, than soil samples. Resin extractable P as a proportion of labile P in dust may be a useful indicator of grazing perturbance. Dust from the currently grazed site has most total P (1551 ugP/g soil), followed by dust from the previously grazed site (1120 ugP/g soil), and by dust from the never-grazed site (737 ugP/g soil), suggesting wind erosion of P. Slope transects on grazed vs. ungrazed surfaces suggest that P and other plant nutrients have been eroded from grazed upper slopes, because near-surface samples (0-10 cm depth) show increases in these elements downslope, whereas deeper samples (30-50 cm) show little change.

B12C-0132 1330h POSTER

Influence of Nitrogen-Fixing Biological Soil Crusts on Nitrogen Gas Fluxes (NO, N_2O + N_2) in Canyonlands National Park, Utah

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Biological soil crusts (also known as microbiotic, microphytic, or cryptobiotic crusts) are communities of fungi, lichens, cyanobacteria, and mosses that colonize soil surfaces in arid and semi-arid ecosystems. Associated cyanobacteria and bacteria species within biological soil crusts fix atmospheric N_2 and are an important source of nitrogen [N] in desert ecosystems. On the Colorado Plateau, estimates of N fixation rates by biological soil crusts are high and range from 4-37 kg N/ha/yr depending on biological crust composition. However estimates of N accumulation within these ecosystems are generally $<$ 1 kg N/ha/yr, leading to considerable uncertainties regarding the fate of the fixed N by biological soil crusts and the dominant N loss pathways in desert ecosystems.

To examine whether N gas losses increase with increasing N fixation potential of the biological crust community, we measured nitric oxide [NO] emissions and denitrification (nitrous oxide [N_2O] + dinitrogen [N_2]) from three biological soil crust communities. Coloration in biological soil crusts is a good indicator of crust community composition and N fixation rates which generally increase with increasing darkness of the biological soil crust. Based on coloration we chose light, medium and dark crusts to represent different N fixation potentials. NO fluxes were measured in the field during June and July 2001. We simulated a 5 mm rainfall event and measured NO fluxes from field chambers over several hours. In July only, we measured N_2O fluxes on soil cores maintained at field capacity. Immediately after N_2O fluxes were measured from soil cores, we injected 10 KPa C_2H_2 into each chamber. C_2H_2 at 10 KPa blocks the reduction of N_2O to N_2 in the denitrification process while simultaneously inhibiting nitrification.

NO fluxes from dark crusts were 4 fold higher relative to light crusts, and 2 fold higher relative to medium crusts in June. By July the pattern was not as strong but dark crusts still had 42% greater NO fluxes compared to light and medium crusts. NO fluxes from the three crust types were in the range of 3-25 ng NO-N/m^2 /s. We detected no N_2O fluxes from soil cores. However, N_2O +N2 fluxes were significantly higher in light crusts relative to medium crusts ([mean ng N_2O + N_2 -N/m^2 /s] Dark=23, Medium=13, Light=32). Our hypothesis of increasing NO losses with increasing N fixation potential by biological soil crusts was supported by our data. However the influence of biological soil crusts on N_2O + N_2 fluxes or denitrification is less clear. Coupling N gas loss data to climate data we estimate that 0.01-0.37 kg N/ha/yr may be lost via nitrification and denitrification pathways during the summer months.

B12C-0133 1330h POSTER

The effect of topography and rock type on soil cation contents and stream solute and phosphorus concentrations of streams in the southwestern Brazilian Amazon basin.

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Topography plays an important role in determining soil properties, stream solute concentrations and landscape denudation rates. Stallard (1985) suggested that catchment denudation rates should depend on soil thickness. Areas with low slopes are limited by the rate of transport of sediment, and typically contain thick soils that prevent interaction of stream waters with underlying bedrock [Stallard 1985]. Steep areas typically have thin soils, but a lower hydrologic residence time that may prevent soil water from coming into thermodynamic equilibrium with the soil-rock complex. In a survey of streams in the Brazilian Amazon basin, Biggs et al. (2001) found that stream solute concentrations correlate with soil cation contents in the humid tropics, but the mechanism underlying the correlation has not been determined.

We combine chemical analyses of water samples from 40 different streams with soil surveys, geology maps, and a 100m resolution DEM to examine

the relationship between topography, rock type, soil cation contents, and stream solute concentrations in the Brazilian Amazon state of Rondnia. The basins are all more than 60% forested at the time of stream sampling and lie on granite-gneiss rocks, tertiary sediments, or sandstone. The catchment-averaged slope correlates positively with both soil cation contents and stream concentrations of P, Na, Ca, Mg, K, Si, ANC, and pH. Though we have no data about the relationship between soil depth and average slope, we assume an inverse correlation, so the data demonstrates that thick soils yield lower solute concentrations. Stream concentrations of Ca, Mg, ANC and pH reach a maximum at intermediate average slopes (3 degrees), suggesting that denudation rates may increase with slope up to a maximum, when the catchment becomes limited by the weathering rate of the basement rock. Catchments on mica-schists or mafic rocks have low average slopes and higher concentrations of Ca, Mg, Si, ANC, and pH than catchments on granite-gneiss, tertiary sediments or sandstone.

B12C-0134 1330h POSTER

Carbon Dioxide Effects on Soil-Chemical Weathering: Laboratory Column Studies with Saprolite Materials

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Column leaching experiments have evaluated effects of sulfuric, nitric, and hydrochloric acids on chemical weathering in soils and rocks. In contrast, research to investigate effects of carbonic acid on chemical weathering is notably absent. Given that rising aboveground CO_2 may increase photosynthesis and may enhance soil respiration, elevated soil CO_2 and carbonic acid may enhance cation leaching via a combination of cation exchange and mineral dissolution. Column leaching studies were conducted using deep soil materials of the southern Piedmont (Enon, Tarrus, and Cecil series soils). Deionized water equilibrated with CO_2 (at 1, 10, and 100%) was used as eluent and soluble products from exchangeable and mineral-bound sources were estimated. Results demonstrated that elevated CO_2 accelerated cation release by both cation exchange and mineral dissolution. Highest cation release rates were from the Enon C horizon, a smectite-rich material from diabase with 23cmol(+)/kg ECEC and 98% base saturation. Lowest releases were from the Cecil Cr horizon, a kaolin-micaceous material derived from granitic gneiss with 1.2cmol(+)/kg ECEC and 40% B.S. Cation exchange was the predominant source of cations released, although mineral dissolution occurred in all three soils in response to elevated CO_2. Remarkably, upto 35% of the cations released by the Cecil Cr horizon was attributed to weathering dissolution, probably from micaceous minerals.

B12C-0135 1330h POSTER

Mineral weathering sources of C, N, and S in an alpine/subalpine, granitic basin

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Inorganic C, N, and S from atmospheric deposition and mineral weathering play important roles in the acid-base balance of alpine/subalpine, granitic basins. N and S sources generally contribute acidity to ecosystems, whereas most inorganic C compounds (eg., carbonate) neutralize acidity. Although atmospheric deposition of inorganic C, N, and S has been reasonably well quantified, mineral weathering contributions of these elements have not because of complex mineral weathering processes and variable bedrock chemistry. In this study, release of C, N, and S through bedrock weathering was quantified for Loch Vale, an alpine/subalpine, granitic basin in Rocky Mountain National Park, Colorado, using mass-balance calculations and measurements of C, N, and S concentrations in the bedrock. The mass-balance calculations indicate that plagioclase, biotite, chlorite, and calcite were the dominant minerals weathered, whereas microcline and pyrite contributed minor amounts of solutes to the watershed. Total moles of mineral weathered were summed and converted to mass of mineral weathered to obtain a chemical weathering rate of 68 kg ha^{-1} yr^{-1}.

Very fine-grained calcite ($CaCO_3$) present in the bedrock in microfractures and along grain boundaries is the main source of inorganic C in the bedrock. Release of C from bedrock occurs as fresh bedrock surfaces containing calcite are exposed via physical weathering; highly soluble calcite is rapidly depleted from weathering surfaces. Thus, the release of C by calcite weathering is controlled by physical weathering rather than chemical weathering . A physical weathering rate was calculated by dividing the calcite weathering rate obtained from mass-balance calculations (6.9 kg ha^{-1} yr^{-1}) by the C release rate expected solely from chemical weathering of the bedrock. The C release rate from chemical weathering was calculated as the chemical weathering rate multiplied by the concentration of $CaCO_3$ in the bedrock (0.059 $\pm$ 0.125%, n = 25). The physical weathering rate was estimated to be 52 times greater than the chemical weathering rate of the bedrock.

Release of N and S from bedrock likely is controlled by a combination of chemical and physical weathering, with the relative importance of the two processes dependent on the weathering kinetics of the minerals in which N and S reside. N resides mostly in biotite as NH_4^+, which substitutes for K^+ in the mineral lattice. S occurs in pyrite as an integral part of the mineral structure (FeS_2). The weathering kinetics of these minerals are intermediate between calcite and quartz or microcline. The upper bound of N and S release from bedrock was calculated by assuming that physical weathering is the limiting factor controlling release of N and S from bedrock. The N concentration in bedrock (0.0014 $\pm$ 0.0006%, n = 12) was multiplied by the physical weathering rate to obtain an N release rate of 0.09 to 0.24 kg ha^{-1} yr^{-1}. Similar calculations for S (average concentration = 0.0027 $\pm$ 0.0044%, n = 9) yield a S release rate of 0.0 to 0.83 kg ha^{-1} yr^{-1}. In comparison, atmospheric deposition contributions of N and S in Rocky Mountain National Park averaged 4.4 and 6.2 kg ha^{-1} yr^{-1}, respectively, during 1996-98. These results indicate that bedrock sources of N and S account for less than 5% of the N and less than 13% of the S input to the Loch Vale ecosystem.

B12C-0136 1330h POSTER

The Effect of Localized Lithologic Variation on Stream Water Chemistry and Nutrient Cycling in the Hoh Rain Forest, Washington

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Nitrogen in rocks has not often been considered in nutrient cycling studies. In geologically complex regions such as the western Olympic Peninsula, lithologic variations too small to be mapped can have important effects on stream water chemistry and nutrient cycling. Stream water nitrogen concentrations among tributaries of the Hoh River, Washington vary in response to the proportion of the channel composed of siltstone. Siltstone contains approximately 2.5 times as much nitrogen (1230 mg N kg-1) as sandstone (470 mg N kg-1). This translates into pools of 3250 and 1050 kg N ha-1, respectively, in the upper 20 cm of unweathered rock and represents a significant portion of nitrogen storage in the region. In addition, the presence of a large pool of nitrogen may predispose the forest and aquatic systems to sensitivity to atmospheric nitrogen inputs, which is evidenced by the rapid alteration of stream chemistry engendered by a period of increased nitrate deposition in the mid-1990s.

B12C-0137 1330h POSTER

Biogeochemistry of Forest Catchments in the Czech Republic With Contrasting Lithology Under Conditions of Acidic Deposition in 1992-2001

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Biogeochemical patterns were studied in two forest catchments in the Czech Republic, one underlain by leucogranite (Lysina), the other by serpentinite (Pluhuv Bor). The objective was to compare and contrast element pools and fluxes in the catchments with similar topography, vegetation, climate, and atmospheric deposition, but different lithology. High weathering rates at the serpentinite site resulted in Mg as the dominant cation on the soil exchange complex and in drainage water. Other base cations (Ca, K, Na) showed relatively low concentrations and outflow in streamwater. The catchment exhibited high base saturation in mineral soil, and near neutral soil and stream pH, despite elevated inputs of acidic deposition. Slow growth of Norway spruce (Picea abies) may be caused by K deficiency, Mg oversupply and/or Ni toxicity. In contrast, the leucogranite site showed low concentrations of exchangeable base cations on the soil exchange complex and in streamwater. Soil and drainage water were highly impacted by acidic deposition. Soil pH was acidic throughout the soil profile, and the base saturation of the mineral soil was low. Supplies of base cations from atmospheric deposition and soil processes were smaller than inputs of sulfate on an equivalence basis, resulting in low pH and high concentrations of Al in drainage water. Needle yellowing in Norway spruce was possibly the result of Mg deficiency. These two catchments served as valuable end-members of ecosystem sensitivity to severe levels of acidic deposition.

B12C-0138 1330h POSTER

Aluminum Chemistry in two Czech Catchments with Contrasting Geology Subject to Acidic Atmospheric Deposition in 1992-1998

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Acidification of soil by acidic deposition and enhanced leaching of Al from soil may contribute to forest dieback in Central Europe. The two Czech catchments we studied are situated 7 km apart, within a large Norway spruce (Picea abies) forest. The catchments, Lysina (LYS) and Pluhuv Bor (PLB), have contrasting bedrock (leucogranite vs. serpentinite). Organically-bound Al is an important pool of potentially labile soil Al, while amorphous Al is relatively minor at both sites. Total pools of reactive Al, as represented by oxalate extractable Al, were only 5% (LYS) or 2% (PLB) of the total Al in the upper 40 cm of the mineral soil. However, the pools of reactive Al were 98% (LYS) or 87% (PLB) of the total Al in the litter horizons. Acidic inputs coupled with a slow rate of base cation supply from weathering of the leucogranite, has resulted in mobilization of soil Al pools at LYS. Indeed, total Al concentrations in stream water at LYS are among the highest values reported (discharge-weighted average 53 umol/L, max. 81 umol/L). Inorganic monomeric Al was the dominant fraction (68

B12C-0139 1330h POSTER

The Strontium Isotope Composition of Fossil Hackberry Seed Carbonate and Tooth Enamel as a Potential Record of Soil Erosion

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The Edwards Plateau in central Texas has experienced significant soil erosion since the Last Glacial Maximum. In contrast to the thin soils that mantle the Cretaceous limestone bedrock of the modern Edwards Plateau, Quaternary fossils of burrowing mammals contained within several central Texas cave deposits suggest soil cover was much thicker in the latest Pleistocene and early Holocene. As the landscape is denuded, the Cretaceous limestone bedrock is exhumed and becomes a more important source of exchangeable Sr to the soils. Therefore, the Sr isotope composition of the soil and organisms deriving nutrients from the soil, such as plants and herbivores, should become more like the Sr isotope composition of the bedrock as erosion continues. Because the marine limestone bedrock has a lower $^{87}Sr/^{86}Sr$ value than the soil, the exchangeable soil Sr should evolve to lower $^{87}Sr/^{86}Sr$ values through time resulting in a decrease in the $^{87}Sr/^{86}Sr$ of plants and animals deriving nutrients from the soil.

In order to test this hypothesis, terrestrial fossils from an extensively dated Quaternary deposit within Hall's Cave, Kerr County, Texas were analyzed by TIMS for $^{87}Sr/^{86}Sr$. The materials analyzed include aragonitic fossil hackberry seeds and rodent tooth enamel. Results indicate an overall decrease in the $^{87}Sr/^{86}Sr$ of fossil hackberry seed aragonite and rodent tooth enamel over the last 16,000 years, with the highest rate of decrease in the $^{87}Sr/^{86}Sr$ of fossil hackberry seeds (0.70982 to 0.70841) occurring between approximately 16,000 and 10,000 Y.B.P. This decrease in

the $^{87}Sr/^{86}Sr$ is interpreted as evidence for an increase in the proportion of bedrock-derived Sr to the soils, corresponding to a general decrease in soil thickness. An increase in aridity or an increase in the seasonality of precipitation during this time could account for the post-glacial soil erosion in central Texas. This study suggests that the $^{87}Sr/^{86}Sr$ of fossils may be a useful proxy for paleo soil depth. Additionally, when applied to central Texas cave fossils, this technique may be able to provide a better understanding of the geomorphic and environmental history of the Edwards Plateau.

B12C-0140 1330h POSTER

Oxygen Isotope Fractionations Between Dissolved Phosphate and Apatite at 22-45 ^{o}C : Effects of P:Ca Ratio and Recrystallization

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Continued expansion of the range of applications of phosphate O isotope ratios, for example, to studies of biogeochemical cycling of P and microbial P metabolism, will require full elucidation of the O isotope systematics and reaction pathways of the $PO_{4(aq)}$-organophosphate-apatite-water system within living organisms as well as in abiotic environments. Although previous studies provide many empirical determinations of the overall fractionation between biogenic phosphates (e.g., teeth, shells) and body fluids, the oxygen isotope effects of important intermediate steps, and O isotope exchange reactions involving $PO_{4(aq)}$ and water, and fractionations between $PO_{4(aq)}$ and apatite, have received little or no study.

Oxygen isotope fractionations between $PO_{4(aq)}$ and apatite have been determined in controlled experiments at 22-45 ^{o}C. $PO_{4(aq)}$ - apatite fractionations from long-term (4 yrs) room temperature experiments were ∼1 permil. Over shorter experimental run periods (1 week to 4 months), fractionations between $PO_{4(aq)}$ and apatite were initially more complex and evolved over time with progressive recrystallization of the apatite. $PO_{4(aq)}$ - apatite fractionations were observed to be influenced by the initial P:Ca ratio as well as initial precipitation rates. The implications of these experimental results for application of phosphate O isotope ratios to studies of P diagenesis, authigenic apatite precipitation, and biomineralization will be discussed.

B12C-0141 1330h POSTER

Ferroan Dolomite Mineralization by Iron-Reducing Bacteria

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We report here the in situ precipitation of a ferroan dolomite by iron-reducing bacteria. This was observed in an anaerobic groundwater on basalt chips exposed to the native microbial consortium for 3 months. The iron reducing bacteria in the aquifer rapidly colonize the basalt surface due to the presence of limiting P and Fe, and preferentially destroy this rock to gain a competitive advantage. Precipitation of ferroan dolomite is triggered by the production of alkalinity and Fe2+ from microbial respiration combined with the release of alkaline earth cations. At the cell membrane surface, the solution chemistry is apparently perturbed sufficiently to directly precipitate ferroan dolomite, making the bacterial cell a vital part of this weathering process. Observing dolomite on bacterial cell membranes from a natural aquifer is a unique observation that provides insight into biochemical cycling of metals, as well as mechanisms of bacterial entombment and fossilization. The ubiquitous nature of bacteria on and in the earth raises the possibility that bacteria participate in earth surface cycles on a fundamental level.

B12C-0142 1330h POSTER

Siderophore Adsorption to and Dissolution of Kaolinite

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This study examined the effect of the synthetic trihydroxamate siderophore, desferrioxamine mesylate (DFAM), on the dissolution of and Fe removal from an Fe-containing (∼0.1 weight %) kaolinite. Batch adsorption and dissolution experiments were conducted at pH 3, 5.5, and 7, at 25^{o} C, in the dark, to 96 hours. Adsorption was considerably stronger than previously reported on goethite (Kraemer et al., 1999, *GCA*), most probably because of differences in the surface charge properties of these two minerals. Adsorption of DFAM was weakest at pH < 5, which is the pH point of zero charge for KGa-2, and increased by several fold as pH increased to 8.

In contrast to dissolution in the simple organic ligand, oxalate, DFAM-promoted dissolution was mostly pH-independent from pH 3 to 7. Si concentrations released in the presence of DFAM remained at the levels of HNO_3 controls over this pH range. Al concentrations were greatly enhanced versus controls, most likely due at least in part to DFAM-Al complexation and enhanced solubility. Aqueous Fe concentrations were negligible at pH 3, and in controls at all 3 pH values, but were in the 10 ppb range at pH 5.5 and 7, in the presence of DFAM. These results show that micromolar amounts of Fe, sufficient for the metabolic needs of aerobic microorganisms, can be extracted from natural kaolinite by DFAM.

B12C-0143 1330h POSTER

Competitive Oxidation Kinetics and Microbial Ecology: Intermediate Sulfur Transformations in Acid Mine Drainage Environments

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Experimental studies have demonstrated that oxidation of pyrite proceeds through several intermediate sulfur species, notably elemental sulfur, thiosulfate, and polythionates (Schippers et al., 1996). However, detailed sampling and analysis of flowing waters and pore waters failed to detect intermediate sulfur species in the 5-way area of the Richmond metal sulfide deposit at the Iron Mountain Mine in northern California. Potential energy available from the oxidation of intermediate sulfur species is considerable, so microbial activity may explain absence of intermediate sulfur compounds at the site. However, the abundance of sulfur-oxidizing microorganisms in areas of active pyrite oxidation at the 5-way is generally low (Bond et al. 2000). Rapid inorganic oxidation rates may prevent microorganisms from utilizing these intermediate sulfur species, thus shaping the structure of microbial communities in acid mine drainage (AMD) environments. Rates and mechanisms of oxidation for tetrathionate and elemental sulfur have been experimentally determined. Batch and flow-through experiments have indicated very slow oxidation of elemental sulfur in inorganic solutions analogous to AMD environments. Results for tetrathionate indicate the importance of non-metabolic and inorganic processes, including surface catalysis and the generation of hydroxyl radicals. Surface catalysis occurs through trithionate on iron oxide surfaces. Hydroxyl radicals may be formed directly by microbes living in proximity to pyrite surfaces, or at pyrite surfaces undergoing wetting and drying cycles. Further experiments investigating the importance of organic compounds associated with iron-oxidizing microorganisms acting as electron transport shuttles and/or wetting agents and ab initio calculations of the electronic structure of potential reactants and intermediates are currently being performed. It is suggested that inorganic processes involved with seasonal wetting and drying of pyritic sediment and the specific types of organic compounds present may be important aspects of the transformation of sulfur species. Investigation of the kinetics of pertinent redox reactions involving intermediate sulfur species at the Iron Mountain Mine may be used as a model in understanding the nature by which specific metabolic activity is linked to environmental constraints.

B12C-0144 1330h POSTER

Phylogenetic Analysis of Microbial Populations Associated with Iron Cycling in the Piquette Mine in Tennyson, Wisconsin

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Neutrophilic iron-oxidizing microorganisms have attracted attention recently due to the geological significance of biological iron cycling and the potential for formation of iron oxide biosignatures. We have been studying an iron oxide-rich biofilm and associated groundwater located in a Mississippi Valley Type lead-zinc mine that was closed and allowed to flood about 30 years ago. The local environment appears to be at a boundary between oxic and anoxic waters. SEM and TEM analysis reveals that the bulk of the biofilm is composed of iron oxide-coated stalks and sheaths characteristic of *Leptothrix* and *Gallionella*. In addition, novel iron oxide filaments, some of which are associated with microorganisms, are found in parts of the biofilm and throughout the cloudy layer of water above. The volume of the biofilm (∼20 cm thick over sections of the tunnel floor) suggests that microorganisms are able to form large deposits of iron oxides, such as those in the geologic record, over short time scales. The conditions at this site also suggest that iron oxidation is an important biological metabolism in the subsurface.

In order to understand the diversity of iron oxidizers and their role in the microbial community, we performed a 16S rRNA phylogenetic analysis of DNA extracted from the iron oxide-rich biofilm and the surrounding water. Analysis shows that the diversity in the biofilm is high. 186 clones were screened: 90 from DNA amplified using universal primers and 96 using bacterial primers. In both cases, ∼40% of the clones possessed distinct sequences (<98% similarity). These sequences are affiliated with a variety of taxonomic groups, notably *Nitrospira* and *β-Proteobacteria* (including close relatives of *Gallionella ferruginea*), but also *Acidobacteria, Actinobacteria, Bacteriodetes, Planctomyces,* and *α-, δ-* and *γ-Proteobacteria.* The dominant physiologies apparent in this clone library are iron oxidation, nitrification, and denitrification. In addition, organisms related to iron reducers, sulfur oxidizers, sulfate reducers, methanotrophs, and methylotrophs are also present. However, many of the cloned 16S rRNA gene sequences do not match closely with cultured or previously cloned sequences, suggesting that a significant portion of the biofilm community is composed of novel organisms. The 16S rRNA clone library of the water above the biofilm is similar to the iron oxide-rich biofilm library in its diversity and dominant metabolism. These results indicate that iron oxidation is occurring in the water column as well as in the biofilm. These data also suggest that the iron and nitrogen cycles are closely coupled in this environment.

The clone libraries from the Piquette Mine have some similarities to the one produced by Stein et al. (2001) from Green Bay ferromanganous micronodules and sediments. Like the Green Bay library, *Nitrospira* and *β-Proteobacteria* are common. However, notable differences in our iron oxide-rich biofilm and cloudy water clone libraries are the higher bacterial diversity and low number of iron reducers.

B12C-0145 1330h POSTER

Multibeam Imagery Shows Extensive Iceberg Reworking of the Lower Glacier Bay, Alaska Fjord

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Multibeam imagery in lower Glacier Bay, Alaska, unveiled extensive, complex iceberg gouge patterns in the glacial marine sediment in water depths ranging from 50-100 m. Individual gouges are as much as 5 km long, a few tens of meters wide, and with several meters of relief. These gouges likely were formed no more than 160 years ago by large ice bergs that calved repeatedly as the glacier, that completely filled the fjord

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about 200 years ago, retreated up bay. Previous side-scan sonar cruises have shown some ice gouging farther up the fjord, but the wide-spread nature of the gouges in the lowermost portions of Glacier Bay, as shown by the multibeam image between Sitakaday Narrows and the fjord entrance, were unexpected. Massive icebergs with drafts to 100m calved repeatedly from the glacier, as it retreated up the fjord. The dominant gouge orientation, roughly parallel to the fjord axis, suggests the strong tidal currents of up to seven knots through Sitakaday Narrows were responsible for driving the iceberg keels across the seabed. The gouges remain unburied in this environment of high sedimentation because even though the glaciers have retreated more than 80 km up fjord from Sitakaday Narrows, the amount of sediment presently reaching the ice gouges is largely restricted to local runoff and plankton debris. In addition, the strong tidal currents through Sitakaday Narrows, effectively keep the ice-gouged fjord floor scoured clean of fine sediment. This multibeam imagery is being used in our joint study of physical and biological characteristics of benthic habitats in Glacier Bay and results will be applied to fisheries problems in south east Alaska, especially to Marine Protected Areas.

B12C-0146 1330h POSTER

A Quantitative Look at Sources and Fates of Inorganic Nutrients at Skorradalur, Iceland

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Bedrock chemistry plays an important role in shaping plant communities in areas where roots contact bedrock or water that contains nutrients derived from the bedrock. Where bedrock and soil lack certain nutrients plants must rely more on atmospheric inputs or efficient recycling-mechanisms. At Skorradalur, Iceland, the bedrock contains little K, and plant growth is particularly sensitive to fluctuations in atmospheric inputs of K.

This study examines the sources and fates of K, Mg, and Ca at 5 small catchments underlain by tholeiitic basalt at Skorradalur, Iceland. The bedrock is overlain by up to 500 cm of basaltic till which was deposited when glaciers retreated from this area between 7000 and 10000 years ago. Catchment vegetation varies from mosses and lichens to birches to mixed conifers. Samples of stream water, throughfall, precipitation, soil, and rock were collected at varying intervals between 1995 and 1998 (Moulton, West, and Berner, 2000). All samples were analyzed for major element chemistry.

Sources of nutrients were calculated as percentage of nutrients derived from atmospheric inputs and bedrock for the summer and winter seasons. Nearly all of the K originates from atmospheric input throughout the year. Relatively more Mg and Ca are supplied from the atmosphere during the summer (about 60 and 50 percent, respectively) than during the winter (about 50 and 25 percent); the remainder is supplied from bedrock.

The fate of K, Mg, and Ca within the catchments was traced using calculations of nutrient fluxes from basalt weathering, atmospheric inputs, biomass storage, and soil storage in secondary minerals. Biomass storage in living and dead tissue accounts for about 60 percent of the total K input, less than 2 percent is stored in soil, and the remainder exits in stream water. Biomass and soil storage account for about 6 and 13 percent, respectively, of the Mg and Ca inputs. These results show that plants at Skorradalur rely almost exclusively on atmospheric inputs and biomass recycling to provide K for growth.

Moulton, K.L., West, J., and Berner, R.A., 2000, Solute Flux and Mineral Mass Balance Approaches to the Quantification of Plant Effects on Silicate Weathering, American Journal of Science, v. 300, p. 539-570.

B12D MC: Hall D Monday 1330h

Assessment and Prevention of Interplanetary Biocontamination

(joint with P)

Presiding: **D Thomas,** University of Hawaii

B12D-0147 1330h POSTER

Developing Planetary Protection Technology: Microbial Diversity of the Mars Orbiter Odyssey and the Spacecraft Assembly and Encapsulation Facility II

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Sampling the surfaces of both spacecraft and their clean-room assembly facilities is crucial in monitoring the microbial burden associated with these pseudosterile, oligotrophic environments. Here, we present the results of a study in which several surface samples, retrieved from both the Mars Odyssey Spacecraft and the Kennedy Space Center (KSC) Spacecraft Assembly and Encapsulation Facility II (SAEF-II), were processed and evaluated by both molecular and traditional culture-based methods for microbial diversity. The findings of this study improve our current understanding of the microbial community structure, diversity, and dispersal in a spacecraft assembly facility, as well as physically associated with co-located spacecraft. Surfaces of 25 cm^2 (spacecraft) or 0.4 m^2 (SAEF-II) were swabbed or wiped, respectively, and were examined for total heterotrophic aerobes and sporeformers. Samples were further subjected to nucleic acid extraction, and 16S rDNA fragments were PCR amplified with eubacterial biased universal primers and cloned. Approximately 30 isolates grown by traditional culture-based techniques were included for 16S rDNA sequencing. For the most part, the population dynamics remained consistent when compared between the spacecraft and assembly facility libraries. Predominant microbes, as indicated by molecular methods, included members of the genera *Variovorax* and *Aquaspirillum*. Members of the *Mesorhizobium, Bradyrhizobium, Enterococcus, Ralstonia*, and *Bacillus* genera were also found to span the various libraries but in less abundance. Traditional culture-based techniques validated the presence of *Bacillus* and *Ralstonia*, while illuminating a larger diversity in revealing the presence of *Staphylococcus, Comamonas, Microbacterium*, and *Actinomycetales*. The bulk of these findings make sense, since species of *Ralstonia, Rhizobium, Variovorax*, and *Bacillus* are known to frequently inhabit rhizospheric environments, like that surrounding the KSC facility, and can thus easily gain way into the clean-room via mixing of surrounding air upon human entry and exit. Also, *Aquaspirillum* species are known to inhabit freshwater and brackish ponds, much like the ones at KSC. Of particular interest to the authors was the presence of *Nicotiana tabacum* chloroplast 16S rDNA in one of the spacecraft samples. The lack of tobacco farming anywhere in the vicinity of the KSC facility leads the authors to speculate that this contamination arose from human contact with the spacecraft, specifically after handling a cigarette, cigar, or other tobacco products. Overall, our findings validate the purpose of planetary protection activities, which improve our knowledge of the types of microbial burden present, and their methods of entry into spacecraft assembly facilities.

B12D-0148 1330h POSTER

Developing Planetary Protection Technology: Microbial Diversity and Radiation Resistance of Microorganisms in a Spacecraft Assembly Facility.

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Europa has attracted much attention as evidence suggests the presence of a liquid ocean beneath this Jupiter moon's frozen crust. Such an environment might be conducive to the origins of life. Since robotic exploration of Europa is being planned, it becomes crucial to prepare for bio-burden reduction of hardware assembled for Europa missions to avoid contamination of Europa's pristine environment. In this study, we examined the microbial diversity of samples collected from two flight-ready circuit boards and their assembly facility. Also, because Jupiter's strong radiation environment may be able to reduce the viable microbial contamination on flight components, we have also studied the effects of radiation on microbial communities found to be associated with the space-flight hardware and/or present in the assembly facility. Surface samples thought to be representative of considerable human contact were collected from two circuit boards and various locations within the assembly facility using polyester swabs (swab samples). Likewise, sterile wipes were used to sample a shelf above the workstation where the circuit boards were assembled and the floor of the facility (wipe samples). The swab and wipe samples were pooled separately and divided into two halves, one of which was irradiated with 1Mrad gamma radiation for 5.5 hours, the other was not irradiated. About $1.2x10^4$ and $6x10^4$ CFUs/m^2 cultivable microbes were detected in the swab and wipe samples, respectively. Radiation proved effective in inhibiting the growth of most microbes. Further characterization of the bacterial colonies observed in the irradiated swab and wipe samples is necessary to determine the degree of the radiation resistance. The16S rDNA sequence analysis of the cultivable microbes indicated that the assembly facility consists mostly of the members of actinobacteria, corynebacteria and pseudomonads. However, the swab samples that include the circuit boards were predominantly populated with Bacillus and Staphylococcus. Molecular microbial diversity was also studied by cloning the 16S rDNA PCR fragment from the samples. The non-irradiated swab samples were largely populated by species of Exiguobacter and Bacillus whereas the irradiated swab samples were dominated by Bacillus and E. coli. Radiation damage of microorganisms was also investigated by epifluorescence microscopy. In summary, our study has shown that gamma radiation can inhibit the growth of most of the cultivable microbes, but preliminary results suggest that radiation such as this has little adverse effect on the DNA molecules of these microorganisms.

B12D-0149 1330h POSTER

Developing Planetary Protection Technology: Recurrence of Hydrogen Peroxide Resistant Microbes from Spacecraft Assembly Facilities

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Hydrogen peroxide vapor is currently the sterilant-of-choice for flight hardware because it is a low-heat sterilization process suitable for use with various spacecraft components. Hydrogen peroxide is a strong oxidizing agent that produces hydroxyl free radicals (·OH) which attack essential cell components, including lipids, proteins, and DNA. Planetary protection research efforts at the Jet Propulsion Laboratory (JPL) are focused on developing cleaning and sterilization technologies for spacecraft preparation prior to launch. These efforts include research to assess the microbial diversity of spacecraft assembly areas and any extreme characteristics these microbes might possess.

Previous studies have shown that some heat-tolerant *Bacillus* species isolated from the JPL Spacecraft Assembly Facility (SAF) are resistant to recommended hydrogen peroxide vapor sterilization exposures. A *Bacillus* species, which was related to a hydrogen peroxide resistant strain, was repeatedly isolated from various locations in the JPL-SAF. This species was found in both unclassified (entrance floors, anteroom, and air-lock) and classified (class 100K) (floors, cabinet tops, and air) areas. The phylogenetic affiliation of these strains was carried out using biochemical tests and 16S rDNA sequencing. The 16S rDNA analysis showed >99% sequence similarity to *Bacillus pumilus*. In order to understand the epidemiology of these strains, a more highly evolved gene (topoisomerase II β-subunit, *gyrB*) was also sequenced. Among