

as PM 2.5, has the potential to induce regional health impacts, such as asthma and allergic reactions in sensitive individuals. Surface measurements of dust aerosols were obtained at Fajardo, on the northeastern corner of Puerto Rico, since November 2000. The PM 2.5 and PM 10 size fractions from the filter samples were related to satellite and sunphotometer measurements of aerosol optical depth before, during, and after Saharan dust events. In 2002, PM 2.5 ranged from 2.5 to 18.4 $\mu\text{g}/\text{m}^3$ while PM 10 ranged from 11 to 60 $\mu\text{g}/\text{m}^3$. The PM 2.5 fraction was approximately 25% of the PM 10. Saharan dust aerosols are also responsible for substantial heavy metal deposition in the tropical western Atlantic. In 2001, Iron increase from less than 4 mg/g during the first four months of the year, to a maximum of 24 mg/g in June, with relatively high values from May through September. An AVHRR 4-year climatology of aerosol optical depth for northeastern Puerto Rico shows a well-defined maximum peak during the last week of June and first week of July.

B21F-0787 0830h POSTER

Geochemical Fluxes Associated With a Long-range Dust Cloud From the Gobi Desert Region, Central Asia.

Christina M Zdanowicz¹ (613-947-5169; czdanowi@nrcan.gc.ca)

Gwendy E Hall¹ (613-992-6425; ghall@nrcan.gc.ca)

Judy E Vaive¹ (613-992-6730; jvaive@nrcan.gc.ca)

¹Geological Survey of Canada, 601 Booth Street, Ottawa, ON K1A 0E8, Canada

In early April, 2001, an exceptionally intense series of dust storms originated in the Gobi desert region of southern Mongolia and northern China. The dust cloud generated during these storms was tracked by satellite over the North Pacific Ocean and was detected all across North America. Instrumented floats deployed in the subarctic western Pacific Ocean revealed a near-doubling of the carbon biomass in the mixed layer over the 2-week period following the passage of the dust cloud, illustrating the impact of the dust on biological productivity in the surface Ocean (Bishop et al. 2002, *Nature* vol. 298). During its passage over northwestern America ca April 13, 2001, the Gobi dust plume deposited a widespread, distinctive layer of yellowish-red dust-laden snow, up to 5-cm thick, in the icefields of the St-Elias mountains, Yukon Territory. The dust fallout was probably enhanced by snowfall scavenging associated with orographic uplift of the moist Pacific air mass over the high mountain range (max elevation 5959 m). Samples of dust-laden snow were collected from a series of sites on the Mount Logan massif (60°N, 140°W), during a glaciological research expedition. The samples, collected between elevations of 2400 and 5340 m, contained as much as 80 ppm (mass) of dust. The dust particles were analyzed in the laboratories of the Geological Survey of Canada to characterize their physical attributes (e.g., grain size distribution) as well as their bulk mineralogical and geochemical composition. The concentrations of over 60 major, minor and trace elements were determined using ICP-MS an ICP-ES, including some important nutrients and biolimiting to biointermediate elements such as P, Si, Ba and Ca. Using these measurements, we calculated first-order estimates of the depositional fluxes for various geochemical elements associated with the Gobi dust fallout. Such detailed compositional data on far-traveled dust clouds are rarely available. We hope our findings presented here will assist researchers engaged in evaluating the potential biogeochemical impact of long-range dust transport events on marine, freshwater and terrestrial ecosystems.

B21F-0788 0830h POSTER

Numerical Modeling of Regional Windblown Dust in the Pacific Northwest: Incorporation of an Improved Dust Emission Model

Irra Sundram¹ (1-509-335-6248;

irra.t-mohanasu@wsu.edu); Candis Claiborn¹ (1-509-335-6273; claiborn@wsu.edu); Tara

Strand¹ (1-509-335-5738; strand@mail.wsu.edu);

Brian Lamb¹ (1-509-335-7632; blamb@wsu.edu);

Dave Chandler²; Keith Saxton³ (1-509-335-2724; ksaxton@wsu.edu)

¹Laboratory for Atmospheric Research, Department of Civil & Environmental Engineering Washington State University, Pullman, WA 99164, United States

²Department of Plants, Soil and Biometeorology, Utah State University, Logan, UT 84322, United States

³USDA-ARS, L.J. Smith Hall Washington State University, Pullman, WA 99164, United States

Soil erosion by wind is a serious consequence of dryland agriculture in eastern Washington where the

main adverse effects are loss of nutrient rich soil, reduced visibility during dust storms and regional air quality impacts in downwind populated areas. A multidisciplinary research effort to study windblown dust in central and eastern Washington was initiated under the Columbia Plateau PM 10 (CP³) program. As part of this study, wind erosion and windblown dust emissions were measured in impacted population centers and a transport and dispersion model was developed for the region. The modeling system includes the use of a prognostic meteorological model, Mesoscale Meteorological Model Version 5 (MM5), coupled with the CALMET/CALGRID Eulerian modeling pair and a new dust emission module (EMIT-PM), developed specifically for this region from extensive soil sampling, portable wind tunnel measurements and intensive field campaigns. Surface wind observations were integrated into the diagnostic meteorological model, CALMET, along with wind fields generated by MM5 for six dust storm events that occurred in November 1990, October 1991, September 1993, November 1993, August 1996 and September 1999. Area dust emissions were generated using the CALMET wind fields along with detailed soil and land use maps in the EMIT-PM model and these hourly, gridded emissions were then used in CALGRID, which calculated hourly averaged concentrations of PM10 (particulate matter of aerodynamic diameter < 10 μm) throughout the modeling domain. The predicted 24-hour average concentrations compared favorably to observed concentrations that were measured at selected locations within the modeling domain. For all the simulated events, with the exception of the August 1996 event, ratios of observed to predicted concentrations were within a range of 0.5 to 6.0. Because these ratios were obtained without the need for a calibrated dust constant, it appears that the EMIT-PM provides an improved representation of PM 10 emissions from eroding fields in the Columbia Plateau. The overall robustness of this modeling approach in terms of the computational resources utilized and the prediction accuracy range achieved is encouraging with regards to developing a predictive based system for dust emissions.

B21F-0789 0830h POSTER

Identifying Dust Sources in North Africa and Modeling Patterns of Dust Emissions From These Sources

John Andrew Ballantine¹ ((805) 893-8816; andyb@bren.ucsb.edu)

Gregory S. Okin² (okin@virginia.edu)

Dar A. Roberts¹ (dar@geog.ucsb.edu)

¹University of California, Santa Barbara, Department of Geography University of California, Santa Barbara, CA 93106-4060

²University of Virginia, Department of Environmental Sciences 921 McCormick Rd. University of Virginia, Charlottesville, VA 22904-4123

Atmospheric models are requiring more accurate representations of the surface in modeling emissions of dust from the surface and the nutrients attached to fine mineral particles. Regional to continental scale characterization of surface landforms that are susceptible to erosion has become possible with the advent of satellites that monitor the land surface at moderate spectral and spatial resolution (e.g. MODIS). The most productive dust sources in the world are in the Sahara Desert and the Sahel, in areas where human pressures may be making the landscape more susceptible to wind erosion. This project seeks to model dust emissions in the Sahara and Sahel with estimates of surface parameters from satellite imagery and ancillary data. A map of landforms for Africa, north of 10 degrees, was constructed using a multiple endmember spectral mixture analysis (MESMA) of the MODIS 500 meter, 7 band, reflectance product. The magnitude of surface winds acting on the landforms was determined from forecast models. Surface parameters (vegetation characteristics, threshold wind velocity, and grain size distribution) were estimated for the imagery. Estimates of nutrient concentration on Saharan/Sahelian dust were used to estimate nutrient emissions. The results highlight patterns of dust emission from sources in North Africa and are compared with modeled and observed sources in the literature.

B21G MCC: 3014 Tuesday 1020h

Impacts of Biomineralization on Earth Environments II (joint with A, OS, PP, V, GC, MR)

Presiding: L Wasylenki, Virginia

Polytechnic Institute and State

University; P Dove, Virginia

Polytechnic Institute and State

University

B21G-01 1020h INVITED

Diatom Production of Opal and the Evolution of Nitrate to Silicic Acid Ratios in the Ocean

Christina L De La Rocha (44 1223 333 479; christina00@esc.cam.ac.uk)

Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EQ, United Kingdom

Diatoms are highly successful phytoplankton and over the course of appearing and radiating are thought to have caused a drop in marine concentrations of silicic acid on the order of about 1000 μM (Siever 1991). Diatoms deposit opal in their cell wall and so require Si in what is a roughly equal proportion to N. Such a great need for Si should not hamper diatom growth in a Si-rich environment, such as the modern ocean with its average N/Si ratio of 0.6 (tabulated from the >17,000 WOCE stations), well below the 1:1 boundary between eventual N- and eventual Si-limitation. But the deeper pumping of Si than N prior to remineralization from biogenic particles produced in surface waters has pushed the average nitrate to silicic acid ratio (N/Si) of the upper kilometer to 1.4. Values peak around 300 m, and decline both above and below this depth. Average N/Si ratios do not drop below 1 until 800 m, suggesting that, in the absence of nitrate-utilization by non-siliceous phytoplankton, most waters upwelling into the euphotic zone of the modern day ocean contain N and Si in proportions that should be Si-limiting to diatom growth. The average ratio of utilization of N/Si appears to be 1.9, which could correspond to the uptake ratio of Fe-limited diatoms or to a significant proportion of the nitrate being taken up by non-siliceous phytoplankton. This high utilization ratio causes the drop in N/Si above 300 m, but the drop in N/Si below 300 m is due to the more efficient remineralization of N than Si from sinking particles. Despite the high N/Si ratio of surface waters, diatoms are not necessarily faced with Si-limitation as much of the N is taken up instead by non-siliceous phytoplankton. Marine N/Si ratios have been high probably only in the last third of the existence of the diatoms. Prior to the appearance and radiation of the diatoms surface ocean N/Si ratios were likely on the order of 0.02 and from that time have probably risen by a factor of 30 to 70. Now that the N/Si ratio of surface waters exceeds the value of 1, the total amount of Si input to the euphotic zone limits the proportion of available N that can be acquired by diatoms and diatoms may at times experience Si-limitation despite the competition with other phytoplankton for N stocks.

B21G-02 1035h

Relative Impact of Biologically versus Physiochemically Dominated Modes of Mineralization on the Earth's Environment

Brent R Constantz (650-723-8177; brentc@stanford.edu)

Stanford University, Biomechanical Engineering Division, 217 Durand, Stanford, CA 94305, United States

Taxonomic groups forming biominerals that have had the largest impact on the earth's environment may have common styles of mineralization processes. Lowenstam recognized that organisms utilize two principal modes in biomineralization: "biologically-dominated" and "physiochemically-dominated" mineralization. The most prolific mineralizing taxa are: (1) reef framework builders, (2) reef sediment formers, (3) pelagic carbonate formers, and (4) planktonic mineralizers associated with upwelling. Taxa that have had the least impact on the earth's environment are mobile organisms with non-massive, often exceptionally strong skeletons. The prolific mineralizing taxa (1-4) have modes of mineralization dominated by physiochemical mineralization processes. The least prolific mineralizers have modes of mineralization dominated by biologically-controlled processes. Examples of biologically-dominated modes of mineralization are the skeletons of mobile echinoderms, mollusks, and arthropods. There are less common sessile examples of these

three phyla (echinoderms, mollusks, arthropods) that have physiochemically-dominated modes of mineralization that have had important impacts on the earth's environment. Taxa that are (1) reef framework builders such as scleractinian corals and rudistid bivalves show a physiochemically-dominated mode of mineralization. Green algae, the most important (2) reef sediment formers in modern reef systems, show a physiochemically-dominated mode of mineralization. Modern coccolithophoridae, the most abundant modern contributors to (3) pelagic realm deep sea carbonates above the calcium carbonate compensation depth, have a mode of mineralization dominated by physiochemical processes. Modern diatoms dominate the biological production of minerals in upwelling environments (4), and demonstrate a physiochemically-dominated mode of mineralization. Changes in the taxonomic assemblages of mineralizing organisms in these ecological settings over the course of evolutionary time have altered the impact of biomineralization processes in each respective ecological setting. Stochastic changes in global carbon cycling and climatic fluctuations may play a role in the relative impact of physiochemically-dominated mineralizers on the earth's environment and their evolutionary success.

B21G-03 1050h

Vital Effects on Stable Isotopes and Trace Elements in Foraminifera and Corals in View of Their Biomineralization Mechanisms

Jonathan Erez¹ (+972-2-6584882; eretz@vms.huji.ac.il)

Shmuel Bentov¹ (+972-2-6584615; bentov@vms.huji.ac.il)

Kenneth Schneider¹ (kenneth@vms.huji.ac.il)

¹Institute of Earth Sciences, The Hebrew University of Jerusalem, Givat Ram, Jerusalem 91904, Israel

Based on microscopic observations, we propose that modified seawater is the solution from which biomineralization in foraminifera and corals commences. Seawater vacuolization is clearly observed in foraminifera while seawater pumping between the skeleton and the chalicoblastic epithelium is proposed for corals. In both cases CaCO₃ precipitation proceeds within a semi-restricted biomineralization reservoir that the organism modifies mainly in term of its pH and in the case of foraminifera possibly its Mg also. The pH may be elevated by an active proton pump and/or by Ca-ATPase, which was demonstrated in corals. Internal cycling of metabolic CO₂ is an important source for the final carbonate ion in the site of calcification in both corals and foraminifera. A competition for CO₂ between the symbiotic algae and the basic biomineralization reservoir has been demonstrated in foraminifera and may also occur in corals. Bicarbonate uptake must be a common feature in both groups especially in endosymbiotic associations. Consequently the isotopic composition of the symbiotic algae in both groups is enriched in ¹³C. The source of inorganic carbon for symbiont photosynthesis is a mixture of respiratory CO₂ and seawater bicarbonate. The δ¹³C of respiratory CO₂ is determined by the proportion of external food carbon and symbiont photosynthesis and their respective δ¹³C values. The fractionation of the symbiotic algae is probably very low and may be in the range of less than 10 ‰. The proportion of seawater carbon to respiratory CO₂ and their respective δ¹³C in the biomineralization reservoir determine the skeletal δ¹³C. Complications arise because of the effect of the carbonate ion on δ¹⁸O, and kinetic fractionation of carbon that is associated with diffusive supply of CO₂ into the basic biomineralization reservoir (Baertschi effect). Trace elements are partitioned into the solid CaCO₃ according to the composition of the biomineralization reservoir. Because this reservoir is essentially slightly modified seawater, the divalent trace elements show a behavior that resembles precipitation from a partially closed reservoir. The main exception is Mg, which in the case of foraminifera may be lowered by the organism (perhaps by complexation with organic compounds associated with the organic matrix or some of its components).

B21G-04 1105h INVITED

Reef Coral Biomineralization: A Geochemical Perspective

Anne L Cohen (508 289 2958; acohen@whoi.edu)

Woods Hole Oceanographic Institution, Department of Geology and Geophysics, Woods Hole, MA 02543, United States

The trace element and stable isotope composition of long-lived reef corals preserve high-resolution records of marine climate from the Paleozoic to the present. However, while skeletal chemistry responds to changing ocean conditions, the relationships between composition and external conditions seldom appear to obey thermodynamics. Deviations from chemical equilibrium, referred to as "vital effects", reflect the imprint

of coral physiology on the kinetics of crystal growth. Although typically viewed as a hindrance, vital effects can provide a window into biomineralization mechanisms and processes. For example, the Sr/Ca ratio of bulk coral skeleton is lower than it would be if the skeleton were precipitated from seawater under equilibrium conditions. This deviation has been attributed to kinetically controlled processes associated with light-enhanced calcification. Because the offset from inorganic precipitates is not consistent, but varies within and amongst coral species, it has proven to be problematic for Sr/Ca-based paleothermometry. I examined the origins of this vital effect using SIMS ion microprobe to measure changes in the Sr/Ca ratio of crystals within a single sclerodermit, from the nucleation site through the tip of the fasciculus, a distance of 50 - 100 m. The Sr/Ca ratio of seed crystals found in centers of calcification is close to that of inorganic aragonite precipitates formed at the same conditions. This indicates that the nighttime precipitation of these submicron, equant-shaped crystals, which constitutes the initial phase of the daily cycle of crystal growth, may occur within a space filled with seawater at precipitation rates slow enough for the system to approach equilibrium. Tight bundles of needle-shaped crystals (the fasciculi) nucleate on the seed crystals and grow outward like spherulites to fill the calcifying space. The Sr/Ca ratio of these crystals decreases linearly as they grow. This observation supports a monocrystalline rather than polycyclic model of crystal growth. Furthermore, the rate of change of Sr/Ca along the fasciculus is greater than is predicted by a closed-system mass balance model. It is highest in fast-growing tropical corals during the summer, and lowest in slow-growing subtropical corals in winter. These observations support previous assertions of a link between Sr/Ca disequilibrium and light-enhanced calcification. However, the uniformity of crystal morphology along the length of the fasciculus suggests that a kinetic process may not be responsible. An alternative explanation involves hourly, daily and seasonal changes in the Sr/Ca composition of the calcifying fluid, brought about largely through changes in the light-driven and carrier-mediated transport of Ca²⁺ into the calcifying space.

B21G-05 1120h INVITED

Microbially Influenced Calcite Precipitation in Archean Communities

Dawn Y Sumner¹ (530-752-5353; sumner@geology.ucdavis.edu)

Megan Murphy¹ (megmurphy@geology.ucdavis.edu)

Ryoji Shiraki¹ (rshiraki@ucdavis.edu)

¹Geology, UC Davis, 1 Shields Ave, Davis, CA 95616, United States

Fenestrate microbialites, which are common in Neoproterozoic carbonates, are composed of two microbial communities that affected calcite precipitation differently in environments where syndimentary calcite precipitation was kinetically favorable. Filmy laminae are composed of >3µm thick zones of organic inclusion. They form planar laminae, drape off topographic highs, and display recumbent folds and roll-up structures. Their composition and deformation demonstrate that they were thin, laterally cohesive, extremely flexible biofilms. In contrast, supports are ~200µm-wide surfaces that tend to be vertically oriented. They are defined by organic inclusions in calcite and commonly are coated with the first generation of calcite cements; they show evidence for compaction where early precipitation did not occur. Although no microbial analogs for support growth are known, they are also interpreted as microbial communities based on their composition and relationships to filmy laminae. Filmy laminae and supports affected calcite precipitation differently. Petrographic relationships demonstrate that where laminae drape off of supports, initial fibrous calcite nucleated only on the supports and not on the laminated mat. In addition, carbon in calcite associated with the supports in the 2.52 Ga Gamohaan Formation, South Africa, is enriched in ¹³C relative to all other calcite in the microbialites. Supports with petrographic evidence for simultaneous calcite precipitation are associated with calcite that is enriched up to 1‰ relative to calcite that precipitated in voids or filmy laminae as little as 250 µm away. Enriched carbon is attributed to microbial fixation of CO₂ or HCO₃⁻ during calcite precipitation due to preferential uptake of ¹²C species. Calcite in compacted supports, which is interpreted as precipitating after growth of the support, is not enriched in ¹³C. To produce measurable carbon isotopic disequilibrium, the microbial communities must have rapidly fixed carbon autotrophically. For this disequilibrium to be preserved in calcite, precipitation must have been contemporaneous with microbial carbon uptake. Thus, isotopic evidence suggests that the support microbial communities fixed CO₂ or HCO₃⁻ and metabolically induced calcite precipitation. Some calcite associated with organic inclusions also is enriched in Mg, which may be due to: 1) locally increased concentration of Mg due to microbial processes or binding to organics;

2) release of Mg as a result of organic decay during diagenesis; or 3) local mediation of diagenetic reactions by organics. The preservation of the carbon isotopic signatures suggests that the increased Mg concentrations are most likely due to locally increased concentration of Mg during microbial growth.

B21G-06 1135h INVITED

Observations and Experiments on Carbonate Secretion in "Calcite Seas": Why Massive Chalk Deposits Formed in Late Cretaceous Time

Steven M. Stanley¹ (410-516-7042; stanley@jhu.edu)

Justin B. Ries¹ (442-722-2163; jries@jhu.edu)

Lawrence A. Hardie¹ (410-516-7050; hardie@ekman.eps.jhu.edu)

¹Morton K. Blaustein Department of Earth and Planetary Sciences, Johns Hopkins University, Charles & 34th Streets, Baltimore, MD 21218, United States

It is now well-established that oscillations in the Mg/Ca ratio of seawater, driven by changes in spreading rates along mid-ocean ridges, have determined the mineralogy of nonkeletal marine carbonate precipitation throughout earth history. Low-Mg calcite has formed at Mg/Ca ratios < 2 ("calcite seas"), and aragonite has formed at ratios > 2 ("aragonite seas"). High-Mg calcite (mole % Mg > 4) has formed by itself at Mg/Ca ratios of 1-2, and along with aragonite at ratios above 2. We report here on experiments rooted in the paleontological observation that the carbonate mineralogy of major reef-building and sediment-producing organisms has tended to correspond to that of nonkeletal precipitates throughout Phanerozoic time. Earlier experiments showed that, with changes in the Mg/Ca ratio of ambient seawater, the Mg content of calcite in coralline algae varies like that of nonkeletal calcite precipitates. New experiments reveal that many kinds of calcite-secreting marine animals exhibit similar mineralogical trends, but with varying partition coefficients. Other experiments address the effects of seawater chemistry on productivity. One can predict that secretion of calcium carbonate will facilitate growth of algae because it releases carbon dioxide that can be used in photosynthesis. Indeed, we found that Halimeda, a major producer of aragonite sediment in present-day aragonite seas, grows less rapidly when living at ambient Mg/Ca ratios below the modern marine level of 5.2. Conversely, calcareous nannoplankton, which secrete calcite, become much more productive when ambient Mg/Ca ratios are below unity and associated concentrations of Ca are high. Such conditions characterized the extreme calcite seas of Late Cretaceous time, when nannoplankton formed massive chalk deposits throughout the world. Thus, we attribute the formation of these deposits, which gave the Cretaceous Period its name, to seawater chemistry. Calcareous nannoplankton in modern seas are adapted to low nutrient levels and are not limited by iron. We conclude that the productivity of present-day calcareous nannoplankton is limited by the high Mg/Ca ratio and/or low absolute concentration of Ca in the modern ocean. Experiments now in progress will examine the relative importance of these two factors.

B21G-07 1150h

Advent of Planktic Calcification and Increased Stability of the Climate System

Andy J Ridgwell¹ (909-827-7721; andyr@citrus.ucr.edu)

Martin J Kennedy¹ (martink@mail.ucr.edu)

Ken Caldeira² (kenc@llnl.gov)

¹University of California - Riverside, Department of Earth Sciences, University of California - Riverside, Riverside, CA 92521, United States

²Lawrence Livermore National Laboratory, Climate and Carbon Cycle Modeling Group, Lawrence Livermore National Laboratory, 7000 East Ave, L-103, Livermore, CA 94550, United States

The evolutionary success of planktic calcifiers stabilized the climate system by introducing a new mechanism that acts to buffer ocean carbonate-ion concentration - saturation-dependent preservation of carbonate in seafloor sediments. In the late Phanerozoic, reduction in carbonate deposition on the continental shelves can be compensated for by the increased preservation in deep sea sediments of biogenic carbonate originating from planktic calcifiers living in the open ocean. The result of this is that ocean carbonate chemistry is strongly buffered and the carbon-climate system relatively stable against perturbation of sea level. However, before the advent of biomineralization by pelagic calcareous plankton and benthic metazoan, carbonate deposition would have been largely restricted to shallow water photic environments. Such a system is susceptible to positive feedback between sea level fall, reduced

shallow water carbonate deposition, atmospheric CO₂ draw-down, and ice-sheet growth, raising the possibility of extreme glaciation. This is consistent with the occurrence of ice ages of near-global extent and multi million-year duration during the Neoproterozoic; climatic events that did not reoccur in the Phanerozoic. We employ a coupled atmosphere-ocean-sediment carbon cycle model to demonstrate the fundamental impact of biomineralization in increased stability of the modern climate system.

B21G-08 1205h

Calcite and Picocyanobacteria in Lakes: Factors Affecting Their Interaction

Maria Dittrich¹ (dittrich@eawag.ch)

Martin Obst¹

Denis Mavrocordatos²

¹Swiss Federal Institute for Environmental Science and Technology, EAWAG, Limnological Research Center, Seestrasse 79, Kastanienbaum 6047, Switzerland

²Swiss Federal Institute for Environmental Science and Technology, EAWAG, Ueberlandstrasse 133, Duebendorf 8600, Switzerland

Calcites build large deposits which have been observed in the rock record throughout geological time at various localities around the globe. Carbonate deposits have affected atmospheric carbon dioxide concentration. As it has been generally accepted, inorganic precipitation represents a source of carbon dioxide on short geological time scales and a sink of inorganic carbon at long time scales from millions to thousands of millions years. However, recent research indicates that calcite deposits may result from microbial calcification instead of inorganic precipitation. In this case the process may reduce atmospheric carbon dioxide on geologically short time scales. Thus the effect of carbonate sediment deposition on global carbon cycling depends on the origin of carbonate. Thus it is essential to understand the cause and the key parameters affecting calcite precipitation. The role of algae and bacteria in calcite formation in lakes has not been evaluated in detail. Some evidence, however, exists supporting precipitation of calcium carbonate by microbes as the origin of whiting. Several field studies on lakes have also produced puzzling results: The peaks of algal blooms were often not found at the same time as precipitation events of calcite. We suspect that parts of the discrepancies in the interpretation of field observations are due to the activity of autotrophic picoplankton. The unicellular autotrophic picoplankton (APP) is a ubiquitous component of pelagic ecosystems. But it has often been overlooked due to its small cell size of 0.2 - 2 µm in diameter. Coccolid picocyanobacteria of the *Synechococcus*-type dominate the picoplankton community in most oligotrophic systems. Recently, laboratory experiments and field observations suggested that APP may play an important role in calcite precipitation. The aim of this study was to examine the influence of environmental factors such as saturation state, concentration of different dissolved ions and characteristics of the surface of cells on interaction between calcite and picocyanobacteria under both laboratory and field conditions. Laboratory experiments were performed with a picocyanobacteria strain *Synechococcus*-type. Using ion selective electrodes we monitored calcite precipitation induced by bacteria in the solutions of a different composition (calcium 0.7 - 48 mM, inorganic carbonate 6 - 35 µM). Electron and atomic force microscopy measurements provided insight into the cell-mineral interface. Furthermore, quantitative investigations of the types and densities of proton binding sites on a bacterial surface will be reported from the acid-base titrations on bacteria. Results of these initial experiments are encouraging and demonstrate by direct measurements the potential of picocyanobacteria to precipitate calcite. The amount of the precipitated calcite varied in experiments with a different ratio of dissolved inorganic carbon and calcium. The microscopic observations provide some evidence that the cell walls of cyanobacteria act as a substrate of nucleation of calcite. Temporal and spatial correlations of cyanobacteria and calcite, as well as images of bacterial shape particles indicated that picoplankton plays an important role in calcite precipitation in Lake Lucerne. This class of phytoplankton has to be considered in studying the biogeochemical cycling of oligotrophic hardwater lakes.

B21H MCC: 3009 Tuesday 1020h

Terrestrial Productivity and Carbon Storage: Research Issues and Tools I (joint with A, H, OS)

Presiding: D Schimel, National Center for Atmospheric Research; C Still, University of California, Santa Barbara; J A Gamon, California State University, Los Angeles; A F Rahman, Ball State University

B21H-01 1020h INVITED

Controls over the fractional stabilization of GPP: key processes and possible geochemical tracers

David S Schimel¹ (303.497.1610; schimel@ucar.edu)

Christopher Still² (805.893.5501; still@icess.ucsb.edu)

Britton B Stephens³ (303.497.1018; stephens@ucar.edu)

¹National Center for Atmospheric Research, Climate and Global Dynamics Division 1850 Table Mesa Drive, Boulder, CO 80307, United States

²UC Santa Barbara, Geography Department 3611 Ellison Hall, Santa Barbara, CA 93106, United States

³National Center for Atmospheric Research, Atmospheric Technology Division 1850 Table Mesa Drive, Boulder, CO 80307, United States

It is often assumed that there is a relationship between biological productivity and carbon storage, but high rates of sequestration can be documented in areas with widely different levels of primary productivity. A number of analyses have shown that estimated global sinks cannot be due only to increases in productivity, because the required increases are too large for known mechanisms. Changes in the rate of storage must also be occurring. Both autotrophic and heterotrophic processes can affect the stabilization of plant material. Likely candidates include high allocation to wood and/or decay resistant organic matter, and increases in residence time of sedimentary organic matter in areas of enhanced erosion. Both of these processes are linked to changes in disturbance regime. In this talk we review mechanisms affecting the fraction of productivity stabilized, the ratio of NBP to GPP, and discuss the utility of this ratio as a tracer. We suggest that because of the chemical and isotopic composition of stable plant material, large-scale geochemical tracers of NBP/GPP may exist.

B21H-02 1035h

The Influence of Stand Development on Annual Carbon Exchange in Ponderosa Pine in Eastern Oregon

Meredith R. Kurpius¹ (541-737-8473; meredith.kurpius@oregonstate.edu)

James Irvine² (541-737-8456; james.irvine@orst.edu)

Beverly E. Law² (541-737-6111; bev.law@oregonstate.edu)

Michael H. Unsworth¹ (541-737-5428; unsworm@coas.oregonstate.edu)

¹Atmospheric Science, Oregon State University, 104 Ocean Admin. Bldg., Corvallis, OR 97331-5503, United States

²Forest Science, Oregon State University, 121 Richardson Hall, Corvallis, OR 97331-5752, United States

It is commonly assumed that productivity, and therefore total carbon sequestration, is higher in young, actively growing stands than in old-growth stands. We show that ponderosa pine stands in Oregon did not fit this pattern. Carbon and water fluxes were measured continuously by eddy covariance above young-, mature-, and old-aged ponderosa pine (*Pinus ponderosa* Dougl. Ex P. & C. Laws.) stands located within 10 km of each other in central Oregon. The general study area is on the east side of the Cascade Mountains and is classified as high desert: winters are cool and wet while summers are hot and dry, resulting in seasonal drought stress. The old site is composed of patches of multiple age classes: 27% (by ground area) old trees (> 250 years old), 25% young trees (< 50 years old), and 48% mixed - with both age classes. The forest has a very open canopy with summer maximum LAI of 2.1 (0.1 in understorey shrubs). The mature site (approx. 90 yrs. old) is naturally regenerating after clear-cutting

and summer maximum LAI is 3.0 (0.1 in understorey shrubs). The young site (approx. 16 yrs. old) was previously an old-growth forest that was clearcut in 1978 and allowed to regenerate naturally, and the maximum summer LAI was 1.2 (0.4 in understorey shrubs). The mature site had the highest gross ecosystem productivity (GEP) (1350 gC m⁻² y⁻¹) but also the highest ecosystem respiration (Re) (940 gC m⁻² y⁻¹). The old site had moderately high GEP (1200 gC m⁻² y⁻¹) and lower Re (690 gC m⁻² y⁻¹). The young site had the lowest GEP (730 gC m⁻² y⁻¹) in 2000-2001 and 790 gC m⁻² y⁻¹ in 2002 and the lowest Re (550 gC m⁻² y⁻¹) in 2000-2001 and 600 gC m⁻² y⁻¹ in 2002). Despite having the highest LAI, the mature site did not have the highest net ecosystem exchange (NEE). The balance of GEP and Re resulted in the highest NEE occurring at the old site (-580 ± 75 gC m⁻² y⁻¹), which experiences the least severe drought stress according to water potential and sapflow data. NEE at the mature site was moderately high (-435 ± 60 gC m⁻² y⁻¹) and was lowest at the young site (-170 ± 20 gC m⁻² y⁻¹) in 2000-2001 and -160 ± 20 gC m⁻² y⁻¹ in 2002) which experiences the most severe drought stress. The ratio of Re:GEP was 0.6, 0.7, and 0.75 for the old, mature, and young stands, respectively, indicating that as the stands age they respire less per unit carbon fixed. We conclude that more established ponderosa pine stands in this region are likely to sequester more carbon than recently disturbed stands, likely due to a low Re:GEP and a more established rooting system which enables older trees to better withstand drought.

B21H-03 1050h

Interannual Variation in the Relationship Between Aboveground Net Primary Productivity and Net Ecosystem Productivity in a Northern Temperate Grassland

Lawrence B. Flanagan (1-403-380-1858; larry.flanagan@uleth.ca)

University of Lethbridge, Department of Biological Sciences, 4401 University Drive, Lethbridge, AB T1K 3M4, Canada

Measurements of aboveground net primary productivity (ANPP) and net ecosystem carbon dioxide exchange (NEE) have been made in a native Canadian grassland during 6 years (1998-2003) of contrasting weather. The eddy covariance technique was used to measure NEE and these measurements were integrated to calculate net ecosystem productivity (NEP). Variation in summer precipitation input was the major environmental factor influencing ANPP and NEP in this ecosystem. Annual ANPP ranged from 40 to 100 g C/m² with a strong positive correlation to the amount of summer (April-August) precipitation (107-412 mm range). However, ANPP varied asymmetrically in response to changes in precipitation, with increases in ANPP during a wet year being much more pronounced than reductions in a drought year. Strong increases in plant water-use efficiency contributed to the resilience of ANPP during times of drought. Annual NEP ranged from a net loss of 18 g C/m² to a net gain of 288 g C/m². The NEP in a year with normal precipitation was 21 g C/m², while years with below normal precipitation had either a net gain of 19 g C/m² or a net loss of 18 g C/m². Differences in soil respiration were responsible for whether the ecosystem was a carbon sink or source in years of low precipitation. Late summer rain, received after most of the plant canopy had gone dormant, can stimulate soil respiration more than photosynthesis, with a resulting net loss of carbon from the ecosystem. Soil moisture was also observed to have strong control on the temperature sensitivity of ecosystem respiration. ANPP and NEP were closely linked when moisture was abundant. However, in years with normal or lower precipitation, variation in soil respiration strongly influenced NEP and disrupted the correlation with ANPP.

B21H-04 1105h

Ecosystem Productivity and Carbon Exchange in Northern Peatlands

Nigel T Roulet^{1,2} (514-398-4945;

nigel.roulet@mcgill.ca); Peter Lafleur³ (705-748-1011 ext 1487; peter.lafleur@trentu.ca);

Pierre Richard⁴ (514-343-8022;

Pierre.Richard@UMontreal.CA); Steve Frolking⁵ (603-862-0244; steve.frolking@unh.edu); Tim

Moore¹ (514-398-4961; tim.moore@mcgill.ca); Bing

Ouyang¹ (514-398-4111; ouyang@geog.mcgill.ca)

¹Department of Geography and the Centre for Climate and Global Change Research, McGill University, 805 Sherbrooke St. W., Montreal, AC H3A 2K6, Canada