Cluster C (A.D. 1980 to present), is attributable to the recent appearance of the invasive Japanese species Trochammina hadai. Oxygen isotopes and trace elements were measured in specimens of Elphidium excavatum at 10 cm intervals throughout the length of the core. From 150-88 cm (A.D. 652 to A.D. 1224), d 18O values (mean = -3.81 mil) average 0.3 and 0.2 mil lighter than below and above this interval, respectively, corresponding to an increase in water temperature of about 1 deg C in the bay. A heightened Mg/Ca ratio at this time also indicates an increase in water temperature (by 0.3 deg C). The timing of this warming correlates well with records of the Medieval Warm Period. Trochammina hadai was introduced into the bay in the early 1980s, presumably in ballast sediment released from transoceanic vessels. In its native Japan, this species is often found in the most heavily polluted urban areas; its presence being regarded as an index for anthropogenic eutrophication. In San Francisco Bay, this species now commonly comprises over 50% of the foraminiferal fauna, peaking at over 90% at some locations. Such dominance suggests that the environmental conditions of the bay have decreased substantially in the recent past. As an arenaceous species, T. hadai's appearance also marks a possible change in the carbon budget for the bay. Whereas the four most abundant species of foraminifera prior to the T. hadai invasion have tests composed of nearly 100% calcite, T. hadai has only about 6%.

GC41B-06 0945h INVITED

Sediment and Carbon Budgets for Chesapeake Bay and its Watershed: Impacts of Land Clearance and Climate Variability

Thomas M Cronin[1] (703-648-6363; tcronin@usgs.gov)

Casey Saenger[1] (703-648-6083; csaenger@usgs.gov)

Debra A. Willard[1] (703-648-5320; dwillard@usgs.gov)

[1]U.S. Geological Survey, 926A National Center USGS, Reston, VA 20192, United States

Sediment and total organic carbon (TOC) flux from continents to oceans are factors for understanding carbon sinks in continental margins sediments in particular, and the global carbon cycle, in general. However, most estimates of river-borne sediment and TOC suffer from a lack of long-term instrumental records and a poor understanding of the impacts of human activities on sediment processes. We constructed sediment and TOC budgets for northern Chesapeake Bay and its watershed, an intensely monitored (>20 years), large (~18,000 km^2 surface area, 166,000 km^2 watershed area) mid-latitude (37-39°N) estuary, for both pre- (1000 AD to 1850 AD) and post-colonial (1850 to present) maximum land clearance intervals. The bay's main channel and tidal tributaries have been catchments for riverine sediment for 8,000 years such that their stratigraphic records provide a detailed history of sediment and carbon flux. Similarly, total suspended solid (TSS) and organic carbon data from monitoring programs and modeling of land-use change in the bay's watershed provide spatially-robust, independent estimates of sediment and carbon yield. Sediment core records indicate that land clearance increased mean annual riverine sediment (total sediment minus that from shoreline erosion) delivered to the northern bay channel and tributaries by 3 to 5-fold. Post-land clearance estimates from the sediment record compare favorably to independent values derived from monitoring riverine TSS and from modeling of land-surface erosion. Using an empirically-derived estimate of 3.7% for carbon content in present day mid-Atlantic sediments, we observed a 3-fold increase in terrestrially-derived carbon flux since the 1800s. In addition to the effects of land clearance, interannual variability in regional precipitation and freshwater discharge during the past 20 years results in annual carbon flux variation of more than 20% around the mean condition.

GC42A CC: 516 A Thursday 1030h

Environmental Records With Anthropogenic Impacts II

Presiding: **J C Varekamp,** Wesleyan University**; T C Ku,** Wesleyan University

GC42A-01 1030h

Chronology of Land Use Change and Industrial Activity in the St. Lawrence Estuary and Saguenay Fjord From the European Settlement to the Present

Guillaume St-Onge[1] (1-418-654-3704; guillaume_st-onge@inrs-ete.uquebec.ca)

Claude Hillaire-Marcel[2] (chm@uqam.ca)

Anne de Vernal[2] (devernal.anne@uqam.ca)

Julie Leduc[2] (leduc.julie@uqam.ca)

Alfonso Mucci[2] (alm@eps.mcgill.ca)

[1]INRS-ETE, P.O. Box 7500, Sainte-Foy, QC G1V 3C7, Canada

[2]GEOTOP-UQAM-McGill, P.O. Box 8888, Succ. Centre-ville, Montreal, QC H3C 3P8, Canada

Geochemical (organic and inorganic carbon contents), isotopic (^{13}C content of organic matter, ^{210}Pb, ^{14}C), micropaleontological (foraminifera, pollen) and sedimentological analysis of several sedimentary sequences (box and piston cores) were used to determine the chronology of land use change and industrial activity in the St. Lawrence Estuary and Saguenay Fjord from the European settlement to the present. In the St. Lawrence Estuary, the chronostratigraphy was derived from ^{210}Pb and AMS ^{14}C measurements, geochemical and isotopic correlations and the relative abundance of the pollen *Ambrosia*, whereas the Saguenay Fjord chronological framework was derived from chronostratigraphic markers associated with the 1663 (M~7) earthquake, 1971 St-Jean-Vianney landslide and the flood of 1996. In both area, paper mill and industrial activity during the 20th century is reflected by the organic carbon (OC) and ^{13}C content profiles and has resulted in terrestrial OC contents growing almost exponentially until the 1970's, when major changes in industrial practices and the implementation of environmental regulations reduced the amount of industrial OC discharged into the Fjord and St. Lawrence River. This reduction of industrial waste inputs is also depicted in the Saguenay Fjord sediments by the decline in the relative abundance of the benthic foraminifera *Spiroplectammina biformis*, an opportunistic and tolerant species previously associated with polluted benthic environments. In addition, major changes in grain size are recorded in a core sampled at the head of the Fjord and probably reflect the impact of dam construction on the Saguenay River discharge. Finally, the chronology of deforestation and agricultural development linked to the European settlement in the St. Lawrence Lowlands as well as the industrial development of the second half of the 20th century are highlighted in the St. Lawrence Estuary sediments by the increase in the relative abundance of the pollen *Ambrosia* and by the two-step increase in sedimentation rates from 0.15 to 0.28 cm/yr and finally to 0.74 cm/yr.

GC42A-02 1045h

Recent paleolimnology and paleoecology of a high-altitude lake in the Southern Central Andes (Lake Laja, Chile): Natural development versus anthropogenic impact, and implications for paleoclimate studies

Anne Mueller[1] (a.muller@earth.uq.edu.au); Burkhard Scharf[1] (scharf@gm.ufz.de); Stefan Woelfl[2] (swoelfl@uach.cl); Roberto Urrutia[3] (rurrutia@udec.cl); Hanns-Christian Treutler[4] (hanns-christian.treutler@ufz.de); Michael Pirrung[5]; Martin Grosjean[6] (grosjean@giub.unibe.ch); F. Cruces[3] (fcruces@udec.cl); Alberto Araneda[3] (aaraneda@udec.cl); L. Torres[3] (ltorres@udec.cl); Oscar Parra[3] (oparra@udec.cl); Walter Geller[1] (geller@gm.ufz.de)

[1]UFZ Centre for Environmental Research, Department of Lake Research Magdeburg, Brueckstr. 3a, Magdeburg 39114, Germany

[2]Universidad de Valdivia, Instituto de Zoologia, Valdivia, Chile

[3]Centro EULA, Universidad de Concepcion, Universidad de Concepcion, Concepcion, Chile

[4]UFZ Centre for Environmental Research, Department of Analytics, Permoser Str. 15, Leipzig 04318, Germany

[5]Institute of Geoscience, University of Jena, University Jena, Jena, Germany

[6]NCCR Climate, Bern University, Bern, Switzerland

High-altitude lakes in the Andes tend to be unaffected by anthropogenic influence. However, some of these lakes have been influenced by humans in the recent past. In this paper we explore the impact of a hydroelectrical power station on the limnology and the ecosystem in the high-altitude lake Laja in the southern central Andes of Chile over the last 50 years. The lake has not exerpienced any other significant local anthropogenic impact than that caused by the hydroelectric power station, which mainly resulted in significant (up to 60 metres) changes in water levels. Organic carbon and nitrogen concentrations, d13C and d15N values, diatoms, crustaceae and other organisms such as chironomids reflect distinct changes in water levels caused by the operation of the hydroelectric power plant in the lake. Noticeably low water levels occurred in the mid-1970s and the early 1990s, which resulted in the significantly higher abundances of crustaceae, dominated by the cladocera of the Bosmina sp, and chironomids. Furthermore, high organic carbon and nitrogen concentrations in the sediments. Susceptibility values in the sediments also mirror the increased input of organic matter caused by higher productivity in the lake at this time. In contrast, high water levels in the early 1960s resulted in high abundances of cladocera of the Daphnia sp. The results of this paper show that the ecosystem of the lake is very sensitive to changes in water levels caused by the operation of the hydroelectric power plant. This finding clearly has to be taken into account when setting up strategies for sustainable management for the ecosystems and environment of high-altitude lakes in the Andes. In the future we will also explore of the potential of our findings to support interpretations of natural changes in the past, for example, in water levels, due to paleoclimatic change in the region.

GC42A-03 1100h INVITED

Algal Populations and Water Quality in Florida Lakes: Sedimentary Evidence of Anthropogenic Impact

Melanie Riedinger - Whitmore[1] (mariedin@stpt.usf.edu)

Thomas J. Whitmore[1] (whitmore@ufl.edu)

Mark Brenner[2] (brenner@ufl.edu)

Joseph Smoak[1] (smoak@stpt.usf.edu)

Jason Curtis[2] (curtisj@ufl.edu)

[1]Environmental Science, Policy and Geography Program, University of South Florida-St. Petersburg, St. Petersburg, FL 33701, United States

[2]Department of Geological Sciences, University of Florida, Gainesville, FL 32611, United States

Cyanobacteria and other algae dominate many highly productive Florida (U.S.A.) lakes. Algal proliferation is often attributed to eutrophication during the last century, but it is poorly documented because Florida's water-quality monitoring programs became common only after 1980. We examined sediment cores from 14 hypereutrophic Florida lakes. Study lakes have been subjected to urbanization, agriculture, and to inputs of municipal sewage effluent and food-processing wastes. Major algal-pigment groups were analyzed in sediments using pigment-extraction and spectrophotometric techniques. We compared myxoxanthophyll, oscillaxanthin, total carotenoid, and total chlorophyll pigment profiles with WACALIB-derived limnetic total-P and chlorophyll a inferences based on fossil diatoms, sediment chemistry, and stable isotope (δ^{13}C & δ^{15}N) signatures of organic matter. Sedimentary evidence showed that cyanobacterial and algal proliferation appeared during recent decades in 10 study lakes in response to eutrophication. Cyanobacterial increase was very recent and abrupt in 7 lakes. Six lakes showed recovery following nutrient-mitigation programs that reduced sewage and other point-source effluent inputs. Four lakes showed long-term presence of cyanobacterial populations because edaphic nutrient supply causes these lakes to be naturally productive. Three of these naturally eutrophic lakes remained unchanged, but one demonstrated eutrophication followed by subsequent recovery. Correlations were particularly strong among sedimented pigment profiles and diatom-inferred limnetic water-quality profiles. Paleolimnological methods provide informative assessment of anthropogenic influence on lakes when long-term water-quality data are lacking. Historic studies also are useful for evaluating the feasibility of improving water quality through lake-management programs, and for defining appropriate lake restoration goals.

GC42A-04 1115h

Cultural Eutrophication of Crawford Lake, Ontario: Effects of Disturbance Upon a Pristine and Pre-modified System

Erik J. Ekdahl[1] (eekdahl@umich.edu)

Jane L. Teranes[2] (jteranes@ucsd.edu)

Eugene F. Stoermer[3] (stoermer@umich.edu)

[1]Department of Geological Sciences, 2534 C.C. Little Building, Ann Arbor, MI 48109-1063

[2]Scripps Institution of Oceanography, University of California-San Diego, La Jolla, CA 92093-0244

[3]University of Michigan, School of Natural Resources, Ann Arbor, MI 48109

Lake eutrophication, a condition where human activities increase nutrient input rates to aquatic ecosystems, thereby stimulating blooms of algae, is a major global water quality problem. Yet, the prehistoric dimension of eutrophication remains relatively undescribed, in part due to limitations in the temporal resolution of paleoenvironmental archives and, perhaps, equally influenced by the preconception (especially in North America) that population density and agricultural practices of native inhabitants would not be large enough to significantly impact local ecology. Here we present fossil diatom assemblages, organic and inorganic carbon accumulations, C/N ratios and calcite δ^{13}C values from a 1000-year sediment core recovered from Crawford Lake, Ontario, Canada that describe cultural disturbance and eutrophication related to Iroquoian settlement of the watershed in the 13^{th} century and to Canadian logging and agriculture in the 19^{th} century. Geochemical and biological data show increased nutrient availability and productivity associated with first evidence for human activity in the watershed at 1268 AD. Sediment accumulation rates of organic and inorganic carbon increase, and higher C/N ratios indicate export was caused by higher rates of algal productivity. A increase in calcite δ^{13}C values show a dissolved inorganic carbon (DIC) pool increasingly enriched in ^{13}C, as ^{12}C is increasingly utilized by primary producers. Diatom assemblages change from a meso-oligotrophic flora to an assemblage dominated by species indicative of nutrient-rich waters within just a few years. Following abandonment of the Crawford Lake watershed by 1486 AD geochemical proxies record a gradual decrease in productivity, related to decreased nutrient loading. Diatoms, however, remain in a meso-eutrophic assemblage. A second period of cultural disturbance, related to Canadians with plow agriculture and deforestation, begins in 1867 AD. Primary productivity is again elevated, yet the diatom assemblages do not change significantly. Carbon isotopes also show little response, potentially due to light limitation of benthic primary producers. We use multivariate statistical analysis to describe the relationship of specific diatom species to increased productivity and to highlight the differing responses in diatom assemblages between the two periods of cultural disturbance. This work emphasizes the importance of initial perturbations to pristine systems, and indicates that a deep historical perspective may be useful for lake and aquatic ecosystem managers.

GC42A-05 1130h

INTERPRETING THE HISTORY OF LAKE ANOXIA USING IRON AND SULFUR GEOCHEMISTRY

Tim Ku[1] (860-685-2265; tcku@wesleyan.edu)

Jolene Lozewski[1] (jlozewski@wesleyan.edu)

Erik Ekdahl[2] (eekdahl@umich.edu)

Jane Teranes[3] (jteranes@ucsd.edu)

[1]Wesleyan University, 265 Church Street, Dept. of Earth and Environmental Sciences, Middletown, CT 06459, United States

[2]University of Michigan, Dept. of Geological Sciences, 2534 CC Little Building, Ann Arbor, MI 48109, United States

[3]Scrippts Institute of Oceanography, University of California - San Diego, La Jolla, CA 92093-0244, United States

Over the last thousand years, anthropogenic activities, such as land cultivation and atmospheric pollution, have increased the flux of growth-limiting nutrients to several North American lakes. The most common effect of this enhanced nutrient supply is a dramatic increase in the abundance of aquatic plants and algae. When these organisms die, the organic carbon in their remains falls through the water column and is oxidized by dissolved oxygen. Thus, eutrophic lakes are characterized by seasonally or permanently anoxic bottom waters because the rate of organic carbon oxidation exceeds the rate at which oxygen is replenished. The depletion of water column oxygen adversely affects lake ecosystems by decreasing water quality and by altering the community structure of fish and algae populations. In this study we examine the history of lake anoxia in two North American lakes, Half-Moon Lake in Michigan and Crawford Lake in Ontario. Sediment freeze cores and water column samples were taken from each site and both lakes contained well-preserved varved sediments. The sediments were analyzed for FeH (HCl-extractable iron), AVS (acid-volatile sulfur), CRS (chromium-reducible sulfur), d34S(CRS), CaCO3, CH2O, C/N, and d13C (CaCO3). Water samples were analyzed for pH, O2, cations, anions, and d34S(SO4). Today, Half-Moon Lake is seasonal anoxic while Crawford Lake has not overturned in the past 15 years. Geochemical and biological data indicate that both lakes have experienced cultural eutrophication events in the 1800-1900s related to European-style agricultural practices. In addition, Crawford Lake experienced an earlier eutrophication episode around 1325 A.D. related to Iroquoian settlement of the area. Each eutrophication event showed an increase in the mass accumulation rate of pyritic sulfur, suggesting that sediments were exposed to longer durations of low-O2, H2S-rich waters during periods of cultural eutrophication. The geochemical parameter DOP (degree of pyritization) is defined as pyrite Fe/(pyrite Fe + FeH) and quantifies the fraction of iron that is converted into pyrite. DOP values from Half-Moon Lake are low (0.1) prior to European settlement and increase to high values (>0.7) after European settlement. In Crawford Lake, our preliminary data indicate that the Iroquoian horizon has lower DOP values than the European horizon. This indicates that the water column was less sulfidic (more oxygen-rich) during the 1300s than in the 1800-1900s. These results show that Fe and S geochemistry can be used to document the history of lake anoxia.

GC42A-06 1145h INVITED

Biogeochemical Cycling and Contamination of Mercury in Arctic Alaska: Modern and Historic Atmospheric Fluxes.

William F Fitzgerald[1] (william.fitzgerald@uconn.edu); Daniel R Engstrom[2]; Carl H Lamborg[3]; Chun Mao Tseng[4]; Prentiss H Balcom[1]; Chad R Hammerschmidt[1]

[1]Dept. of Marine Sciences, U. of Connecticut, Groton, CT 06340, United States

[2]St Croix Watershed Res. Station, Sci.Museum Minnesota, Marine on St. Croix, MN 55047, United States

[3]Dept. of Chem. and Geochem., Woods Hole Oceanographic Institution, Woods Hole, MA 02543, United States

[4]Natl.Center for Ocean Research, Natl. Taiwan Univ., Taipei 106, Taiwan

Our research in the U.S. Arctic is focused on (a) atmospheric Hg deposition and contamination of lakes and watersheds, (b) in-lake cycling of Hg, especially methylHg, and (c) the behavior and fate of elemental Hg, whose production and mobilization via water-air exchange are quite significant. These studies are being conducted in the lacustrine and tundra wetland environs near the Arctic LTER Site at the Toolik Field Station (68°38' N, 149°38' W). Atmospheric Hg deposition over the last several centuries has been established with dated sediment archives from five carefully selected (i.e., headwater; small watershed) remote arctic lakes. Mercury budgets for the study lakes have been constructed from atmospheric, water column, watershed, and sedimentary investigations. Results indicate that (1) impact from anthropogenic Hg in the Arctic is of similar magnitude to that at temperate latitudes; (2) whole-lake Hg sedimentation determined using 55 210Pb-dated cores from the five small lakes demonstrates a 3-fold increase in atmospheric Hg deposition since the advent of the Industrial Revolution, (3) the linear correlation between Hg and 210Pb found in rainwater from other locations is observed in the Arctic, and this behavior can be used to constrain the wet atmospheric flux of Hg to lakes and watersheds, (4) volatilization accounts for about 20% of the Hg losses (evasion and sedimentation) from lakes, and (5) another source term is needed to balance the evasional and sedimentation sinks. This additional flux, though small, is comparable to direct atmospheric Hg deposition. It may be due to some combination of Springtime Hg Depletion Events and more generalized deposition of reactive gaseous Hg species in this tundra region, which is about 150 km from the Arctic Ocean.

GC43A CC: 220 C-E Thursday 1330h

Environmental Records With Anthropogenic Impacts III Posters

Presiding: **J C Varekamp,** Wesleyan University**; T C Ku,** Wesleyan University

GC43A-01 1330h POSTER

Tritium Accumulation in Salt Marsh Sediments From the Severn Estuary, UK

Jennifer E Morris[1] (+44-02380-596632; jem3@soc.soton.ac.uk)

Phillip E Warwick[1] (pew@soc.soton.ac.uk)

Ian W Croudace[1] (iwc@soc.soton.ac.uk)

Alan G Howard[2] (A.G.Howard@soton.ac.uk)

[1]Southampton Oceanography Centre, School of Ocean and earth Sciences, University of Southampton, European Way,, Southampton SO14 3ZH, United Kingdom

[2]School of Chemistry, University of Southampton, Highfield, Southampton SO17 1BJ, United Kingdom

Two shallow sediment cores (to 0.5 m) have been collected from salt marshes in the Severn estuary, UK, as part of a study of the impact of tritium (3H) discharges into the estuary. These discharges are atypical; they have routinely contained both tritiated water (HTO) and organically bound tritium (OBT) since 1982. Tritium present as HTO is usually assumed to be diluted and dispersed on release into the marine environment. However the organic component of this discharge has resulted in significant accumulation of 3H in the estuarine sediments (0.8 Bq/g fresh weight) and biota (24.8 Bq/g dry weight in flounder (McCubbin et al, 2001)). The tritium profiles from the dated salt marsh cores correlate with the decay-corrected organic 3H discharge record. This chronological record suggests that tritium has been retained over decadel timescales, with limited loss by organic matter degradation. This indicates that the tritiated organic molecules are refractory. The apparent persistence of 3H labelled sediments in the estuary has implications for the long-term impact on the environment of 3H discharges containing high proportions of OBT.

GC43A-02 1330h POSTER

Paleoproductivity Indicators in Long Island Sound

Nathan Andersen[1] (nandersen@wesleyan.edu)

Johan C Varekamp[1] (jvarekamp@wesleyan.edu)

[1]Earth and Environmental Sciences, Wesleyan University, Middletown, CT 06459, United States

Oxygen depletion in bottom waters is considered to be the most pressing environmental problem affecting Long Island Sound (LIS). Summer anoxia occurs as a result of two factors: 1) Stratification of the water column due to warming of the shallow water preventing mixing and thus homogeneous distribution of oxygen. 2) Eutrophication resulting in increased primary productivity leading to a greater oxygen demand in the bottom waters as the larger amount of organic matter decays. The goal of this project is to create a paleoproductivity record for LIS and to attempt to link recent increases in productivity with anthropogenic nutrient sources, most notably wastewater treatment plant effluent. Two cores, WLIS-75 from the western narrows and B1GGC1 from near the mouth of the Housatonic River, have been analyzed for biogenic silica (BSi), total carbon, nitrogen, and sulfur. The BSi data was obtained through analyses of timed sequential extracts from an alkaline solution that reacted with the sediment at 85 C. Sediment densities were calculated from measured core water contents and assumed dry rock densities. A preliminary age model was developed using the onset of mercury pollution (about 1820 AD) as a reference point. At around 1800, the C, N, S and BSi concentrations all start to increase. In WLIS-75, BSi was higher throughout the core compared to core B1GGC1, suggesting an overall higher rate of productivity in the western section of LIS. In both cores the mass accumulation rates of BSi, C, N, and S increased exponentially over the last 300 years. A coarse layer was deposited around 1950-1960 in core WLIS-75, and is marked by abundant coarse debris of rocks and coal fragments. This layer may represent a flood deposit or stem from local (illegal?) dumping; its presence impacts the data for the last 30-40 years of the core. A