summer time, for evaporation and transpiration. This is equivalent to the average amount detected at such sites. The GST tracks the SAT (surface air temperature) in this region, except when it is below 0° C. Climatic warming in the winter time would not be detected by this method, except in the very southern, coastal part of this region. Proxy data indicate that winter temperatures have not changed significantly in the north. Therefore I suggest changing amounts of precipitation and their distribution in time are causing glacial recession.

GC41A-08 0830h POSTER

Synchronicity of Holocene climate changes in Europe and North America

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We estimated transitions in pollen diagrams from Europe using two sets of data. The first is radiocarbon dates from the European Pollen Database that are assumed to preferentially date transitions in vegetation. A second is the Pollen Assemblage Zones defined by palynologists in a series of regional summaries (Berglund, B., et al., eds. 1996. Palaeoecological events during the last 15 000 years. J Wiley). Major transitions in Holocene and late-glacial vegetation, as recorded in pollen diagrams, were widespread throughout Europe and synchronous with vegetation transitions identified in North America as well as major environmental changes recorded in North Atlantic marine records and Greenland ice cores. This synchronicity suggests that the major vegetation transitions in Europe during the Holocene and late glacial were primarily caused by large-scale climate changes.

URL: http://www.uottawa.ca/academic/arts/geographie/lpcweb/

GC41B CC: 516 A Thursday 0830h

Environmental Records With Anthropogenic Impacts I

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

GC41B-01 0830h

The Eutrophication of Long Island Sound

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Long Island Sound (LIS) is an urban estuary that receives waste fluids from millions of coastal inhabitants. This influx of nutrients has led to high organic productivity with resulting hypoxia in the western and central sections of LIS during the summer months. We collected a set of short cores to determine the history of eutrophication and determined organic Carbon, Biogenic Silica, and stable isotope ratios on carbonates from core samples. Dating was accomplished with 137Cs, 210Pb and 14C determinations and the onset of Hg contamination, which was dated in land sections. Time constraints are not very precise because of variations in 14C reservoir effect and minor bioturbation effects. The tests of Elphidium excavatum were analyzed to determine paleo water temperature (from Mg/Ca), paleo salinity (from T and d18O) and dissolved O2 levels (from T, S and d13C). The various parameters were calibrated in modern LIS through measurements on live foraminifera' from surface sediment and water column analyses. The strong seasonal temperature fluctuations and variable life span of live collected foraminifera introduce a certain amount of noise into these calibrations. A simple mixing model was created for the Sound using river waters and pure seawater as endmembers. The paleo temperature record seems to indicate a warm period around 1000 BP , followed by the Little Ice Age. The dissolved O2 record for the last 1000 years shows mean annual values of about 70 percent saturation prior to 1800 AD, when mean values dropped to about 30 percent saturation. Eutrophication thus started as early as 1800 AD as indicated by the increased accumulation rates of organic carbon, biogenic silica and low d13C values in carbonate. The Sound has shown a trend of increasing productivity from east to west for many hundreds of years. Earlier warm periods lack evidence for hypoxia and we therefore surmise that the increase in organic productivity is the main driver for the modern hypoxia. The western LIS cores show possibly some evidence that the Sound has become less saline over the last few 100 years, possibly the result of changes in land use that has increased run off. Reductions in sewage and/or nutrient inputs most likely will reduce the occurrence and overall intensity of hypoxia, although climate will always modulate the strength of the hypoxia.

GC41B-02 0845h INVITED

Nitrogen Isotopic Ratio Records The Eutrophication History of Long Island Sound

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Increasing coastal population and industrialization has led to the steady degradation of the Long Island Sound (LIS) environment. Increased nutrient loading from sewage inputs has resulted in eutrophication and decreased summertime subsurface oxygen concentration particularly at its western end. It is critical to develop a detailed history of these environmental changes, both to understand causative processes and for design of optimal and cost effective remediation plans. We are developing a detailed time line of environmental changes in LIS over the last few centuries based on the study of geochemical and paleo-ecological proxies in geographically distributed sediment cores. Sediment nitrogen isotopic ratio (d15N) in particular is being used as an indicator of perturbations of the nitrogen biogeochemistry. Higher d15N is expected from sewage inputs as well as from the initiation of subsurface denitrification during low O2 conditions. Contemporary correlation between eutrophication intensity and d15N is seen in sediment core top data which show a substantial 4 per mil increase in d15N going from eastern to western LIS. This observation is consistent with greater nutrient loading toward New York City with its greater coastal population density. Downcore data from a site in western LIS show 4 per mil lower d15N prior to 200 years ago, documenting the point at which significant anthropogenic impact began. Increasing d15N over the last 200 years correlate with productivity proxies and other proxies for anthropogenic influence.

GC41B-03 0900h INVITED

Paleoredox Reconstructions on the Century Time Scale; Place of Molybdenum in the Toolbox

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The need to set realistic goals for restoration of coastal environments calls for knowledge of conditions prior to anthropogenic impacts. Environmental monitoring data mostly span less than 3 decades, whereas human impacts have accrued for several centuries. Therefore, the pristine state of coastal environments usually is not determinable from archived data. Where restoration of eutrophic or hypoxic-anoxic ecosystems is contemplated, paleoredox indicators in dated sediments can be used to fill the knowledge gap. The requirement that sediments be datable limits application of this approach to deep, anaerobic sediments that are minimally turbated physically or biologically. Examples of indicators that have been found useful in Chesapeake Bay are trace elements (Mo, U), isotopes (15-N), organic biomarkers (fatty acids, sterols), bulk components (TOC, TON, biogenic silica, degree of pyritization) and microfossils (ostracods, diatoms, foraminifera). Most of these, especially those depending on viability of indicator organisms, respond to multiple environmental forcing factors. They therefore do not provide information solely about paleoredox conditions. Molybdenum concentrations in sediments appear to be an exception. Although Mo is biologically an essential trace element, its concentration in coastal and estuarine waters is large relative to needs of organisms, so biological mechanisms affect its distribution in a minor and often undetectable way. Even though Mo is enriched in coal vs. continental crust and is an important component of stainless steels, anthropogenic sources of Mo rarely control Mo concentrations in coastal sediments. Seawater is a strong and uniform source of Mo, dampening temporal variations in other sources to estuarine and coastal waters. Molybdenum is deposited in sediments primarily in Mn oxydyroxides, in Fe mono- and disulfides and in organic materials. The first of these is unstable and redissolves in the anoxic sediments that are most suitable for dating. Fe monosulfides are also ephemeral, but may be important in the initial capture of Mo. Fe disulfides have been reported to be the chief host phases of sedimentary Mo, but there is also good evidence for a competing role for organic matter. Depending upon circumstances, the degree of Mo enrichment in sediments can be controlled by chemical reactions or by diffusion. The key chemical reaction is transformation of molybdate to thiomolybdates, which occurs when molecular hydrogen sulfide in pore waters is near or above 10 micromolar. Thiomolybdates can react with zero-valent sulfur donors, such as polysulfides, to produce dissolved species which are readily sorbed to pyrite surfaces and which are probably reactive to organic materials.

GC41B-04 0915h

Geochemical Screening of Contaminated Marine and Estuarine Sediments

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Waterways near urban centers have been subject to pollution by human activities for centuries. This process greatly intensified with the advent of the Industrial Revolution and the attendant exponential population increase in coastal areas. The co-occurrence of port facilities for ocean-going vessels, large factories, major power generating stations, dense automotive transportation networks, and massive wastewater outfalls, all in compact geographical areas, has produced severe environmental stress. In recent decades, the growing awareness of the seriousness of coastal urban environmental degradation has inspired intensive efforts at pollution prevention and remediation. To better understand pollution dynamics over time in an aquatic urban setting, a program of intensive sampling and analysis leading to the creation of geographic information systems (GIS) would be desirable. Chemical evaluation of sediments for pollution remains a costly and time-consuming procedure, particularly for organic analysis. Pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS) offers a practical alternative for rapid, inexpensive molecular organic analysis, simply employing milligram quantities of dry, whole sediment. The compounds detected comprise an information-rich mixture of thermally extractable components and the products of the thermal decomposition of (bio)polymers present in the sample. These include PAHs, petroleum-derived hopanes, organonitrogen compounds, and linear alkylbenzenes, as illustrated with examples from Long Island Sound and the Passaic River (USA) and Barcelona harbor (Spain).

GC41B-05 0930h INVITED

Record of Environmental Change in San Francisco Bay, California

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Benthic foraminifera in a 3.52 m core recovered from San Francisco Bay, CA yield a 3,800-year sediment record of climate and environmental change. The microfaunal assemblage of the core contains abundant subtidal estuarine benthic foraminifers found today at shallow water depths (<10 m) in the bay. A Q-mode cluster analysis of the samples grouped them into two clusters and one outlier. Cluster A is dominated by the herbivorous species Elphidium excavatum; its abundance often comprises 70-90% of the foraminiferal assemblage. Today, the species typically resides in cold, estuarine waters. Its dominance in the core from 352-150 cm (1920 B.C. to A.D. 652) and 88-18 cm (from A.D. 1224 to A.D. 1980) suggests that this area of the bay has remained relatively cold and shallow for about 3400 years out of the last four millennia. Cluster B, the Ammonia beccarii-Elphidium gunteri association, occurs from 150-88 cm in the core and is interpreted as representing warmer and possibly lower oxygenated conditions from A.D. 652 to A.D. 1224. The outlier,

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

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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

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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

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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

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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.