Institute for Quaternary and Climate Studies

University of Maine

9th Annual Agassiz Symposium

Program and Abstracts

May 4-5, 2001
Soderberg Center, Orono

http://www.ume.maine.edu/iceage/

FRIDAY, MAY 4

12:00	Lunch
1:00	Marine Geology
1:45	Paleoecology
2:45	Break
3:30	Glacial Geology and Landscape Evolution
4:45	Keynote address

SATURDAY, MAY 5

8:00	Doughnuts and coffee
8:30	Glaciology I: Ice Cores
9:30	History of Science
10:00	Break
10:30	Archeology and Anthropology
12:00	Lunch
1:00	Climatology
1:30	Glaciology II: Glacier Dynamics
2:45	Adjourn

PROGRAM

FRIDAY, MAY 4

12:00-1:00	Lunch
	Marine Geology
1:00-1:15	**Belknap**, The Penobscot Paleodelta: A step in the Holocene transgression in Penobscot Bay, Maine
1:15-1:30	**Daly**, Late Holocene sea level change around Newfoundland
1:30-1:45	**Kelley**, Late Pleistocene/Early Holocene influences on modern estuarine sediment: Cobscook Bay, Maine
	Paleoecology
1:45-2:00	**Kellogg, T.**, Non-marine diatoms in Antarctic ice cores: Provenance and potential for use as indicators of past atmospheric transport paths
2:00-2:15	**Davis**, Hurricanes and landscape dynamics during the past millenium around Freshwater Lake, Dominica, W.I.
2:15-2:30	**Jacobsen**, Variations in Florida climate during the past 70,000 years are linked to both northern North Atlantic and Tropical Pacific phenomena
2:30-2:45	**Dieffenbacher-Krall**, Post-glacial and holocene lake levels in eastern Aroostook County: Work in progress
2:45-3:15	*Break*
3:15-3:30	**Houk**, El Niño and Molluscan Paleoclimate Records
	Glacial Geology and Landscape Evolution
3:30-3:45	**Hooke**, Time constant for equilibration of erosion with tectonic uplift
3:45-4:00	**VandenHeuvel**, Landscape evolution of the western Olympus Range, Southern Victoria Land, Antarctica
4:00-4:15	**Black**, Investigating the Little Ice Age signal in the Swedish Laplands: A comparative lichenometry study
4:15-4:45	**Denton**, Terminations from a Southern Hemisphere perspective
4:45-5:15	**Lowell**, The Great Lakes Lobes of the Laurentide Ice Sheet: Their view of the LGM **KEYNOTE**

SATURDAY, MAY 5

	Glaciology I: Ice Cores
8:30-8:45	**Kreutz**, Ice core records of Late Holocene climate variability in the Tien Shan Mountains, Central Asia
8:45-9:00	**Dixon**, Spatial soluble ion variability in snowpits along central West Antarctic US ITASE traverses
9:00-9:15	**Meyerson**, South Pacific variations in atmospheric circulation
9:15-9:30	**Mayewski**, Antarctic multi-decadal scale climate variability over the last 500 years
	History of Science
9:30-9:45	**Maasch**, Retrospective: John Kimball de Laski, 1814-1874
9:45-10:00	**Kellogg, D.**, The place of political and religious ideology in the scientific explication of evolutionary processes
10:00-10:30	Break
	Archeology and Anthropology
10:30-10:45	**Sanger**, Bone ceremonialism: A new approach to demography
10:45-11:00	**Dickinson**, Technology of a paleoindian stone tool
11:00-11:15	**Robinson**, Stone lines or cultural pavements from the early Holocene
11:15-11:30	**Tanner**, Lithic analysis of chipped stone artifacts recovered from Quebrada Jaguay, Peru
11:30-11:45	**Sobolik**, Cannibalism in the prehistoric American Southwest?
11:45-12:00	**Sanger**, Remembering Douglas Kellogg
12:00-1:00	Lunch
	Climatology
1:00-1:15	**Zielinski**, Toward a 300- to 400-year record of New England Nor'easters and their societal impact
1:15-1:30	**Lagerklint**, Sea-surface temperature and salinity estimates from the eastern equatorial South Atlantic linked to African climate for the last 27,000 years
	Glaciology II: Glacier Dynamics
1:30-1:45	**Spikes**, Motion and mass balance of the Allan Hills meteorite stranding surfaces, Antarctica
1:45-2:00	**Grosswald**, Deductive model of past glaciation in NE Siberia and Beringia
2:00-2:15	**Hughes**, The role of calving ice in initiating and terminating Quaternary glaciation cycles
2:15-2:30	**Fastook**, Marine embayment "white holes" yield alternative ice sheet initiation scenarios
2:30-2:45	**Hamilton**, Changes in the East Antarctic Ice Sheet at South Pole: Comparison between field measurements and modeled responses

KEYNOTE PRESENTATION

THE GREAT LAKES LOBES OF THE LAURENTIDE ICE SHEET, THEIR VIEW OF THE LGM

Lowell, T.V., Department of Geology, University of Cincinnati, Cincinnati, OH, 45221, USA, (Thomas.Lowell@UC.EDU)

Contrasting ice core records at high latitudes suggests an examination of glacier response at middle latitudes during the last glacial maximum (LGM) provides additional controls on the evolution of the full glacial climate system.

During the LGM the Laurentide Sheet extend fingers south of the Great Lakes to latitudes approaching 37°. These thin, land-based lobes provide sensitive trackers of millennial scale climate changes, but one challenge of such records is to understand the signal recorded. If the sawtooth pattern of abrupt changes recorded at high latitudes also occurs at middle latitudes, then arguments can be made that these glacial records track the transition from cooling to warming and thus allow comparison with other records.

For the Des Moines and Erie-Huron Lobes multiple dating of individual sites indicates advances at 13,790±23; 17,490 ±230 19,590 ±35, and 20,770±59 14C yr BP. Complementary stratigraphic evidence indicates an older warm interval ended about 22,800 14C yr BP. These timings indicate a pulsing climate system operated at the middle latitudes and taken at face value maximum occur at the same time as ice rafted debris peaks in the North Atlantic. In total, they suggest that the southern lobes of Laurentide Sheet displayed a "glacial maximum" extending from some 21,000 to 17,000 14C yr BP years before present in a pattern similar to that archived in the Greenland ice cores. At least the last major expansion appears to lag Alpine glacier behavior in the Southern Hemisphere significantly.

Retreat patterns are more problematic because few sites currently record events prior to Termination 1, but a limited number suggest ice-margin retreat was well underway prior to 15,770±80 14C yr BP in a pattern broadly similar to the slow decline recorded in the Antarctica ice cores. These patterns coupled with the observation that the total ice-sheet volume, as recorded in deep sea sediment, is still growing until 14,000 14C yr BP provide an interesting paradox. Why should the margin of the largest relic Ice Sheet begin to retreat during the LGM conditions?

One resolution is that the ice margins themselves record the high-frequency millennial scale oscillations because of sensitive response to ablation forcing whereas the overall position of the Laurentide Ice Sheet reflects a decrease in accumulation supply to the southern margins. Irregardless of the cause, it appears that the Great Lakes Lobes were situated to enjoy a complex view during the LGM.

MARINE GEOLOGY

THE PENOBSCOT PALEODELTA, A STEP IN THE HOLOCENE TRANSGRESSION IN PENOBSCOT BAY MAINE

Daniel F. Belknap, Allen M. Gontz, and Joseph T. Kelley. Department of Geological Sciences, Univ of Maine, 111 Bryand Global Sciences Bldg, Orono, ME 04469-5790

Recent high-resolution seismic reflection surveys reveal a series of prograding clinoforms preserved in paleo-fluvial, and estuarine channels in upper Penobscot Bay, Maine terminating in a Holocene paleodelta graded to a sea level of approximately -30 m ca. 8700 14C years BP. The geometry of these channels, their infill, and the lower and upper bounding surfaces constrain models of evolution of the bay in relation to changing rates of sea-level rise within the complex bedrock-framed glaciated coast. A well-preserved, buried channel with 20 m relief occurs in the eastern arm of Penobscot Bay, overlying glaciomarine sediments. The channel is filled with steeply dipping clinoforms that onlap and fill the channel. The eastern base of the channel is concentric with the underlying draped glaciomarine beds, while a chaotic reflector (channel lag?) underlies the thalweg. This succession is interpreted as a point-bar or prograding spit facies. The southern margin of these facies is a broad arcuate sand body with prominent clinoforms that prograde generally southward into a muddy and gas-rich estuarine facies. We informally name this system the Penobscot Paleodelta. It is buried under late embayment mud. Channels at the head of the paleodelta are cut by the tidal ravinement unconformity and abruptly overlain by Holocene embayment mud. The underlying paleochannel may represent the primary channel of the Penobscot River following deglacial rebound and relative sea-level fall to lowstand 50-60 m below present, approximately 10.8 ka. The major channel backfilled during early stages of transgression, and then migrated west. Abandonment of the channel may have occurred during the rapid rise in sea level between 10 and 8.5 ka. Alternatively, the major estuarine channel may have switched to the west of Islesboro Island. The thick Holocene muds and a large natural gas and pockmark field in that location, however, argue for a quieter depositional system, perhaps protected by a subsequently breached morainal sill. This newly recognized, well preserved paleodelta and channel infill facies may be strong evidence for rapid local relative sea-level rise in the early Holocene, that increased its preservation potential. Tidal ravinement surfaces remove early estuarine facies in analogous settings in several narrower estuaries on the Maine coast. Total sediment volume in the sandy paelodelta and channel facies is ca. 126 x 106 m3. This is comparable to all the sand in the shoreface of the Wells embayment (145 x 106 m3), larger than the total volume of sand in the Saco Bay barriers and shoreface (78 x 106 m3), but about an order of magnitude smaller than the Kennebec and Merrimack Paleodeltas. Coring and further seismic reflection profiling are planned for this year.

LATE HOLOCENE SEA LEVEL CHANGE AROUND NEWFOUNDLAND

J. Daly, D. Belknap, J. Kelley

Salt-marsh records of sea-level change indicate variable trends around Newfoundland during the late Holocene. Published numerical models predict a range of Holocene sea-level histories for the island due to the passage of a decaying glacial forebulge from southeast to northwest. We investigated the stratigraphy of salt marshes at four locations around Newfoundland: a) Hynes Brook, Port-au-Port Peninsula, b) St. Paul's Inlet, c) Deadman's Bay, and d) Southeast Arm, Placentia. At each location, we collected cores and surficial samples for foraminiferal analysis, and leveled the sampling locations. Cores were analyzed for vegetation and fossil agglutinated foraminiferal assemblages. Fossil foraminiferal assemblages are compared to modern surficial assemblages, and interpreted to determine a paleo-elevation range for a basal peat sample. Sea-level histories for each location are constructed by combining AMS ^{14}C dates with paleo-elevation ranges for a series of basal samples. Initial results indicate differential sea-level change during the late Holocene for Newfoundland. At three locations (Hynes Brook, Deadman's Bay, Southeast Arm) sea level has risen during this time. There is significant variation in sea-level trends along the west coast, however. At St. Paul's Inlet, sea-level change during the late Holocene appears to have a more complex history. Sea level has remained close to present over the past 2,000 years, but may have experienced a subtle transition from falling to rising between 2000 and 1000 years BP. This trend contrasts strongly with the transgression interpreted at Hynes Brook, approximately 160 km to the southwest, and supports the hypothesis of continuing glacio-isostatic influence on the Northern Peninsula. In addition, the salt-marsh

stratigraphy at each location was unique, emphasizing the influence of local processes on salt-marsh development and the stratigraphic record. The results of this study do not precisely constrain Holocene sea-level change for the Northern Peninsula, but do confirm the trends predicted by numerical models.

LATE PLEISTOCENE/EARLY HOLOCENE INFLUENCES IN MODERN ESTUARING SEDIMENT: COBSCOOK BAY, MAINE

Joseph T. Kelley, Alice R. Kelley, University of Maine, Department of Geological Sciences, Orono, ME 04469-5790

Cobscook Bay, ME, the easternmost estuary in the US, is the most important aquaculture and scallop fishing site in Maine. It appears typical of many rock-framed, formerly glaciated estuaries in northeast North America, but departs from traditional models of estuarine facies distribution. To characterize this macrotidal bay, earlier intertidal habitat maps and numerical circulation models were augmented by more than 100 km of seismic reflection and side scan sonar records. Models of estuarine sediment and facies distribution generally depict a gradational landward decrease in wave energy and increase in tidal/riverine influence within a rectangular box model. Surficial sediment is presumed to become finer grained away from the sea, with coarser sediment and migrating bedforms at the estuary mouth. Lacking significant quantities of sandy sediment, the outer area of Cobscook Bay is erosional, with truncated reflectors of glacial-marine sediment and bedrock cropping out extensively. The bedrock structure, a plunging anticline, provides numerous constrictions to water movement, generating modeled current velocities of 2m/sec and leaving the seafloor bare rock in many places. Near the entrance to the largest constriction, large gyres occur as tides change, and a thick deposit of Holocene mud has accumulated beneath them. Blocks of this mud appear to slump into the channel thalweg as they become oversteepened. Bedrock crops out in random locations throughout the bay, causing many scour holes, abrupt facies shifts and creating localized concentrations of carbonate sediment. Most of the remainder of the subtidal region is a gravel/sand lag deposit resting over glacial-marine mud. Tidal current lineations are the dominant sedimentary structures, with fishing drag marks also common. Fine sediment is most common on tidal flats, which abruptly transition to the coarse-grained subtidal areas. Lack of significant river contributions and sandy sediment, large tidal range and complex bedrock structure cause sediment distribution patterns in Cobscook Bay to differ from that of standard models.

DID PALEOINDIANS CO-EXISTS WITH REMNANTS OF LAURENTIDE ICE IN NORTHERN MAINE?

Harold W. Borns, Jr., Richard T. Will

The remnants of the Laurentide Ice Sheet in northern Maine thinned over the higher elevations, separated and stagnated as masses in the basins of Chase and Munsungan Lakes, and other lowlands, finally disappearing by about 10,000 years ago. Between 11 and 10,000 years ago, an interval known as the Younger Dryas cold time, the wasting ice expanded as recorded near Oxbow, south of Ashland, Maine. Presently the levels of the adjacent south-draining lakes, Chase and Munsungan, are controlled by bedrock thresholds at the Thoroughfare between the lakes, and at the south end of Munsungan. When wasting ice blocks occupied the Chase and Munsungan Lake basins the Thoroughfare channel was filled with glacial deposits. When the ice to the south of Munsungan wasted, it allowed the lake to drain to its present level. Consequently, Chase was then allowed to drain into Munsungan by cutting a terraced channel into the glacial deposits of the Thoroughfare.

Paleoindian lithic artifacts of Munsungan chert are found only on the high terrace in the Thoroughfare while the younger archaic-age artifacts are commonly present on the lower terraces. Because of this history it is hypothesized that the lower terraces did not exist at Paleoindian time because down-cutting drainage was prevented by the ice masses primarily in Munsungan Lake and to the south of Munsungan. Hence, it is concluded that the Paleoindian presence coincided with large dissipating ice masses, and that the people occupied in the Thoroughfare area in order to procure very desirable Munsungan chert from adjacent Norway Bluff for making artifacts in the time range of 11 to 10,000 years ago.

PALEOECOLOGY

NON-MARINE DIATOMS IN ANTARCTIC ICE CORES: PROVENANCE AND POTENTIAL FOR USE AS INDICATORS OF PAST ATMOSPHERIC TRANSPORT PATHS

Thomas B. Kellogg and Davida E. Kellogg

In this paper we evaluate the possibility of using non-marine diatoms found in Antarctic ice cores and other high-altitude deposits to ascertain past variations in atmospheric transport of particulates and precipitation. This analysis is possible for the first time because we recently completed a compilation of over 1575 known non-marine diatom species' occurrences from Antarctica (~350 sites) and the Subantarctic (~75 sites) (Kellogg & Kellogg, 2001). A total of 293 taxa were found to be restricted to Antarctic coastal locations and the islands south of the Antarctic Convergence (e.g., South Shetlands, South Orkneys, South Georgia). Many of these taxa are known from other locations elsewhere in the world, but they have not been reported from the Subantarctic areas included in our data base. An additional 740 species occurred only at Subantarctic sites in South America, New Zealand, Tasmania, Australia, or the oceanic islands, and 542 species have reported occurrences in both the Antarctic and Subantarctic areas.

Seventy-four of these non-marine taxa have been reported to date from high-elevation sites in Antarctica. Eight species have been reported only from Antarctic locations, all from the Ross or Antarctic Peninsula sectors; 10 solely from Subantarctic sites, one only from New Zealand, one from New Zealand and Australia, and 3 only from South America. For the remaining 51 taxa reported from both Antarctic and Subantarctic locations, 32 species, including all those reported at 30 or more locations were dominantly from Antarctic sites. Most (13) of the remaining 19 taxa had higher proportions at Subantarctic sites but were known from less than 15 locations, and two had equal numbers of Antarctic and Subantarctic species. We conclude that while the possibility exists that some taxa known from both the Antarctic and Subantarctic may have been transported to high-elevation sites from Subantarctic locations, the existing database of modern species distributions would seem to suggest that this is at best a possible, but not most likely interpretation.

We conclude by showing possible changes in source of precipitation and precipitates for four different levels in the South Pole ice core. These include samples at and immediately before the Little Ice Age. While the changes in source area are subtle, they appear to suggest a switch from the Antarctic Peninsula area to the Ross Embayment.

HURRICANES AND LANDSCAPE DYNAMICS DURING THE PAST MILLENNIUM AROUND FRESHWATER LAKE, DOMINICA, W.I.

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A 9.76 m long, 10 cm diameter piston core was obtained in 1997 from Freshwater Lake on the West Indian island of Dominica. The 4.1 ha, 15 m deep lake is located at 750 m asl. It is surrounded by young montane rain forest that has regenerated since Hurricanes David and Allen in 1979 and 1980. The lake sits in a moat between the eastern rim of a 2 km wide volcanic crater and a massive dacite dome that rises 470 m above the lake. Excessive rainfall (~8 m/yr), rapid weathering of dacitic rock, non-anthropogenic and anthropogenic disturbances, and steep slopes above the lake result in intense erosion, high sediment accumulation rates in the lake, and an exceptionally detailed record of disturbances and landscape conditions over the past millennium. At 8.90 m sediment depth, the sharpened core tube encountered a tree fern trunk in vertical position, cored 0.26 m through it and then through 0.6 m of compacted, washed sand and gravel to rejection on rock at 9.76 m. Carbon-14 dates on the trunk and a wood fragment from the gravel, and sediment properties suggest that a stream and forest occupied the moat, and that the stream was dammed around 980 AD. In this seismically active area, it is likely that an earthquake initiated the andslide that blocked the drainage. After lake formation, continued catchment instability and high sediment input to the lake resulted in deposition of ~3.5 m of dacitic silts and fine sand at the coring site. This rapidly (<100 yr) deposited material is nearly devoid of clay minerals and aquatic microfossils. The ensuing 5.4 m of deposition was much slower, consisting of lake sediments rich (25-65%) in organic matter including

abundant well-preserved remains of terrestrial and aquatic biota. In this section, until 1961, there is an underlying cyclicity of 33 and 14 years in LOI and % water profiles, assuming uniform sediment accumulation rates between dates. Several major non-cyclic peaks of LOI and total plant debris display also occur. I postulate [for prehistoric time (pre-1493)] that these non-cyclic peaks were caused by hurricane defoliation of adjacent rain forest. More recent peaks correlate with documented historic hurricanes. This approach has considerable potential for chronicling prehistoric hurricanes. These rain forests have undergone frequent disturbances, maintaining an abundance of early successional species. Starting in 1961, a series of power dams and diversion to the lake of runoff from an adjacent catchment have raised lake level and increased inflow. Lead-210 dating and 137Cs/241Am chronostratigraphic markers indicate that since these disturbances began, mean sediment accumulation rate has been 4.4 cm yr-1. Analyses of this sediment and soil cores from the catchment indicate extreme high inventories of 210Pb, commensurate with the extremely high rainfall.

VARIATIONS IN FLORIDA CLIMATE DURING THE PAST 70,000 YEARS ARE LINKED TO BOTH NORTHERN NORTH ATLANTIC AND TROPICAL PACIFIC PHENOMENA

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Well-documented shifts in paleo-vegetation are revealed in a 70,000-year stratigraphy of fossil-pollen and other lake-sediment data from Lake Tulane, Florida. Recent studies have confirmed the temporal association of Tulane pine peaks with Heinrich layers deposited by late-Quaternary ice rafting in the northern North Atlantic.

Close analyses of the Tulane pollen stratigraphy reveal that conditions during several of the mid-Wisconsinan pine peaks closely resemble those of the late Holocene in Florida. Significant temporal variations of Holocene ocean temperatures in the eastern-tropical Pacific appear to match the timing of key events in the Tulane stratigraphy. Such linkages between events in peninsular Florida, the eastern-equatorial Pacific, and the northern North Atlantic imply global mechanisms involving both ocean currents and atmospheric circulation.

POST-GLACIAL AND HOLOCENE LAKE LEVELS IN EASTERN AROOSTOOK COUNTY: WORK IN PROGRESS

Ann C. Dieffenbacher-Krall, Harold Borns, George L. Jacobson, James Fastook, Institute for Quaternary and Climate Studies, University of Maine, Orono, ME 04469

Preliminary data suggest that Holocene lake-level fluctuations of Eastern Aroostook County were comparable to those reported for Mansell Pond, Alton, Maine. A transect of cores from Whited (Whitehead) Lake, Bridgewater, provides evidence of shoreline recession and rises for the past 12,000 years. Maximum water depths are inferred based on the macroscopic remains of aquatic and terrestrial plants found in the sediment, as well as the composition of the sediment matrix. Radiocarbon dates will confirm whether the timing of observed hydrologic changes coincides with that of Mansell Pond. The Whited Lake study will provide the second lake-level reconstruction for Maine and will greatly augment current knowledge of post-glacial and Holocene water balance of Northeastern North America. Results of lake-level research and chironomid-based estimates of past temperatures, along with geologic evidence, will be included in a computer model of the remnant Younger Dryas ice cap of northern Maine.

EL NIÑO AND MOLLUSCAN PALEOCLIMATE RECORDS

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Climate records constructed from growth increment and stable isotope analyses of modern and fossil mollusks from the north coast of Peru provide a high-resolution proxy for interannual sea surface temperature (SST) oscillations. Oxygen isotopes were measured in fossil and modern mollusk shells along the axes of maximum growth. Acetate peels of shell cross-sections record daily and semi-daily growth

increments. The locations of drilled samples taken for oxygen isotope analyses are visible in the acetate peels. SST time series are constructed by counting the number of growth increments between and contained in each drilled sample.
Both modern and mid-Holocene (5-7 ka) shells have been analyzed. Modern shells include *Trachycardium procerum*, *Chione subrugosa*, and *Anadara tuberculosa*. The ancient shells are *C. subrugosa*, *A. tubersulosa*, and *Protothaca ecuatoriana*. The age of the mollusks at time of death ranges from 3 to 5 years. Short time series with 3 to 5 annual SST cycles can be used to test the hypothesis that prior to 6 ka, El Niño cycles did not occur as they do today. This hypothesis suggests that warm-tropical water of the Panamanian biogeographic province extended 500 km south of the modern boundary with the Peruvian biogeographic province prior to 6 ka. Collections of warm-tropical mollusks from archaeological shell middens in what is today the Peruvian biogeographic province support this hypothesis.

ISOTOPIC COMPOSITION OF HOLOCENE GASTROPODS IN WHITED LAKE, MAINE.

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A 6.6m core was taken from the deepest part (350cm) of Whited Lake (46.4556°N, 67.8639°W) in eastern Aroostook County, Maine. The core sediments were predominantly interbedded calcareous marl and gyttja. A dense, blue-gray clay is present at the base of the core. This is commonly recognised in Maine lake-cores as the Late glacial. From this point to the top there are no sediment hiatuses, and thus the core displays a complete record of the Holocene. Six different species of gastropod were recognised within the sediments, with the most commonly occurring species being *Gyraulus circumstriatus*. Samples of this species were picked from fifteen intervals within the core. Small sample populations of the shells removed from each interval underwent stable isotope ($\delta^{18}O$, $\delta^{13}C$) analysis. Values of $\delta^{18}O$ varied between -6.6‰ and -8.5‰, and values for $\delta^{13}C$ varied between -4.4‰ and -6.8‰, indicative of freshwater conditions. The trends in $\delta^{18}O$ and $\delta^{13}C$ were similar, displaying significant covariance ($r=0.622$, $P<0.0001$). Between 740cm and 530cm depth in the core there is a general decrease in both $\delta^{18}O$ and $\delta^{13}C$. Above 530cm, both $\delta^{18}O$ and $\delta^{13}C$ increase, and this increase continues to the top of the core. The variations in $\delta^{18}O$ and $\delta^{13}C$ within the core are interpreted as regional Holocene climate variability affecting the lake basin. One hypothesis is that the decrease in $\delta^{18}O$ is an indication of altered seasonal precipitation distribution such that a greater percentage of the annual precipitation occurred during the winter months when the precipitation is isotopically light.

GLACIAL GEOLOGY AND LANDSCAPE EVOLUTION

TIME CONSTANT FOR EQUILIBRATION WITH TECTONIC UPLIFT

Roger LeB. Hooke

Following a change in the rate of tectonic activity, such as a change in the rate of convergence in a continent-continent collision zone, the rate of rock uplift changes. This will result in a change in the rate of erosion, as the erosion rate varies directly with relief. Eventually a new steady state is reached in which the rock uplift rate equals the erosion rate. An analysis based on perturbation theory shows that the time constant for this adjustment is of order 10^6 years, which, while appreciable, is short compared with the time scale of orogeny.

LANDSCAPE EVOLUTION OF THE WESTERN OLYMPUS RANGE, SOUTHERN VICTORIA LAND, ANTARCTICA

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The Transantarctic Mountains (TAM) represent a rift-margin upwarp associated with development of the early-Cenozoic West Antarctic Rift System. The Olympus Range, in the Dry Valleys sector of the TAM, features a relict butte and mesa topography that likely represents fluvial erosion accompanying initial rifting about 55 Ma. Superimposed on the butte and mesa topography is a widespread erosion surface. This surface includes dissected drift sheets, huge channels scoured to bedrock, potholes, and corrugated bedrock. . One hypothesis to explain the erosion is wind deflation and chemical weathering under current desert conditions. An alternate hypothesis suggests the erosion was a product of sub-glacial meltwater during a major expansion of the East Antarctic ice sheet. In order to differentiate between the two hypotheses, I mapped the glacial geomorphology and surficial stratigraphy of the western Olympus Range. Pristine boulder belt moraines that rest directly on the erosion surface indicate that the corrugations, channels, and dissected drift are not forming today. If true, then wind deflation and chemical weathering are not effective geomorphic agents. I collected thirty sandstone boulders on nine different moraines that rest directly on the erosion surface for ^{3}He cosmogenic radionucleide analysis. I will complete the cosmogenic analyses at the University of Edinburgh in August under the direction of William Phillips. A significant byproduct of this research is the development of a radiometric chronology of the alpine glacier expansion in the western Olympus Range that post-dates the erosion surface.

INVESTIGATING THE LITTLE ICE AGE SIGNAL IN THE SWEDISH LAPLANDS: A COMPARATIVE LICHENOMETRY STUDY

Jessica L. Black, Institute for Quaternary and Climate Studies, University of Maine.

The Little Ice Age (LIA) was a late Holocene interval of climate cooling registered in the North Atlantic region by expansion of alpine glaciers and sea ice. Here the LIA includes an early phase from about AD 1280 to AD 1390, along with a main phase from about AD 1556 to AD 1860, followed by warming and ice. In the Swedish Laplands, individual advances during the main phase of the LIA culminated about AD 1916, 1890, 1850, 1780, 1710, and about 1500 to 1640. The validity of the lichenometry method used to date the glacier advances in the Laplands has been questioned. To verify results from his initial study in AD 1973, Wibjorn Karlen remeasured three glaciers in the Swedish Laplands, using the 5 largest lichen technique: Isfallsglaciären, Storglciären, and Kårsjökeln. *Rhizocarpon geographicum* and *Rhizocarpon alpicola* are considered the lichen species most useful for dating glacial deposits in the Swedish Laplands, and were measured in this study.

A new lichenometry technique, the Fixed Area Largest Lichen (FALL) method pioneered by Bull and Brandon (1998), was adapted for dating Holocene moraines in the Southern Alps of New Zealand. The FALL method allows for a large sample size (n=100) that can filter out effects of differential growth rates, effects of microclimate, and operator error. In the Swedish Laplands, the FALL method was used alongside the 5-largest lichenometry method to test for the differences between the two methods, and act as a test for the applicability of the newly developed FALL method. A series of historically dated sites were measured

using the FALL method in order to construct a lichen growth curve for the Swedish Laplands. Preliminary results show the 5 largest lichen technique is remarkable consistent. The results from the FALL method are pending.

TERMINATIONS FROM A SOUTHERN HEMISPHERE PERSPECTIVE

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New paleoclimatic records from temperate and polar latitudes of the Southern Hemisphere suggest the following sequence of events during terminations. The planet north of the Southern Ocean reaches glacial maximum conditions. As a result, the rate of formation of North Atlantic Deep Water is sharply curtailed from a high flux of icebergs shed by ice sheets that extend to the edge of North Atlantic continental shelves. Because of the behavior of bipolar seesaw of thermohaline circulation, this leads to greatly increased production of Antarctic bottom water, pulling relatively warm water at depth into the Southern Ocean, where it upwells to warm high southern latitudes. Hence, Antarctica begins a long and slow warming even as the rest of the planet remains locked in glacial maximum conditions. The rise in trace gases that accompanies this early Antarctic warming finally reaches the threshold for abrupt termination of glacial conditions elsewhere on the planet. The first step involves snowline rise that causes retreat of alpine glaciers in both hemispheres, along with fluctuating recession of the Scandinavian, Laurentide, and Cordilleran Ice Sheets. The marine equivalent is the massive collapse of ice from North Atlantic continental shelves during the last Heinrich event in each glacial cycle. Of course, this collapse cripples the glacial mode of the Atlantic salinity conveyor. But after the collapse is complete, the conveyor circulation reorganizes abruptly into its interglacial mode of operation. This reorganization was the fundamental event that completed the termination and switched the global climate system into an interglacial mode. The probable reason for this reorganization is that the Heinrich collapse is large enough to deplete the grounded marine ice reservoir and its feeder ice streams adjacent to the North Atlantic. Therefore, once the collapse ends, the North Atlantic becomes largely free of icebergs for the first time since early in the long buildup phase of a 100,000-yr asymmetric cycle. North Atlantic salinity can then increase rapidly, triggering renewed vigorous downwelling in the Nordic Seas.

Large ice sheets are required to produce a termination for two reasons. First, by curtailing production of North Atlantic Deep Water, they are indirectly responsible for early Antarctic warming and the concomitant rise of atmospheric trace gases. Second, only large ice sheets can produce a gravitational collapse massive enough to reset the North Atlantic salinity conveyor into an interglacial mode. The Younger Dryas climate reversal simply confuses any attempt to understand terminations, for such a reversal is present only in the most recent of the last four terminations.

GLACIOLOGY I: ICE CORES

ICE CORE RECORDS OF LATE HOLOCENE CLIMATE VARIABILITY IN THE TIEN SHAN MOUNTAINS, CENTRAL ASIA

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Ice cores recovered from selected high-elevation sites in Asia can provide robust information on climate and environmental variability, as has been demonstrated from the Sentik, Dunde, Guliya, Xixabangma, and Mt. Everest cores. While the existing ice core records provide an invaluable record of climate change in central Asia, they do not provide adequate spatial coverage to fully document past climate variability for this geographically large and diverse region. Moreover, high-resolution (annual to decadal-scale) ice core records which have been calibrated to instrumental records, and which span at least the last few hundred years, are not available.

In contrast to the Tibetan/Himalayan ice core records that have been recovered in regions dominated by monsoon circulation, the Tien Shan Mountains lie on the upwind side of Tibetan Plateau and act as the initial barrier in central Asia to the westerly jet stream and Siberian High. During summer 2000, a multi-institutional project funded by NSF and DOE recovered two 165 m firn/ice cores from elevations of 5100

and 5120 masl in the accumulation zone of the Inilchek Glacier, Central Tien Shan Mountains, Kyrgyzstan. The overall goal of the project is to develop high-resolution paleoclimatic records covering the last 500 years, which will be calibrated with meteorological data from the robust station network in the former Soviet Central Asian countries including several high elevation stations in the Tien Shan. Initial results of the project, including modeling of regional precipitation isotope data, and continuous dD records from both cores, will be presented.

SPATIAL SOLUBLE ION VARIABILITY ALONG CENTRAL WEST ANTARCTIC US ITASE TRAVERSES

Dan Dixon

Ice cores collected during oversnow traverses, such as US ITASE, offer the potential for mapping the distribution and impact of major atmospheric pressure systems affecting Antarctica. Snowpits from traverses across central West Antarctica are used to investigate recent characteristics of major West Antarctic air masses. The snowpits are 2m deep (each covering approximately 3-5 years), spaced approximately 75-100km apart and centered around Byrd Station. The snowpit samples, collected and analyzed at 2cm resolution, were examined for their soluble major ion and methyl sulfonate content (Na^+, K^+, NH_4^+, Mg^{2+}, Ca^{2+}, Cl^-, NO_3^-, SO_4^{2-}, MS). Beta and gamma-spec profiles taken from shallow cores along the transect are used to verify annual accumulation rates estimated from seasonal ion signals in the snowpits. These data sets are used to evaluate temporal and spatial variations in accumulation, glaciochemical concentration and flux relationships.

SOUTH PACIFIC VARIATIONS IN ATMOSPHERIC CIRCULATION

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The Siple Dome A-Core deep drilling project in West Antarctica provides a detailed look into long-term climate variations. High resolution (approx. bi-annual sampling) ion chromatography analysis was conducted on this core to produce glaciochemical time series of the major cations (Na, Mg, Ca, K) and anions (Cl, SO4, NO3). Previous work has linked variations in the Siple Dome glaciochemistry to atmospheric pressure changes in the Amundsen-Ross Seas region of the southern Pacific Ocean. This instrumental calibration allows the Siple Dome ion chemistry to be used to investigate past atmospheric circulation changes in this region of the Southern Pacific.

The background sea-salt trend in the Siple Dome is generally increasing from the mid-Holocene (approx. 5000 years before present) to the present. The corresponding trend in insolation at 60 degrees South Latitude for this time period is decreasing for the season of sea-salt deposition (September-October). This relationship is inverse to the background sea-salt values over the same period in the Greenland Ice Sheet Project Two (GISP2) (O'Brien et al., 1995). GISP2 displays decreasing sea-salt values over the same time period that correspond to an increasing trend in insolation at 60 degrees North in the winter (December-February), the season of sea-salt deposition at GISP2. The relationship between the orbital cycles and atmospheric circulation variations represented by the ice core sea-salts appear to have influence on long-term time scales as well as in conjunction with other climate events. These background trends in sea-salts also have an influence on the transition into the Little Ice Age (LIA) climate change event seen at Siple Dome and GISP2. Kreutz et al. (1997) discussed the presence and timing of the onset of the LIA at Siple Dome and compared this to the LIA signal seen in the GISP2 sea-salt (O'Brien et al., 1995). The recent extension of the Siple Dome time scale shows that there is a relatively gradual increase of sea-salt into the LIA, as opposed to a rapid shift to higher sea-salts in the GISP2 record. This difference is due to the superimposing of the LIA event on opposing background trends in sea-salt.

In addition to constructing a longer bipolar comparison between Siple Dome and Greenland, the Siple Dome record helps complete a transect of chemistry sites across the Pacific sector of Antarctica. The quality of these ice cores records (Siple Dome, Taylor Dome, South Pole, Law Dome) allows for detailed survey of the last 1000 years. Variations in these records show climate events within the LIA that have

similar timings and structure as seen in the tree ring Carbon-14 residuals (proxy for solar irradiance). There are, however, differences in these cores that most likely arise from the different atmosphere circulation patterns across the Pacific sector of Antarctica.

ANTARCTIC MULTI-DECADAL SCALE CLIMATE VARIABILITY OVER THE LAST 500 YEARS

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High resolution ice core environmental records from South Pole and Law Dome (East Antarctica) and Siple Dome (West Antarctica) have been calibrated with instrumental series of sea level pressure and sea ice extent to develop proxies for the latter.

The robust spline component of the South Pole MS record and sea ice extent in the Amundsen-Ross Sea (A-RS) region share 55% of their variance in common. The South Pole MS series and the Southern Oscillation Index (SOI) share 25% and 50% of their variance, respectively (Meyerson et al., in review).

The annual seasalt record developed from the Law Dome ice core is significantly correlated to June mean sea level pressure across a broad area of East Antarctica and adjacent regions of the Indian Ocean sector of the Southern Ocean ($r=.41$ to .65, $p<.05$) (Souney et al., in review).

The annual seasalt record from Siple Dome is significantly correlated with variability in the Sept-Nov behavior of the Amundsen Sea Low and Sept – Nov sea level pressure in adjacent regions of the Pacific Sector of the Southern Ocean ($r=.32$ to .75, $p<0.001$) (Kreutz et al., 2000).

Comparison of these ice core proxies for sea level pressure and sea ice extent, and:
Law Dome stable isotope series (Morgan et al., 1991).
Law Dome carbon dioxide series (Etheridge et al., 1998)
plus
Tree ring $\delta^{14}C$ residual series Stuiver and Braziunas, 1993)
over the last 500 years demonstrate interesting associations that are important in understanding Antarctic multi-decadal scale climate variability.

(1) The South Pole ice core record reveals the impact of the ENOS phenomena at South Pole.
(2) The Davis Sea Low (DSL) deepens and migrates east when Law Dome temperatures decrease,
(3) DSL and ASL behavior is similar over the last 500 years,
(4) Major breaks exist in all records near the end of the Maunder Minimum (1750-1800).
(5) All records reveal 20-30, 35-40 and 80+ year periodic behavior suggesting similar climate forcing and a possible association with the ~20 and ~70 year quasi-periodic behavior of the Pacific Decadal Oscillation..
(6) Strong associations exist between the $\delta^{14}C$ proxy for solar variability and major climate events in the Siple Dome record (Kreutz et al., 1997), and the proxies for atmospheric circulation, temperature, and sea ice from South Pole and Law Dome records. This strong association suggest that solar-climate forcing plays a role in Antarctic multi-decadal scale climate variability.

ISOTOPIC COMPOSITION OF SNOWFALL IN THE ECUADORIAN ANDES

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Water isotope ($\delta^{18}O$ and δD) data from fresh snow samples collected on Ecuadorian glaciers during January 2001 (EC01) are used to investigate high-altitude precipitation processes in the northern Andes. To examine source, location, and/or elevation effects on precipitation isotopic composition, snow samples were collected along altitudinal transects on three peaks: Cayambe, Cotopaxi, and Chimborazo. Average

isotopic values at the three sites are consistent with data from regional sites in the Global Network of Isotopes in Precipitation (GNIP). The local mean water line (LMWL) extrapolated from January data of the fourteen GNIP sites (slope ≈ 7.2) is similar to the LMWL from Cayambe (8.7), Cotopaxi (9.1), and Chimborazo (8.4). However, the difference in LMWL may reflect variability in hydrological processes, particularly at high elevation. There is a correlation between increased elevation and decreased $\delta^{18}O$ values when the GNIP and EC01 date are compared together. However, data from individual EC01 sites display a weaker trend with respect to elevation and $\delta^{18}O$, suggesting that over a limited elevation range temperature-driven equilibrium fractionation is not significant. Deuterium excess (*d*) values from both GNIP and EC01 sites vary with both elevation and location, and particularly with longitude; sites within the Andes have d values that are 5-10 ‰ higher than coastal sites. Thus, *d* values may provide an additional method for investigating moisture sources and transport in the Andes.

HISTORY OF SCIENCE

RETROSPECTIVE: JOHN KIMBALL DE LASKI, 1814-1874

Kirk A. Maasch, David C. Smith, and Harold W. Borns, Jr.

John Kimball de Laski was born June 9, 1814 in St. John, New Brunswick. He married Anne Wise in Eastport, Maine on July 27, 1839. Children were born in Lubec and Elliottsville. In the early 1850's the family moved to Vinalhaven, and then to Iron Point, and later the village on North Haven. Dr. de Laski practiced medicine for nearly 30 years, during which time he also carefully observed the Maine landscape. He meticulously described, in minute detail, the evidence on the ground of former extensive glaciation of the region. Through the decade of the 1860s he compiled his observations into a book manuscript which never ended up being published (although pieces of it were in the local newspaper, and as a paper in the American Journal of Science). It is apparent that de Laski had an appreciation for the immensity of the ice sheet that once covered much of North America. In the preface of his book de Laski wrote "In presenting the following pages to the public, I am actuated by the conviction that the views hitherto had of the ancient great Glacier of North America, by scientific men as well as by geological readers generally, have not come up to the magnitude of the mass, nor to the gigantic work which it has performed upon the floor of our continent." John de Laski died on December 11, 1874 while he was still a resident of Carver's Harbor (the village of Vinalhaven). We plan to publish de Laski's book, along with a short biography of the man and a description of how his scientific endeavors fit into the historical development of ice age theories.

THE PLACE OF POLITICAL AND RELIGIOUS IDEOLOGY IN THE SCIENTIFIC EXPLICATION OF EVOLUTIONARY PROCESSES

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On the one hand, the scientific method requires the evolutionary biologist to act as a close approximation of the ideal objective observer, whose overruling concern is to elucidate the empirical facts of how organic life on Earth evolves. On the other, he is warned at every turn by writers like Gould and Eldredge, Lewontin, and more recently, Bradie, that the observations of even the most disinterested and dispassionate among them cannot help but be colored by the all-pervasive *Weltanschauung* of the society in which he lives. No-one, no matter how clear-eyed and clinically unemotional, can resist having his powers of observation and reasoning corrupted by these extra-scientific influences, especially, we are repeatedly lectured by Socialist colleagues and reviewers, if he happens to live and work in a capitalist society. Even a personality as withdrawn as Darwin stands accused of underwriting the economic and social injustices of the Victorian English elite by his characterization of evolution as gradual change through the agency of natural selection. "When Darwin cleaved so strongly to gradualism - ignoring Huxley's advice that he did not need it to support the theory of natural selection - he translated Victorian society into biology where it need not reside," Gould and Eldridge have charged, though I suspect that Darwin was more concerned with distinguishing organic speciation from the Biblical account of Creation than with justifying sweat shops, child labor, and the British Raj. In addition, Feminists make cases of varying strength that the (male) sex of

the overwhelming majority of evolutionary biologists has been at least as confounding an influence on their science as their political or religious persuasions.

According to Lewontin, social influences manifest themselves in the particular metaphors we all use as lenses to focus our observations into hypotheses about the nature of organic evolution. And these metaphors have, he warns, a "powerful grip on our [biological] thinking," whether we are conscious of them or not. The proposition that no matter how conscientiously we might endeavor to observe the natural world, we are all proceeding under the confounding influence of highly subjective personal and cultural biases raises the truly chilling question of whether it is even possible to do objective science at all. Moreover, since the observations the evolutionary biologist makes may not only be affected by, but may seriously affect society, he may have an overriding moral obligation, analogous to that of the physician, to "first, do no harm" in making public his hypotheses, data, and conclusions, as those of us whose research is supported by government agencies are legally obligated to do. In the wake of sociobiology, genetic engineering, and "ethnic cleansing," the feeling has grown up among many evolutionary biologists that it is not enough to do work that is scrupulously honest, but that it must be morally responsible as well. The assumption of such responsibility implies that place must be made for ethical considerations and their political, socio-economic, and religious expressions in the practice of science. What I examine in this paper is whether a legitimate place for such subjective considerations can be made in scientific thought and procedure without compromising the objectivity of both observed results and conclusions, and, if so, where that place might be.

What so many American scientists of my generation, largely unschooled in philosophy of science, seem to imagine is that there is a disconnect between ethics and science that forces them to choose between a socially conscious and a rational approach to science, when in fact, when in fact they are both rational processes in which intellectual honesty is a *sine qua non*.. The choice for the evolutionary biologist of conscience seems to me to be not between politically motivated "bourgeois" and "proletarian" research programs that dictate *a priori* what experimental results, observations, and interpretations of data are acceptable, but in the making of reasoned ethical decisions as to the uses to which the honestly arrived at results of a rational research program are to be put. Here is where I believe that a rational and socially conscious intersection of religion and /or politics with philosophy of science (Ruse, 1991) resides.

ARCHEOLOGY AND ANTHROPOLOGY

BONE CEREMONIALISM: A NEW APPROACH TO DEMOGRAPHY

David Sanger, Anthropology and Quaternary Studies.

Using artifacts and settlement pattern data leading to seasonality reconstructions, I previously hypothesized two populations for pre-European Maine—coastal and interior.
Indications of the "two population" model extend to 5,000 B.P., but are especially strong for the Ceramic period (3,000 to 350 B.P.). Examination of differential bone disposal patterns between coastal and interior sites suggests different attitudes towards animal prey. Given the strong ethnographic evidence for the inseparable link between humans and animals, it suggests that the differential pattern of bone disposal seen in the archaeological record may reflect two different philosophies towards correct ceremonial behavior. It is suggested that this spiritual evidence combines with the material culture and seasonality data to reinforce the "two population" model.

TECHNOLOGY OF A PALEOINDIAN STONE TOOL

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A morphological and technological analysis of spurred end scrapers from two Paleoindian sites (ca. 10,500 years B.P.) are compared with respect to continuity and variability to spurred end scrapers from two Late Maritime Woodland sites (ca. 500 years B.P.). The range of technological variation of the spurred end scrapers between the two culture periods was determined. An analysis of the spurred scrapers from the four sites indicates similarities between culture periods in the type of lithic materials employed in tool production, as well as the initial stages of core technology. Variability occurs in the later development of

the spur. The similarity and variability identified between culture periods was then applied to two multi-component sites in New Brunswick. Both sites have spurred end scrapers that morphologically resemble those from the two Paleoindian sites analyzed. However, no other evidence of a Paleoindian component has been identified at the sites. An analysis of the spurred end scrapers from the New Brunswick sites has not determined that a Paleoindian component does exist, but suggests further investigation is warranted.

STONE LINES OR CULTURAL PAVEMENTS FROM THE EARLY HOLOCENE

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Between 7500 to 8500 radiocarbon years B.P. there is evidence that Northeastern cultures buried some of their dead in large, semi-subterranean pits or chambers that held relatively few individuals. These are the earliest burials known in the far Northeast (from southern New England to Labrador) and they are potentially the most labor intensive burial facilities up until at least 3000 years ago. One problem is that the earliest cemeteries in southern New England were all excavated by avocational archaeologists between 20-70 years ago, when few archaeologists recognized the effect of soil development processes on very early archaeological sites. This presentation represents work-in-progress evaluating a major site on the Merrimack River, on the southern Gulf of Maine.

LITHIC ANALYSIS OF CHIPPED STONE ARTIFACTS RECOVERED FROM QUEBRADA JAGUAY, PERU

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Quebrada Jaguay, a Terminal Pleistocene to Early Holocene archaeological site in Southern Peru, is recognized as one of the few sites in the Americas that features evidence of a Paleoindian maritime adaptation. Lithic remains recovered from the site over the course of two field seasons provide information about the technology of the site's inhabitants and afford comparisons with other contemporary sites. A systematic survey of several potential quarry sites offers useful information about source locations and compliments the lithic analysis. At Quebrada Jaguay, there is a strong preference for finer-grained materials during the earliest occupation, with a wider variety of materials present later on. In general, as distance from the quarry increases, waste-flake size decreases. Lithic materials from the various components indicate later stage reduction, with primary production focused on the manufacture of use flakes from prepared cores, as well as the maintenance of bifacial and unifacial tools. In the Early Holocene component from the site, there is a shift from late-stage reduction to initial reduction. Quantification of debitage attributes permits the comparison of Quebrada Jaguay lithic materials to materials from Quebrada Tacahuay, another late Pleistocene maritime site.

CANNIBALISM IN THE PREHISTORIC AMERICAN SOUTHWEST

Kristin Sobolik

In this paper, I discuss the human skeletal remains of eight individuals from the Grinnell Site, a site in southwestern Colorado that has been used by other researchers as evidence of cannibalism in the prehistoric Southwest. This study is a comprehensive reanalysis of the human remains with focus on potential evidence for cannibalism. The concept of cannibalism as it relates to the Grinnell Site specifically and the Southwest in general is also reviewed, with emphasis on potential alternative hypotheses. The human remains provide evidence for violent perimortem trauma including numerous cranial breaks, long bone spiral fractures, anvil-percussion fractures, blunt trauma, cut marks on long bones, and numerous cut marks on cranial bones indicative of skinning and/or scalping. The bone remains, however, do not exhibit one characteristic considered by Turner and Turner (1999) as a crucial indicators of cannibalism, pot polishing. Therefore, according to Turner's criteria, the Grinnell Site human remains cannot be considered a cannibalized assemblage.

CLIMATOLOGY

TOWARD A 300- TO 400-YEAR RECORD OF NEW ENGLAND NOR'EASTERS AND THEIR SOCIETAL IMPACT

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Large, winter storms along the eastern seaboard of the U.S. (i.e., nor'easters) are a significant component of the region's climatic system. Their influence is particularly apparent on the socioeconomic structure of New England given the physical controls on nor'easter formation in relation to New England's setting and the importance of the maritime industry of this region. Other industries and services in New England that are highly controlled by the weather also are greatly impacted by these large storm systems. As is the case for all severe meteorological events, a lengthy record of the variability in the frequency and magnitude of past events is essential for a better understanding of the range of intensity in these storms as well as for establishing their cyclicity and trends (or lack there of) that ultimately can lead to predictive capabilities. The abundant and lengthy record of historical documents (e.g., personal diaries, annals, journals, newspapers) in New England provide an excellent opportunity to completely develop and evaluate a 300-year-plus record of nor'easters. Two interesting aspects of this record standout. For example, the highly detailed record of the number of snowfall events and amounts found in the Samuel Lane diary (Stratham, NH 1734-1801) indicates that there were several winters in the 1700s with snowfall amounts that equaled or exceeded the record breaking snows of 1995-96 in New England. Furthermore, overall snow fall amounts were greater in southeast New Hampshire during the 1700s compared to the instrumental records of the 1900s. An additional aspect of critical information obtained from the written record is the frequency of upper-air patterns inferred from surface conditions. A two-week period of heavy snows in February 1893 in New England produced monthly records for snowfall totals that still remain today (i.e., Concord, NH). A series of four nor'easters over this two-week span suggest the prevalence of a deep, upper-air trough over the eastern U.S. Although such conditions wreak havoc on air-travel and other aspects of modern society, severe impacts on travel and other aspects of early New England culture are also apparent in these diaries, including blocked roads, livestock deaths and excessive damage to wharves and ships. Collaboration with individuals evaluating similar records in the Middle Atlantic region can provide a more complete understanding of how the characteristics of these huge coastal storms may have varied with time along the entire east coast.

SEA-SURFACE TEMPERATURE AND SALININTY ESTIMATES FROM THE EASTERN EQUATORIAL SOUTH ATLANTIC LINKED TO AFRICAN CLIMATE FOR THE LAST 27,000 YEARS

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High-resolution alkenone and stable isotope records from ODP 1077A-1H, taken on the Congo Fan, equatorial South Atlantic, show a glacial-interglacial temperature difference of almost 4.5°C. The transitional warming began after 24,000 calendar years BP, a time when Northern Hemisphere ice sheets were still near their maximum size and arid conditions prevailed on the African continent. Variations in salinity, sedimentation rates, and marine organic carbon derived from stable isotope analysis and radiocarbon dating reflect increased discharge from the Congo River during the early Holocene. This is consistent with terrestrial evidence for a strengthened monsoon circulation and increased precipitation. A late Holocene cooling event occurred between 6,000 and 2,000 calendar years BP. Comparison with low latitude Northern Hemisphere insolation changes suggests that orbital variations may be an important forcing mechanism for climate in this area.

GLACIOLOGY II: GLACIER DYNAMICS

MOTION AND MASS BALANCE OF THE ALLAN HILLS METEORITE STRANDING SURFACES

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Precise measurements of mass balance at the Allan Hills show that the blue ice areas have an average thinning rate of -0.03 ± 0.011 m/a. The snow plains in between blue ice areas are found to be complex ablation/accumulation zones with an average thickening rate of 0.016 ± 0.026 m/a that is subject to large errors and therefore could actually be thinning. Landsat imagery of the Allan Hills region show that firn is present down-glacier of blue ice areas, which is further evidence that ice in this region is thinning.
Clear evidence for climatic change in East Antarctica has been derived from the Vostok and Dome C ice cores (Jouzel *et al.*, 1989; Petit *et al.*, 1999). The ice cores show climatic changes in many aspects, and especially in accumulation rate. The accumulation rate of the ice sheet interior is determined to have increased 15,000 years ago indicating that the ice sheet may be thickening. It was expected that mass balance measurements on the Allan Hills ice fields would reflect what the ice core records are indicating. However, GPS measurements show that ice flow at the Allan Hills may not be linked to the rest of the ice sheet. The computer model presented here shows that ice outcropping on the NWIF is from a local catchment that is only a few kilometers up-glacier of the ice field. It is assumed that the MIF and MWIF also have local catchments. This indicates that ice from the interior of East Antarctica does not flow through the Allan Hills ice fields and it explains why there is a discrepancy between mass balance measurements at the Allan Hills and the ice core records.
Meteorite concentrations at the NWIF can be explained by the current behavior of the ice sheet according to the computer model. However, the catchments for the Allan Hills ice fields have most likely changed through time supplying the ice fields with varying amounts of ice and meteorites. A conclusion from the model is that the maximum meteorite ages for each ice field represent a lower limit for the maximum ice age. This allows an estimate of the age of the ice to be made for each ice field using only meteorite ages, but this does not tell us how long the stranding surface itself has existed. Understanding the longevity of the stranding surfaces will reveal more about how these areas respond to past and future climate change.

DEDUCTIVE MODEL OF PAST GLACIATION IN NE SIBERIA AND BERINGIA

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The model of an Arctic Ice Sheet (AIS) proposed by Hughes, Denton and Grosswald in 1977 implied, among other things, that the AIS had been incepted largely in the Arctic Ocean, not on the mid-latitude continents. This developed into the Marine Ice Transgression Hypothesis (MITH) by Hughes (1986), .
Our current (circumpolar) AIS model features the central component of the AIS, a floating ice shelf of the deep Arctic Basin, which was surrounded by marine ice sheets grounded on the circumpolar continental shelves. This model appears fairly consistent with the Arctic paleoclimate and glacial geology, but has some serious shortcomings.

Now, an alternative - asymmetrical - model of the last AIS is proposed. It assumes that only the North-American, Greenland and Barents-Kara ice sheets were covering the polar continental shelves, and that no substantial glaciation developed on the shelves of NE Siberia and Beringia. This paleogeography resembles that of Huybrechts & T'siobel (1997), but I disagree with these and many other modelers on the role of ice calving into the Arctic Basin. For them, all calf ice was lost in the "Black Hole" of the basin, while for me, the calving and all other forms of ice inflow was a major input item in the AIS mass balance. Indeed, that inflow ice would neither melt, nor escape the basin, nor sink in it. Thus, during the whole Late Weichselian glaciation, mass balance of the Central Arctic ice shelf had remain positive, so the ice shelf kept thickening. Rate of this thickening, as inferred from my (conservative) estimates of the mass balance and from the Greenland paleotemperature curve, turnes out to be at least 1 km per 5 kyr for as long as 55- 60 kyr.

No ice shelf could ever become 10 km-thick, so it had to discharge its excess mass on reaching a 2.5-3 km-mark, doing this gradually or by way of periodical collapsing/surging. I favor the second mechanism. Judging by ice-sheet geography, the Central Arctic ice could transgress only upon NE Siberia and Beringia, rapidly moving on a thick pillow of sea water. The latter would be squeezed out of the western Arctic Basin when the adjacent marine ice sheets collapsed, giving rise also to (concurrent?) Heinrich events in the North Atlantic. So the process can be described as cataclysmic eruptions of ice-water masses.

Conclusion: The continental shelves of NE Siberia and Beringia were subject to cataclysmic transgressions of ice from the Central Arctic and to megafloods originating in the Arctic Basin. Probably, these were short-lived transient events. During the rest of glacial time, the region was dry and ice-free, providing ground for development of perma-frost and burial of tabular bodies of glacier ice; an environment favorable for terrestrial vegetation, big animal and human life. Thus this new model resolves some puzzles of NE Siberia and Beringia, including the "Beringian controversy". This author emphasizes that the region was mostly glaciated by transient invasions of allochthonous ("alien") ice, while the researchers sticking to traditional school remain focused on the indigenous glaciation.

THE ROLE OF CALVING ICE IN INITIATING AND TERMINATING QUATERNARY GLACIATION CYCLES

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Based on studies of an ice wall calving into a crater on Deception Island, conducted from 1970 to 1974, a model for the calving rate of ice slabs above land or water and of ice ledges below water was developed. The model gives calving rates in the range from several hundred to several thousand meters per year, with the higher calving rates linked to higher longitudinal creep rates on the glacier surface. These high calving rates would prevent ice caps on Arctic highlands and islands from advancing very far into water, which therefore prevents them from coalescing to form Quaternary ice sheets in the Northern Hemisphere. The fact that these ice sheets formed leads to the conclusion that sea ice had to thicken into ice shelves in the water bodies separating these ice caps, so that calving was suppressed and the ice caps would then merge with the ice shelves. That would allow the ice shelves to thicken and become grounded, thereby becoming the cores of Quaternary ice sheets. As the ice sheets mature, they increasingly become drained by ice streams, which discharge up to 90 percent of the ice and turn on and off in the nature of surging mountain glaciers. During the off phase, calving bays can migrate up the stagnating ice streams until the next surge turns the ice streams on. Termination of a Quaternary glaciation cycle occurs when calving bays migrate into the heart of the ice sheets, thereby preventing another surge of the ice streams by depriving ice streams of the interior ice reservoirs that sustain the surges. This perspective gives calving ice a critical role in delaying initiation and hastening termination of Quaternary glaciation cycles. Because calving delays initiation, the ice sheets form rapidly after ice shelves suppress calving. Because calving carves out ice-sheet interiors, rapid destruction of ice sheets is guaranteed.

MARINE EMBAYMENT "WHITE HOLES" YIELD ALTERNATIVE ICE SHEET INITIATION SCENARIOS

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Terry Hughes has suggested that low-lying marine embayments adjacent to known paleo-ice sheets could have acted as ``white holes" or nucleation centers for the growth of these ice sheets.

This is in contrast to the more traditional highland-growth hypothesis where ice sheet growth results from a lowering of the equilibrium snowline elevation.

In the "white hole" hypothesis, these more-or-less enclosed basins can capture all the precipitation that falls within their catchment areas. They do this if the marine embayments consist of almost grounded ice shelves, which could possibly be produced by some mechanism such as sea ice thickening.

We show different ice sheet initiation scenarios that result from this "white hole" hypothesis of marine embayments being almost grounded ice shelves, and contrast them with more traditional highland-growth scenarios that result from a lowering of the equilibrium snowline elevation.

CHANGES IN THE EAST ANTARCTIC ICE SHEET AT SOUTH POLE: COMPARISON BETWEEN FIELD MEASUREMENTS AND MODELLED RESPONSES

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Models for the behavior of the East Antarctic Ice Sheet are tested by measuring the current rate of thickness change at South Pole. This rate is obtained using the coffee can method, that is by computing the difference between ice vertical velocity from precise global positioning system surveys and snow accumulation rate from core stratigraphy. Measurements are conducted at two sites approximately 5 kilometers apart in regions of different surface slope. The results are slow thickening (30 mm/yr) but the error estimate is 20 mm/yr, so this interior portion of the ice sheet appears to be close to mass balance. This small rate of change is consistent with conventional theoretical prediction and suggests that the large East Antarctic Ice Sheet is not currently contributing to sea level rise.