15th Biennial AMQUA Meeting

Sept. 5-7, 1998
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Invited abstracts: preliminary digital version[1]

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Program and Invited abstracts

ATMOSPHERIC AND OCEANIC INTERCONNECTIONS

9:00 Lehman, S.
Abyssal Circulation and inter-hemispheric climate change

9:45 Brook, E.
Interhemispheric correlation of ice core paleoclimate records using atmospheric gas records: methods and recent results

10:15 *Coffee Break*

10:45 Hughen, K. A.
Climatic linkages between high latitude North Atlantic, tropical South America, and ocean circulation: evidence from the Cariaco Basin

11:15 Baumgartner, T., A. Soutar, and V. Ferreira
Comparison of interdecadal and centennial variability in the ocean climate of the California and Peru-Chile Current System

11:45 Dunbar, R. B., G. Wellington, and B. K. Linsley
Coral records of ENSO and decadal ENSO-like climate variability from the Eastern Pacific: a multi-site synyhesis from Galápagos to Baja California

12:15 *Lunch*

1:30 Webb, R. S., K. E. Taylor and Participating PMIP Members
High versus low latitude glacial climate sensitivity in the Americas: results from PMIP simulations and NASA-GISS sensitivity experiments

GEOLOGICAL AND LACUSTRINE INTERCONNECTIONS

2:00 Luckman, B.
Holocene glacier history of the North American Cordillera

2:30 Seltzer, G. O.
Late Quaternary glaciation and climate change in the tropical Andes

3:00 Thackray, G. D.
Chronology of glaciation in the Olympic Mountains, Washington: regional controls and possible hemispheric correlations

3:30 *Coffee Break*

4:00 Stine, S. W.
Late Quaternary fluctuations of hydrologically closed lakes in the western Americas (**canceled**)

4:30 Fritz, S. C.
Holocene paleohydrology of the AMERICAS from paleolimnological records

5:00 Wiles, G. C., R. Villalba, D. J. Barclay, and P. E. Calkin.
The last millennium of ocean-atmosphere variations along the western coast of the Americas inferred from tree-rings and glacial records

5:30-7:00 *Poster Session*

Sunday, September 6

MEXICAN INTERCONNECTIONS: QUATERNARY PALEOENVIRONMENTS OF MEXICO

8:30 Macias, J. L. and M. M. Caballero
Late Quaternary volcanic activity and its influence on lacustrine sedimentation in central Mexico

8:55 Carriquiry, J. D., J. F. Soto-Castro, C. Charles, and M. Moore
Stable isotope and trace element records in coral growth bands as tracers of ENSO activity in the Mexican Pacific

9:20 Molina-Cruz, A. and L. Pérez-Cruz
High resolution paleoceanography of the bay of La Paz, Gulf of California, evidenced by recent Radiolarians

9:45 Arroyo-Cabrales, J., O. J. Polaco, and E. Johnson.
Late Quaternary environments and mammal faunas from Mexico

10:10 *Coffee Break*

10:40 Lozano-Garcia, M. S., M. Caballero-Miranda, B. Ortega-Guerrero, J. Urrutia-Fucugauchi, and S. Sosa Najera
Late Quaternary history of the lakes, the vegetation and climatic trends in the basin of Mexico: Lakes Chalco, Texcoco and Tecocomulco Studies on late Quaternary vegetation in the basin of Mexico

11:05 Villanueva-Diaz, J., D. W. Stahle, M. K. Cleaveland, and M. D. Therrell
Tree-ring chronologies and ENSO in northern Mexico

11:30 Mellink, E.
Ranching Sonoran rangelands: using the Pleistocene as a model

11:55 McClung de Tapia, E.
Archaeological approaches to the reconstruction of paleoenvironments: an example from Teotihuacan, Mexico

12:20 *Lunch*

ARCHAEOLOGICAL INTERCONNECTIONS

2:00 Stanford, D.
Putting a new face on the first Americans

2:30 Dillehay, T.
The peopling of South America: a paleoecological and archeological perspective

3:00 *Coffee Break*

3:30 Manzanilla, L.
Cultural interconnections between northern and southern hemispheres

4:00 Fish, P. and S. Fish
Cultural interconnections between Mesoamerica and the North

5:30 Reyman, J.
As the macaw flies: Mesoamerican-Anasazi trade across the Chichimec Sea

5:00 Brenner, M.
Climate and culture in pre-Columbian America

5:30-7:00 Poster Session

7:00 AMQUA General Business Meeting

Monday, September 7

BIOLOGICAL INTERCONNECTIONS

8:30 Webb, S. D.
Chronology and ecology of vertebrates: who went when

9:00 Colinvaux, P., P. E. De Oliveira, and M. B. Bush
Climatic history and biodiversity of equatorial America

9:30 Markgraf, V. and C. Whitlock.
Forest ecosystem response to climatic changes on millennial time scales in the western Americas

10:00 *Coffee Break*

10:30 Moreno, P. I., H. Almquist-Jacobson, G. H. Denton, E. C. Grimm, G. L. Jacobson Jr., and W. A. Watts.
Interhemispheric correlation of millennial scale climate changes during the termination of the last ice age: the southern Andes, peninsular Florida, and central Europe

11:00 Ashworth , A.C.
The beetles' response to the last glaciation in the mid-latitudes of South and North America

11:30 Swetnam, T. W., T. Kitzberger, and T. T. Veblen
Synchronous changes in fire history and El Nino in the southwestern United States, and northern Patagonia, Argentina

LATE QUATERNARY ENVIRONMENTS AND MAMMAL FAUNAS FROM MÉXICO

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The late Pleistocene (120,000-11,000 years BP) was a complex period of climatic shifts, changing faunal and floral communities, and impacted landscapes representing now extinct ecosystems. In México, late Pleistocene sediments are widespread all over the country; however, most findings have been isolated, lacking stratigraphic and radiometric controls, even accurate plotting of locality data, with inadequacy of descriptions for a good part of the assemblages. From the two land mammal ages recognized for the North American Pleistocene: Irvingtonian and Rancholabrean, the largest mammal diversity is known from the last one; true Irvingtonian localities are very few, if not only two, El Golfo (Sonora) and El Cedazo (Aguascalientes). The few Irvingtonian localities may suggest: (1) lack of radiometric finite techniques; (2) lack of prospective excavations to look for early Pleistocene and; (3) there is not any locality in existence.

Twenty years ago, five major faunas were defined for the Mexican Rancholabrean age (San Josecito Cave and Cedazo local faunas, and the Mexican, Chapalan, and Valle de Pueblan-Tlaxcalan faunal assemblages). Those sites accounted for 10 orders, 31 families, 66 genera, 86 species, and 32 genera and-or species undetermined, totaling 225 taxonomic levels. Since then, one of those faunas has gained more detailed data, both chronological and stratigraphically, providing elements to reevaluate the concept of faunal assemblages instead of local fauna (San Josecito Cave), while new important localities have been discovered in search for early human activities in México (Tlapacoya, El Cedral, Loltún Cave, etc.), accounting for the last 40,000 years.

Presently the knowledge for the Mexican Pleistocene mammals is been enhanced by the Mexican FAUNMAP Project sponsored by the Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO). This is a bibliographic-based database that is being compiled from most of the available sources in México, as well as using publications found in the USA and Europe. One of the important points on the database is that most localities are located by geographic coordinates, as well as have available most data related to radiometric dating from the bone or related materials.

Currently there are 15087 mammal records in the database, accounting for 286 species from 13 orders, 44 families, and 145 genera. Among the extant taxa, there are records for all of the orders and families occurring presently in México, but some marine mammal families.

From the 286 species, there are 84 globally extinct (29.4%) and nine extirpated in México (3.1%). One order is not longer occurring in the Americas (Proboscidea), as well as three families (Herpestidae, Equidae, Elephantidae), while three other families do not occur anymore in North America (Camelidae, Hydrochoeridae, Megalonychidae), and five more families are extinct (Gomphotheriidae, Mammutidae, Glyptodontidae, Megatheriidae, Mylodontidae). Among the 145 genera, 27 are extinct (18.6%), and nine are considered as extirpated (6.2%), i.e., *Bison*, *Camelops*, *Cervus*, *Cuon*, *Tremarctos*, *Equus*, *Synaptomys*, *Marmota*, and *Myrmecophaga*.

The previous data indicate a different species composition of the mammal fauna at the end of the Pleistocene. Although clearly the fossil record is biased toward the medium- and large-sized animals, still there is a pattern shown by our data. If we take into account the species of the orders Artiodactyla, Perissodactyla, and Proboscidea that are extinct, and those within the orders Xenarthra and Carnivora that weighted above 100 kg, then we find than from 78 species, 63 are extinct (80.8%), and those represent the 75% of the globally extinct species. Those extinct species included mostly herbivores, but also some carnivores.

Many species expanded their distribution to lower or higher latitudes and altitudes, and had a much northern or southern distribution during the Pleistocene than at present. Trends in the movements of tropical mammals appear to be similar to temperate mammals. The present distribution patterns of several sets of species are mostly explained as a result of Pleistocene glacial effects.

THE BEETLES' RESPONSE TO THE LAST GLACIATION IN THE MID-LATITUDES OF SOUTH AND NORTH AMERICA

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North America: in response to climatic cooling, arctic species replaced boreal forest species along the southern margin of the Laurentide ice sheet at about 21,500 yr B.P. Colonization was probably from populations that dispersed southward in front of the growing Laurentide ice sheet and from populations that dispersed westward and eastward from montane refugia in the Appalachian and Rocky Mountains, respectively.

This "glacial" fauna, dominated by tundra species, inhabited the ice margin until about 14,500 yr B.P. (Morgan, 1987; Schwert ,1992; Ashworth, 1996). Several of the species, such as *Diacheila polita*, are presently restricted to habitats in Alaska and Yukon territory and not from the tundra of central and eastern Canada. The only species presently restricted to the eastern arctic that is part of this fauna, is the hydrophilid beetle, *Helophorus arcticus*. Mean July temperature along the ice margin is estimated to have been between 10-12^{o}C compared to a mean July temperature of 22^{o} C today. Climatic warming in combination with the ice sheet acting as a barrier to northward dispersal caused the extirpation of tundra species in the mid-latitudes at about 14,500 yr B.P. (Schwert and Ashworth, 1988; Schwert, 1992). The ice marginal fauna until 12,500 yr B.P. was characteristic of open terrain but warmer climatic conditions than had existed earlier. By 12,500 yr B.P. this fauna was replaced by a boreal forest fauna.

In the Pacific Northwest, only a few beetle assemblages have been examined from deposits of the last glaciation. From a Kitsap Formation fauna (16,640 yr B.P.), Seattle, mean July temperature is estimated to have been similar to the 18^{o} C of the present day (Nelson and Coope, 1982). The fauna is typical of an open woodland and not the closed canopy forest of today. Greater summer aridity rather than a lower temperature regime is believed to be the cause for the openess of the environment. Faunas from Kalaloch on the Olympic Peninsula (17,970; 16,700 yr B.P.) also indicate open environments. The occurrence of an alpine species of a chrysomelid beetle at low elevation, and the occurrence of a few boreal forest species that had dispersed in from the north, suggested that the mean July temperature was possibly 3^{o} C cooler than that of today (Cong and Ashworth, 1996). Even though few studies have been conducted in the Pacific Northwest it is evident that the faunal response to climate change was less dramatic than on the eastern side of the Rocky Mountains. At the present day, mean July temperatures vary from 18 to 24^{o} C from the Pacific coast to the interior. During the last glaciation, mean July temperatures were warmer on the Pacific coast than in the interior of the continent.

South America: In the montane and island-fragmented landscape of southern Chile, species became regionally extinct as the climate cooled before 24,000 yr B.P. Montane and marine barriers, however, prevented the recruitment of colder-adapted species from more southerly latitudes. The result was a glacial fauna consisting of a small number of species including, 1) species presently restricted to higher elevation habitats at or above treeline in the Cordillera de la Costa and the Cordillera de los Andes that had dispersed downslope to the lowlands during the colder climatic conditions, 2) species that are 'climatic generalists' with existing populations occurring through a range of elevations. Based on the occurrence of the high-elevation species at low elevations, the mean January temperature is estimated to have been 4-5^{o} C lower than the present day. The glacial fauna is very different than the species-rich forest fauna that started to replace it at about 14,000 yr B.P. (Ashworth and Hoganson, 1996). The last occurrence of the most characteristic beetle of the glacial fauna, the weevil *Germainiellus dentipennis*, is at 12,800 yr B.P. By 12,500 yr B.P., it is inferred that the lowland biota had a similar diversity to that of the present day.

General Comments:
1) The onset of glaciation, marked by the appearance of glacial faunas, was at least 1500 years earlier in southern South America than at equivalent latitudes in the continental interior of North America. When species of the glacial fauna started to appear in the Pacific Northwest has yet to be determined. 2) The replacement of glacial faunas occurs at about the same time in southern South America as it does in the continental interior of North America. This is very different than Europe where replacement occurs initially at 13,000 yr BP and later at 10,000 yr BP. The termination of the glacial fauna in the Pacific Northwest has yet to be determined. 3) Mean summer temperature during the last glaciation for the continental interior of North America is estimated to have been in the range 10-12^{o} C, for the Chilean Lake Region 10-11^{o} C, and for the Pacific Northwest 15-18^{o} C. 4) The glacial fauna of each region was a unique combination of species that does not occur today (non-analog). Most recruitment occurred in the fauna of the mid-continental North America where species dispersed in from the north and probably from mountains to the west and to the east. Species-richness in the faunas of the three regions was determined by landscape factors as much as temperature. The most species-poor fauna was that of the Lake Region of Chile where marine and mountain barriers blocked recruitment of species dispersing northward.

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COMPARISON OF INTERDECADAL AND CENTENNIAL VARIABILITY IN THE OCEAN CLIMATE OF THE CALIFORNIA AND PERU-CHILE CURRENT SYSTEMS

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This presentation discusses the results of a study to compare the variability in ocean climate along the western margins of North and South America using a combination of high-resolution paleoceanographic data from fish-scale-deposition combined with historical instrumental observations. The accumulation rates of fish scales of sardines and anchovies in coastal sediments provide indeces of their population sizes related to climate change. These are small, schooling, planktivorous species whose abundance and distribution depend on the quality and extent of suitable habitat within the California and Peru-Chile Current systems. The association of the fish-scale-deposition rates with observed environmental changes in both systems provides an independent means to mark changes between climate regimes strong enough to bring on sustained biological change. Continuous records of high-resolution fish-scale-deposition are limited to near coastal areas characterized by bottom waters depleted in oxygen where bioturbation is suppressed and preservation of the fish scales enhanced. We are developing a number of these sites in both the California and Peru-Chile systems to integrate the history of spatial variability with temporal change in habitat expansion and contraction. The currently available sites are the Santa Barbara Basin off sourthern California at 34°N and a site off Callao, Peru at 12°S. The Santa Barbara site is much better developed with a record extending through the past 1600 years; so far the Peru site reaches back only to AD 1875.

This study concentrates on the relationships between physical parameters obtained from COADS data and variability in the fish populations as recorded in the sediments after 1870. We characterize variability in the California Current by sea surface temperature (SST) averaged over one degree squares between 30° to 38°N latitude and extending offshore four degrees longitude. The Peru system is represented by the averaged SST from the area extending four degrees offshore between 4° and 12°S latitude. We use the meridional winds from one degree squares adjacent to the coast to provide an index of upwelling potential and to constrain our description of interdecadal climate regimes by combining the coastal winds with the regional SSTs. Although the COADS wind observations contain significant gaps prior to 1950 off Peru, the record is still useful for the period after 1905. The wind records off California are continuous after 1930.

Ocean-atmosphere coupling in the tropical Pacific acts to synchronize variability in the climate of the California and Peru-Chile Current systems over the ENSO time scale of several years to a decade. Our study seeks to determine the extent to which interdecadal to centennial climate change along the eastern boundary of the Pacific is synchronized across the equator. We are interested in this synchroneity as evidence for the origin of climate change occurring beyond the ENSO time scale. Synchroneity in events occuring on either side of the equator would suggest a tropical origin with interdecadal variability over the Pacific displaying an "ENSO-like" signature, with climate shifts between regime states of tropical warming and cooling persisting for several decades. Conversely, a lack of synchroneity and climatic symmetry across the equator would suggest independent sources, which would likely be linked to the climate of the mid-latitudes.

Comparisons of the SST and wind anomalies, plus the fish-scale deposition data from Peru and California indicate four major climate regimes between the 1870s and 1990 which can be recognized in both systems. Each of the four regimes lasted between 30 and 40 years, and although they generally coincide, the California system may lag Peru by as much as five years. The overall agreement in SST and the coastal winds suggests that the ENSO-like pattern in the changing distribution of SST anomalies has dominated the interdecadal scale climate change during this period, with higher tropical SSTs associated with warming along the mid-latitude eastern boundaries in both North and South Pacific and cooling in the subtropical central and western Pacific (with the reversal of the pattern associated with tropical cooling). The relationships of the sardines and anchovies to these climate regimes indicate that the quality of habitat for each species is determined by both ocean temperatures and upwelling (a principal determinant of quality and abundance of prey) which combine to create distinct optimal environmental windows for each species.There is one important exception to the broad similarity in the patterns of variability off California and Peru. In the period from roughly 1920 through 1940, the tendencies of the monthly SST anomalies off Peru and California are contrary to one another. The few Pacific-wide distributions of COADS SST anomalies which are available for this period, show a clear asymmetry across the equator, with coastal warming in the mid-latitudes of the North Pacific (and cooling in the central subtropical North Pacific, centered over Hawaii) and the opposite picture in the South Pacific, with coastal cooling off Peru and Chile and warm anomalies in the central-western South Pacific. This suggests a second possible mode, apart from the ENSO-like changes, influencing interdecadal variability and capable of sustaining a climate regime over a period of roughly 20 years.

The spectrum of the 1600-year record of fish-scale-deposition in the Santa Barbara Basin shows periods in the interdecadal band which are consistent with the approximately 30-year climate regimes (corresponding to a half-period) off Peru and California. The dominant period of the sardine record averages between 50 and 70 years, while a corresponding anchovy peak is centered between 60 and 65 years. The Santa Barbara records also indicate centennial-scale warming and cooling associated with periods generally known from European sources as the Medieval Warm Period (950-1350 AD) and the Little Ice Age (1400-1800 AD). Recent work by L. Ortlieb and others on a site off northern Chile suggest synchroneity with this centennial-scale variabilty in the North Pacific. The apparent agreement of these longer records, combined with the results from this study, indicate a strong role for the tropics and tropical-extratropical links to synchronize climate variability across the equator at both interdecadal and centennial scales in the Pacific. The one clear exception to this pattern indicates that at least one other distinct mode of variability may act to interrupt this synchroneity.

CLIMATE AND CULTURE IN PRE-COLUMBIAN AMERICA

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Human cultures are influenced by the environments in which they develop. In turn, humans modify regional landscapes such that there is a continuous feedback between people and their "natural" surroundings. It has sometimes been assumed that cultures of the past arose, flourished and declined in ecological contexts similar to those that prevail today. Archaeologists are increasingly aware that past environmental conditions varied as a consequence of both climatic and anthropogenic factors.

Lake sediments are a rich repository of information about past environments. Combined archaeological and paleoecological studies have shed light on long-term environmental changes in selected tropical areas where Precolumbian cultures developed, persisted, and collapsed. This paper reports results from Guatemala and Mexico (Maya Lowlands) and the Bolivian/Peruvian Altiplano (Chiripa/Tiwanaku). I discuss the role of long-term climate change on regional landscapes and the interaction between human populations and their environment.

A composite long sediment core from deep Lake Quexil (z_{max}=32m), Peten, Guatemala contains a continuous record of lacustrine sedimentation from ~36 kyr BP to present. Pollen analysis, mineralogy, and stable isotope geochemistry document a shift from a cool, arid late Glacial to a warmer, moister early Holocene ~10.7 kyr BP. Tropical, lowland dry forest vegetation spread rapidly with the onset of Holocene conditions and persisted for >7000 years. Late Holocene forest disappearance began with Middle Preclassic Maya settlement ~3000 BP, and reflects agricultural land clearance. Vegetation removal caused severe soil erosion that is inferred from rapid accumulation of clay-rich deposits on the lake bottom. Despite the 9th century AD Maya demographic decline, Postclassic population densities were sufficient to prevent regional reforestation. Forest regrowth apparently coincided with European intrusion about 400 years ago.

Paleolimnological studies in Lakes Chichancanab and Punta Laguna on the northern Yucatan Peninsula provide high-resolution records of Holocene climate changes. Relatively moist conditions prevailed in the early and middle Holocene. Differences between summer and winter insolation were maximal in the early Holocene, and there was pronounced northward migration of the ITCZ during the northern hemisphere summer. Regional drying began ~1000 BC, associated with reduced seasonality. Initial Maya settlement was associated with the onset of drier conditions and the Classic Period (250-850 AD) was even drier. The period 800-1000 AD was the driest of the middle to late Holocene, and the protracted drought coincided with the Classic Maya collapse, i.e. termination of temple construction, cessation of stelae erection, the end of polychrome pottery production, and concomitant population decline. Paleoecological data suggest that both climatic factors (drought) and anthropogenic factors (deforestation and soil erosion) may have stressed Maya agricultural production and contributed to the Classic decline.

Sediment cores from the southern basin of Lake Titicaca (Lago Wiñaymarka), Bolivian/Peru, indicate dry conditions in the Andean Altiplano during the early and middle Holocene. Lago Wiñaymarka, with a current z_{max} of 43m, desiccated between about 7.6 and 3.5 kyr BP. Chiripa culture developed in the southern Titicaca watershed ~1500 BC, coincident with greater moisture availability and rising lake level. Tiwanaku culture emerged about 400 BC. By 600 AD, the Tiwanaku had built a network of raised agricultural fields ("camellones") in riparian wetlands. Bordered by spring-fed canals, raised fields were built to protect crops from freezes, to fix and conserve plant nutrients, to raise crop roots above the phreatic zone, and to protect local soils from salinization. Titicaca sediment cores and the Quelccaya Ice Core document a prolonged dry period that began ~1100 AD. This drought was associated with raised field abandonment and cultural decline.

Holocene climate trends in the Maya lowlands and Andean Altiplano are out of phase and largely explained by astronomic forcing. Cultural development and population expansion occurred in both regions under conditions favorable to agriculture. Both cultural groups modified their environments significantly and altered local biogeochemical cycles. The Maya and Tiwanaku declines were associated with protracted droughts that are as yet unexplained. The data suggest there are climatic thresholds for cultural development and that abrupt, unpredictable climate changes can have dire consequences for human populations by disrupting agricultural production.

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INTERHEMISPHERIC CORRELATION OF ICE CORE PALEOCLIMATE RECORDS USING ATMOSPHERIC GAS RECORDS: METHODS AND RECENT RESULTS

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Precise comparison of climate records from ice cores in the southern and northern hemispheres can be accomplished by matching records of atmospheric gases preserved in the ice. The isotopic composition of atmospheric O^2 (e.g., Sowers *et al*., 1991; Bender *et al*., 1994), and the methane mixing ratio (e.g., Steig *et al*., 1998; Sucher, 1998) have been employed for this purpose. In principle, other gases could also be used. The technique requires that the atmospheric lifetime of the component used is longer than the interhemispheric mixing time, and that processes that trap and preserve atmospheric composition in ice are understood. The major recent motivation for this work is to understand the interpolar phasing of rapid climate change during the last glacial period. By correlating records of $\delta^{18}O$ of O^2 from GISP2 and Vostok Bender et al. (1994) showed that interstadial events in Greenland have Antarctic counterparts, but could not establish precise phasing due to uncertainties the age difference between the gas and surrounding ice at Vostok. Sowers and Bender (1995), employing records from GISP2 and the Byrd ice cores, showed that Antarctic warming during the deglaciation preceded the main Greenland warming by ~ 3 ka, and that the Antarctic Cold Reversal occurred ~ 1 ka before the Younger Dryas. Recent work on the Taylor Dome ice core, in the Ross Sea sector of Antarctica, suggests that this phasing may not be a ubiquitous feature of Antarctic paleoclimate. Correlation of methane and $\delta^{18}O$ of O^2 records with their GISP2 counterparts shows that the deglaciation at Taylor Dome was a sharp transition that occurred within less than 1 ka of the analogous warming in GISP2, and that a small cooling in the Taylor Dome isotope record occurred at approximately the same time as the Younger Dryas (Brook *et al*., 1996; Steig *et al*., 1998). The implications of this result, and the longer Taylor Dome record that extends through the last interglacial, will be discussed.

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STABLE ISOTOPE AND TRACE ELEMENT RECORDS IN CORAL GROWTH BANDS AS TRACERS OF ENSO ACTIVITY IN THE MEXICAN PACIFIC

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ENSO Activity in the eastern tropical Pacific Ocean is characterized by high positive anomalies in SST, sea level and rainfall. During these episodes, it has been documented that the Central and Eastern Tropical Pacific become strongly oligotrophic because of the deepening of the thermocline, and therefore reduced nutrient injection to the ocean surface by upwellings. ENSO effects in the Mexican Pacific have been largely undocumented either from physical, chemical or biological perspectives. In order to understand the historical characteristics of ENSO activity in the Mexican Pacific, we collected coral colonies from Socorro Island, in the Revillagigedo Archipelago, and from Pulmo reef, off the Southern tip of Baja California, in the mouth of the Gulf of California. Coral growth bands were analyzed for trace element ratios (Cd/Ca, Mn/Ca) and stable isotopes.

Our results show that corals from these localities show low levels of Cd and high (peak) levels of Mn towards the end of each ENSO episode, when ENSO events are fully in their mature phase all over the Eastern Tropical Pacific. The mean Cd/Ca ratio (nmol/mol) in Pulmo reef corals is about 3 times higher (10.0) than in Socorro corals (3.0), in good agreement with oceanographic conditions (the mouth of the Gulf of California is eutrophic all year round whereas the Revillagigedo Archipelago is characterized by more oligotrophic conditions). The mean Mn/Ca ratio (nmol/mol) in Pulmo reef corals is nearly 3 times lower (29.0) than at Socorro corals (83.0), suggesting that Socorro corals appear to be closer to the Mn source responsible for the interannual variation of this element in the region. $\delta^{18}O$ and SST data display a good correlation, for which SST controls 85% of the isotopic signal. However, during ENSO episodes the $\delta^{18}O$ data display strong excursions from SST data indicating strong δ_w effects in the coral $\delta^{18}O$ composition. The overall results indicate that during ENSO episodes this region becomes dominated by more oligotrophic waters that are characterisically enriched in Mn and with a markedly different δ_w composition. The intensification of the North Equatorial Cyclonic Gyre (NECG) has been suggested to be the main feature of ocean circulation during ENSO conditions in this region (Baumgartner and Christensen, 1985). More recently, it has been observed that Kelvin waves, in conjuction with the NECG, or as a causal factor for it, is responsible for transporting large pulses of tropical water masses from the equatorial region of the eastern Pacific to as far north as the interior of the Gulf of California. These oceanographic processes would provide a mechanism explaining the lateral advection of oligotrophic waters (lower Cd levels) flowing along the continental shelf of Mesoamerica (higher Mn levels), characterized by markedly different δ_w composition (tropical water masses).

CLIMATIC HISTORY AND BIODIVERSITY OF EQUATORIAL AMERICA

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Secular change in equatorial climates in response to glacial cycles included reduced CO_2 and lowered temperature, with the added possibility of changes in patterns of precipitation.

CO_2 reduction is the most ubiquitous and best measured property of glacial climates and is certain to have altered the distribution and abundance of tropical plant species, though in ways that we do not yet understand. Reduced CO_2 is expected to have favored plants using C4 and CAM photosynthesis. Because tree-line trees in the tropics are all C3 the suggestion has been made, and supported by biome models or mass balance calculations, that the poor uptake of carbon by the rubisco enzyme at tree-line elevations should have depressed tree-line regardless of temperature. This result still lacks experimental verification. If treelines were set by CO_2 concentration in glacial times, but by temperature in interglacials, both the principles of uniformity and Occam's razor are intriguingly violated.

Pollen and other paleobotanical data from low elevations in both Ecuador and Panama show that a number of trees and other plants lived in the lowland forests in glacial times, though now maintaining significant populations only at high elevations. *Podocarpus*, *Alnus*, *Drymis*, *Magnolia*, *Hedyosmum*, *Quercus* and others developed significant populations at least 1000 m below their normal modern altitudinal ranges, entering plant communities of the lowland forest. We associate these descents with the tropical cooling in the order of 6^{o} C demonstrated for coral reefs in the Bahamas and by measurements of noble gasses in fossil groundwater from tropical northeastern Brazil, as well as by such paleobotanical data as the northward spread of *Araucaria* forests in southeastern Brazil. The Ecuadorian and Panama pollen data show clearly that the descents were of species populations only, not of whole associations or biomes. This was not a shift of vegetation types or belts but rather a reshuffling of associations.

Reduced precipitation in parts of the ice-age tropics is suggested by climate models, including those recently put forward to allow equatorial cooling. Speculations that serious aridity might have been inflicted on Amazonia has colored interpretations of both biogeography and geomorphology, yielding hypotheses of fragmentation of the Amazon forest into enclaves dubbed 'refugia', or even the wholesale elimination of rainforest except in riveraine systems, and its replacement by savanna.

The geomorphological arguments rest on remote sensing data interpreted as demonstrating former dune fields in regions peripheral to the Amazon basin and so-called 'stone lines' buried in Amazon soils. For two of the three areas of suspected fossil dunes recent data allow dismissal of the hypothesis that these are relics of glacial aridity. The easternmost area on the Sao Francisco river is a Tertiary dune field, reactivated in the early Holocene (8000 - 4000 B.P.) but not in the lateglacial. Ground truth survey in the Pantanal region suggests that the land forms postulated to be dunes were in fact not of aeolian origin. And extensive reexamination of 'stone lines' suggests multiple causations that do not require an arid landscape.

The aridity hypothesis is vulnerable to testing by core drilling and pollen analysis because it requires that grass-dominated savanna vegetation occupy most of the basin in glacial times. The pollen signal of Brazilian savannas is highly distinctive, as shown by a pollen diagram from Crominia in cerrado *sensu stricto* from the central Brazilian highlands. This savanna pollen signature is utterly unlike that from closed lowland forest as illustrated by the long pollen record from the lowland Amazon forest at Lake Pata. Pollen diagrams from Lake Pata and adjacent lakes show that closed tropical forest occupied the west central Amazon lowlands continuously for at least the last 40,000 years. Pollen data from edaphic vegetation on the Carajas Plateau is consistent with evidence of lowered water levels in glacial times in suggesting reduced precipitation in this climatically sensitive region.

A pollen record from the Amazon fan and continental shelf shows roughly constant transport of grass pollen from Amazon watersheds at all stages of a glacial cycle, effectively eliminating the possibility of widespread replacement of lowland forest with savanna in glacial times.

We conclude that closed forest cover remained intact over most of the Amazon lowlands throughout the last glacial cycle. The forest was never fragmented into refugia. Rather the high diversity has been maintained throughout the Pleistocene by a restless process of recombination of plant species within the forest formation. Changes in climatic forcing (CO_2, temperature, and precipitation - all three) would have impacted ecotonal areas, as for instance the forest-savanna boundary in Bolivia. Fossil evidence for Pleistocene megafaunas in the western Amazon basin is evidence that their component mammal species were adapted to landscapes not very different from those of the present day.

THE PEOPLING OF SOUTH AMERICA: A PALEOECOLOGICAL AND ARCHEOLOGICAL PERSPECTIVE

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When, how, and where humans first populated the Americas has been a controversial topic for more than fifty years in American archeology. In recent years several new archeological finds, including the Monte Verde site in Chile, have changed much of our current thinking about the timing and nature of the first Americans. Added to the archeological evidence is new genetic, linguistic, physical anthropological, and paleogeographic information to shed new light on this first chapter of human history in the New World.

I will discuss the merits and demerits of the new interdisciplinary data and critically evaluate who were the first Americans, with special emphasis given to the new and exciting finds in South America.

CORAL RECORDS OF ENSO AND DECADAL ENSO-LIKE CLIMATE VARIABILITY FROM THE EASTERN PACIFIC: A MULTI-SITE SYNTHESIS FROM GALÁPAGOS TO BAJA CALIFORNIA

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The El Niño-Southern Oscillation phenomenon (ENSO) is the single most important cause of interannual climate variability in the global tropics and subtropics and produces particularly strong responses in the Americas. ENSO events are accompanied by basin-wide perturbations of sea surface temperature patterns in the Pacific that are manifest by either strong equatorial cooling or warming east of the dateline and corresponding opposite sign SST anomalies both north and south of the equator. On timescales longer than interannual, the dominant climate pacemaker in the Pacific Ocean and overlying atmosphere also has an ENSO-like spatial distribution (Battisti,1998). While the physical mechanisms responsible for decadal ENSO-like variability are not known, the resulting climate anomalies are significant. Furthermore, the interannual ENSO and decadal ENSO-like phenomena are associated with qualitatively different climate anomalies over the mid and high latitudes of the Americas. This observation by Battisti and coworkers presents a challenge for the AMQUA community, particularly in the context of this meetings' focus on interconnections between the northern and southern hemispheres. Can the forcing/response dynamics and origin of ENSO and ENSO-like decadal variability be better understood via synthesis of land and sea-based paleoclimate records of appropriate length and resolution?

In this paper, we provide a synthesis view of ENSO and ENSO-like decadal variability in the eastern Pacific tropics derived from modern corals. The tropical eastern Pacific is a highly sensitive region for monitoring and understanding ENSO and associated variability in near-equatorial rainfall. We have analyzed long time series of stable isotope ratios in approximately 19 coral cores from 9 sites spanning a range of latitudes from 23°N to 1°S (**Table 1**).

Our longest records are from the Galápagos islands and the Gulf of Chiriquí (Panamá). Galápagos corals (Urvina Bay) primarily record ENSO-related changes in SST and indicate that recurrence intervals and intensity of ENSO warm and cool periods have changed significantly over the past 400 years. Relatively rapid shifts separate periods of stable ENSO characteristics that each last between 50 and 100 years.

Here we describe a new subannual coral record from the Galápagos Islands that provides an absolutely-dated (and multiple core cross-dated) record of Eastern Pacific Cool Tongue temperature extending back to 1853 A.D. This allows comparison with other absolutely dated records from tropical tree-rings and corals and also permits revision of our previously published 380-year coral ENSO time series.

In the Gulf of Chiriquí, $\delta^{18}O$ in corals reflect changes in salinity. The annual cycle is the dominant feature in isotopic time series', accounting for half of the total variance. The next most significant oscillatory mode has an average period of 9 years which is also seen in instrumental rainfall records from Panamá. As in Galápagos records, we see evidence for a shift in the periods at which variance is concentrated during the early-to-mid 1800's. However, in Panamá we see relatively little concentration of variance at higher frequency periods (3-5 years) usually associated with ENSO. At this site counteracting influences of temperature and salinity on the $\delta^{18}O$ record may attenuate the high frequency El Niño signal or these results may indicate occasional decoupling between thermal anomalies and unusual excursions of the ITCZ related to ENSO.

The new Galápagos and Panamá $\delta^{18}O$ records show inverse correlations at interannual to decadal timescales since the mid-1800's. In general cool years/decades in Galápagos correspond with wet years/decades in Panamá. We also interpret the Galápagos results as indicating a very small century-scale temperature decrease through time while the Panamá data is consistent with an increase in ITCZ precipitation through time. An inverse relationship between these two series is expected based on two considerations. First, as part of the normal annual cycle, SST's are at a minimum in Chiriquí and at a maximum at Galápagos during March/April. The converse is true in September/October. Second, we expect an inverse relationship at ENSO and longer periods as a results of coupling between rainfall and SST distribution in the ITCZ/cold tongue complex. If the ENSO warm anomaly persists through the year, the ITCZ becomes anchored near the equator producing dryer than normal condition in Central America. Our analysis of long coral records suggests that only stronger warm events, with return periods of 6 to 10 years (or more) produce Panamanian droughts coherent with Galapagos SST's. Our results suggest that interannual ENSO, decadal, and longer climate variability have similar patterns of expression in the eastern tropical Pacific. If the causes of variability are different at the different timescales, then the eastern Pacific climate system must serve to rectify the regional responses.

Table 1. Present coral study sites in the Eastern Pacific

Site	Location	Max. Record Length[1]	Length of ^{18}O series	Objectives
Baja California	23°N,110°W	~80 yrs	65 yrs	SST, Baja Upwelling
Clipperton	10°N,109°W	~120 yrs	120 yrs	SST, ITCZ boundary
Caño Island	9°N ,84°W	79 yrs	79 yrs	ENSO, SST
Gulf of Panamá	8°N ,79°W	~200 yrs	90 yrs	SST, ITCZ, upwelling
Gulf of Chiriquí	8°N ,82°W	278 yrs	278 yrs	ITCZ
Cocos Island	6°N ,87°W	~300 yrs	200 yrs	SST, ITCZ
Bartolomé	0° ,91°W	96 yrs	96 yrs	SST, ENSO
Urvina Bay	0° ,91°W	387 yrs	374 yrs	SST, ENSO
Champion	1°S ,90°W	160 yrs	160 yrs	SST, ENSO

CULTURAL INTERCONNECTIONS BETWEEN MESOAMERICA AND THE NORTH

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Mesoamerica is recognized as a unique prehistoric phenomenon that exhibited exceptional vigor in formulating cultural patterns with longterm coherence and strong influence on surrounding areas. At its North American limit, Mesoamerican influence has been cited as influencing geographically and culturally distinctive regions in the southwestern and southeastern United States. These developments took many forms over the centuries following the appearance of the "Mesoamerican" complex in Mexico and Central America. We examine two broad aspects of interconnection that had implications for quite different spheres within northern societies: 1) subsistence, including cultigens and technologies; and 2) symbols and structures of hierarchical organization. Subsistence and organizational realms illustrate the inter-regional and intra-regional variability with which Mesoamerican influences were incorporated into Southwestern and Southeastern societies.

Ideas about the transmission of tropical cultigens from Mesoamerica northward have been rapidly changing with new data in recent years, in tandem with re-examinations and re-datings of early domesticates in Mexico. Currently, it appears that Mesoamerican crops were both transmitted and economically integrated into Southwestern societies at significantly earlier dates than in the Southeast. Agricultural technologies were also adopted and elaborated differentially in the two regions. Modes of transmission, pre-existing economic configurations, and environmental factors contribute to varied subsistence outcomes.

The incorporation of organizational themes and symbols reveals equally distinct trajectories. Architectural symbols of hierarchy, primarily platform mounds, and the iconography of power and coercion in the southeastern and southwestern United States also bear the imprint of Mesoamerican precursors. The developmental history of mounds as public architecture has few parallels in the two regions, but share areas of convergence in late prehistoric times. Expressions of a Mesoamerican-inspired iconography of social power, on the other hand, appear to have been highly differential, with unequivocal and specific borrowings of imagery in the Southeast and virtual absence of such images in the Southwest.

HOLOCENE PALEOHYDROLOGY OF THE AMERICAS FROM PALEOLIMNOLOGICAL RECORDS

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Paleolimnological records that reflect climatic change are relatively rare, and spatial coverage is extremely patchy. The majority of these indicate changes in hydrologic budget, evidenced as shifts in lake level or lakewater hydrochemistry, and I focus on these records in the following discussion. However, in some areas, particularly high-latitude or high-elevation regions, thermally driven shifts in stratification or the duration of ice cover can be derived from lacustrine proxy records.

In North America, the majority of Holocene paleolimnological records are from the northern continental interior, with relatively few from western and eastern NA. In nearly all NA records the mid Holocene is an interval of maximum aridity, although the onset, duration, and magnitude of aridity varies considerably among sites. In the northern Great Plains and midwest, lake levels began to decline in the early Holocene, and some lakes became hydrologically closed (Laird *et al*., 1996; Dean *et al*., 1996; Webb *et al.,* 1993). Maximum salinity and lowest lake levels occur between 7 and 5 ^{14}C yrs BP and can be attributed to increased zonal flow and the dominance of dry Pacific air masses during summer. The timing of maximum aridity appears to be time transgressive, beginning earlier in the western interior sites, and in the west dry conditions persisted until about 2 ka, whereas to the east increased moisture began earlier.

In the Great Basin and elsewhere in the southwestern US. many lake basins became dry in the mid Holocene, following early-Holocene levels higher than at present. The modern hydrologic regime is one dominated by summer monsoonal precipitation, which was enhanced at 9 ka, as a result of insolation-driven warming, and then subsequently decreased. The timing of maximum aridity is unclear, but there is widespread desiccation throughout the southwest by 5.5 ka (Holliday, 1989; Thompson *et al.,* 1993; Waters, 1989; Blinn *et al.,* 1994), which generally persisted until modern times. Some sites show pluvial phases within the mid- to late-Holocene arid interval, thus suggesting short intervals of enhanced summer precipitation.

Interpretations of lake records from the Great Lakes region of eastern NA disagree about Holocene moisture patterns. Records suggest that lake levels were highest during the early Holocene and subsequently fell. Most authors agree that the climate was warm from 8 to ca 2 ka, however, some suggest that maximum aridity occurred from 8 to 5.5 ka (Edwards *et al.,* 1986, Colman *et al*., 1990, Anderson *et al*., 1997), whereas others suggest it was driest between 5 and 2 ka (Yu *et al*., 1997; Dwyer *et al*., 1996). Clearly more sites are needed, as well as a more-developed understanding of lacustrine isotopic variation, which forms the foundation for many of the climatic interpretations.

A number of paleolimnological records exist from central America and the Caribbean, between 22° and 15° N latitude. The regions today are within a summer precipitation regime, with moisture derived from the Atlantic. Lake levels were generally low during the late-glacial period, because of southerly displacement of the ITCZ. Although lake-level patterns at the onset of the Holocene are regionally variable, by 7 ka nearly all the sites suggest wetter conditions than today and thus enhanced summer precipitation, probably caused by shifts in the position of the Bermuda high (Metcalfe 1997; Hodell *et al.* 1991). Between 6 and 4 ka sites in western and central Mexico became drier, whereas high lake levels persisted in the Yucatan and Caribbean, suggesting a decrease in the westerly penetration of summer storms. After ca 3 ka, some lakes in central Mexico show rising lake levels, high lake stands persist in the Yucatan, whereas the Caribbean became dry. Between 2 and 1 ka the Yucatan shows some of the lowest lake levels of the Holocene, whereas moisture appears to increase in the Caribbean (Hodell *et al.,* 1991, 1995).

In South America very few detailed Holocene records exist at present. In the northern Altiplano of Bolivia and Peru dating of paleolake shorelines (Servant and Fontes, 1978) and evidence from cores in Lake Titicaca (Mourguiart and Carbonel, 1994) indicate high lake stands at the onset of the Holocene, although the ages are not very well constrained. Clearly the interval from ca 8.8 to 3.6 ka was one of extreme aridity both in the northern and southern (Grosjean *et al.,* 1995) Altiplano, and many lakes went dry or dropped significantly below modern levels. Evidence from Chilean lakes indicates that this dry interval was punctuated by humid phases of relatively short duration, and ongoing investigations are underway elsewhere to refine understanding of the mid-Holocene. Lake levels began to rise throughout the Altiplano about 3.6 ka, and attained modern levels about 3.0 ka in the southern Altiplano and by 2 ka in L. Titicaca (Cross *et al.* 1998; Abbott *et al*. 1997). However, clearly the climate of the last 2000 years was variable, punctuated by intervals of both high effective moisture (Grosjean) and drought (Binford *et al.,* 1997).

Only a few high-resolution lacustrine records of decadal-scale climate variation exist at present from the Americas, and these are restricted to north-central NA (Laird *et al.,* 1996; Dean, 1997) and the circum-Caribbean region (Curtis *et al.,* 1996; Hodell *et al.,* 1995). These records clearly show dynamic short-term oscillations between wet and dry conditions and climate intervals more extreme than those of the 20th century, both in magnitude and duration.

CLIMATIC LINKAGES BETWEEN HIGH-LATITUDE NORTH ATLANTIC, TROPICAL SOUTH AMERICA AND OCEAN CIRCULATION: EVIDENCE FROM THE CARIACO BASIN

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Sediments of the anoxic Cariaco Basin contain high-resolution paleoclimatic and paleoceanographic evidence for teleconnections linking the high-latitude and tropical North Atlantic regions. Located on the north coast of Venezuela, the Cariaco Basin experiences strong seasonal shifts in climate due to the annual north-south migration of the Intertropical Convergence Zone (ITCZ). During the northern hemisphere winter, the ITCZ is at its furthest south, rainfall over the Cariaco region is at a minimum, and strong trade winds blow along the coast, inducing Ekman upwelling. During northern hemisphere summer when the ITCZ has migrated north, rainfall increases and both trade winds and upwelling are reduced. This alternation between a dry, upwelling season and a rainy season with little or no upwelling results in the deposition of laminae couplets – light layers containing primarily siliceous microfossils from plankton blooms and dark layers containing terrigenous grains from river runoff. Independent dating of the sediments using both excess ^{210}Pb concentrations and historical records of earthquakes that caused turbidity flows demonstrates that the laminae couplets are annually deposited varves.

Relative reflectivity (grey scale) and light laminae thickness measurements correspond to the amount of seasonal productivity and upwelling intensity. Upwelling in turn is controlled by the strength of the trade winds. Cariaco Basin sediments record rapid fluctuations in trade winds that agree closely with high-resolution paleoclimate records from throughout the high-latitude North Atlantic region. Trade winds experienced rapid oscillations during the last deglaciation, including the Bølling/Allerød and Younger Dryas events. Some of the transitions surrounding these events were extremely abrupt – for example, the Younger Dryas termination occurred in less than a decade. In addition to large millennial-scale oscillations, the Cariaco Basin records detailed patterns of change that agree at the decade-to-century-scale with δ^{18}O and accumulation records from Greenland ice cores. A comparison of high-resolution paleoclimate records from the Cariaco Basin and GISP2 ice core, both plotted against individual annual time scales, show that the independent chronologies agree within 20 years over most of the last deglaciation, and always agree well within the combined errors of the two chronologies. This calendar-age agreement, together with the striking similarity of decade-scale patterns of change, suggest that climatic changes occurring in the high-latitude and tropical North Atlantic regions were essentially synchronous. The dynamic mechanism linking these distant regions is trade winds responding to changes in latitudinal temperature gradient. Instrumental data as well as atmospheric and coupled ocean-atmosphere general circulation model experiments show that reduced high-latitude North Atlantic sea surface temperature results in increased trade wind strength. ODP cores recently recovered from the Cariaco Basin show millennial-scale variability throughout the last glacial cycle that is similar in pattern and character to Dansgaard-Oeschger events. Individual Dansgaard-Oeschger events, as well as larger-scale 'Bond cycle' variability, can be clearly identified and used to provide a calendar-age time scale back to marine isotope stage (MIS) 5a. The sea surface temperature-trade wind mechanism linking high and low latitudes appears to function at time scales from 10 to 10,000 years. Cariaco Basin grey scale records extending back to MIS 13 suggest that this mechanism may have been in operation during at least the past 4-5 glacial-interglacial cycles.

In addition to records of trade wind variability, the Cariaco Basin also preserves evidence of changes in deep ocean circulation. The annually laminated sediments of the Cariaco Basin permit calibration of radiocarbon during the period of the last deglaciation. Calibrated radiocarbon dates can be used to calculate atmospheric ^{14}C concentration, or Δ^{14}C. Δ^{14}C fluctuates as a result of changes in ^{14}C production rate, primarily due to shifts in the earth's geomagnetic field strength and solar variability, as well as changes in the distribution of ^{14}C between different reservoirs. The ocean stores 60 times more carbon than the atmosphere, and changes in deep ocean ventilation rates have a large influence on the Δ^{14}C of the atmosphere. The Cariaco Basin provides grey scale and Δ^{14}C records from the same sediments, allowing a direct comparison of North Atlantic paleoclimate and deep ocean ventilation and a precise determination of potential lead-lag relationships. A large (50-60‰) increase in Δ^{14}C is observed at the same time as the onset of the climatic Younger Dryas, suggesting they were caused by the same forcing mechanism. Geochemical box model experiments indicate that the paleoclimatic and Δ^{14}C changes observed during the Younger Dryas were likely caused by a reorganization of deep circulation in the North Atlantic Ocean. The evidence suggests that, during the Younger Dryas, North Atlantic Deep Water (NADW) formation abruptly ceased, but was gradually replaced by the formation and export of North Atlantic Intermediate Water (NAIW). NAIW formation gradually increased throughout the duration of the Younger Dryas, then itself was abruptly replaced by NADW formation at the Younger Dryas termination. The Cariaco Basin records demonstrate that changes in ocean circulation during the Younger Dryas were more complex than a simple shutdown of NADW formation alone. Ongoing research into radiocarbon changes during MIS 3 Dansgaard-Oeschger events is investigating whether similar reorganizations of deep ocean circulation may have caused the large and abrupt climate changes observed throughout the last glacial cycle.

ABYSSAL CIRCULATION AND INTER-HEMISPHERIC CLIMATE CHANGE

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One of the most remarkable scientific findings of the last decade is the evidence from Greenland ice cores for abrupt shifts in local air temperature of 5-10° C in decades or less. These typically recur on millennial to centennial timescales and are characteristic of at least the last ~100 kyr. Similarly large and abrupt changes in proxy SSTs are evident in marine sediments of the subpolar and polar North Atlantic ocean (> 45° N) and these appear to be in phase with the Greenland record to within a few decades (that is, within one half the duration or the briefest well-correlated signals). The circum- North Atlantic changes may have also produced a variety of tightly teleconnected environmental signals at distant locations such as the Cariaco Basin (via changes in latitudinal SST gradient and wind stress) and Santa Barbara Basin (via atmospheric cooling and associated changes in thermocline ventilation). All of these can be explained as a direct or indirect response to variations in mode and strength of North Atlantic Deep Water production.

Julian Sachs and I have recently developed a record of SST variations at Bermuda Rise (33° N) with approximately 50-100 yr resolution for the interval ~70-30 kyr BP. Millennial changes in SST are typically 2-4°C and intimately associated with changes in NADW proxies (that is, "in phase" to within the stratigraphic resolution). Bill Curry and Delia Oppo have obtained similar results at Cearra Rise, at 5° S off of Brazil. There, planktonic $\delta^{18}0$ variations suggest SST variations of approximately 2° C, also in association with changes in NADW indicators. The reconstructed SST changes at both locations are larger than expected from modulation of NADW alone (at least as depicted in current A/O GCMs) suggesting that additional and as yet undetermined forcing and/or feedbacks augment the temperature response at lower latitudes. Irrespective of their origin, these SST changes ought to have produced significant climatic responses over low latitude land masses.

The positive relationship between "strong" NADW and high SST observed north of 5° S appears to break down in the high latitudes of the Southern Hemisphere. Chris Charles and coworkers have shown that proxies of SST (planktonic $\delta^{18}O$) and of the proportion of NADW in Circum Polar Deep Water (benthic $\delta^{13}C$) at 41° in the South Atlantic are out of phase. These observations agree qualitatively with objective correlations of isotope paleo-temperature records from Greenland and interior Antarctic ice cores (via correlation of mixing- and isotopic- ratios of enclosed gases) showing an out-of-phase (possibly anti-phase) relationship in estimated temperatures. One suggestion is that this may be due to a so-called 'see-saw' in ocean heat convergence and/or strength of convection between the North Atlantic and Southern Ocean seen in many A/O-and O-GCMs. However, modelers do not seem to have much confidence in their ability to simulate the complex dynamics of the Southern Ocean. Futhermore, a new, objectively-dated paleotemperature record from Taylor Dome (near the E. Antarctic coast of the Ross Sea) shows a warming schedule during deglaciation similar to that on Greenland and roughly consistent in timing with increases in the proportion of NADW in CPDW. At the very least, this record suggests that the circum-Antarctic temperature response to changes
in global overturning circulation varies in space and in sign.

Needless to say, oceanographers are not yet in a very good position to tell terrestrial investigators what to expect. Indeed, any insights from well-dated, well-resolved low latitude and Southern Hemisphere land records would be more welcome than ever

LATE QUATERNARY HISTORY OF THE LAKES, THE VEGETATION AND CLIMATIC TRENDS IN THE BASIN OF MEXICO: LAKES CHALCO, TEXCOCO AND TECOCOMULCO

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During the Quaternary evolution of the Trans-Mexican volcanic Belt several closed basins were formed, among them the basin of Mexico (BM) which was developed after a huge volcanic activity within the Chichinautzin range at *ca.* 0.78 Ma. After the damming, lacustrine sedimentation began and according to geomorphologic and geological evidences an extensive lake system evolved. By the beginning of the XVI century this lake system was reduced into several smaller lakes including: Chalco (LCH) in the south, Texcoco (LTX) in the center and Tecocomulco (LTC) in the northeastern part. Eleven cores were drilled in these lakes in order to document paleoenvironmental changes, vegetation, lake-levels and volcanic activity, during the late Quaternary by using a multiproxy approach.

Recently published data on the evolution of Popocatepetl (1) gives evidence that volcanic activity has been a major factor in the evolution of the landscape in the BM. Several tephra layers identified in the lacustrine sequences, products of the volcanic activity of Popocatepetl (2) and other volcanoes, are used for tephracorrelation. Chronology is based on 42 radiocarbon dates (AMS and standard ^{14}C dates).

Early glacial pollen records from the BM show high values of *Pinus* in most of the records. The presence of this taxa is already recorded in the Pliocene pollen data form the BM although in low abundance**.** In the LTX and LTC sequences, from ca 40 kyr to 28 kyr, pines dominated the landscape and high lake levels are recorded, suggesting temperate-cool subhumid conditions. Prevalence of *Pinus* forest continues from ca 28 kyr to ca 16 kyr but a more open forest is detected. The presence in LCH, LTX and LTC pollen records of *Picea* pollen, which nowadays is present only in the north of Mexico, indicates cooler climates in the BM. Low lakes levels in LCH and expansion of xerophytic elements (*Mimosa*) at ca 17 kyr and 15 kyr are signals of dry conditions periods. In the LTX sequences increment in grass pollen with evidence of swamp conditions in the lake also points to climates drier than the present. In the northern part, the LTC record, shows very low lakes levels after ca. 16 kyr BP with a hiatus in sedimentation.

During the last termination (ca. 14.5 kyr) the record in the BM is not clear as volcanic activity was intense. In LCH there is some evidence of moister conditions but this trend is not clear in LTX or LTC. By the end of the Pleistocene dry conditions and the presence of hiatuses are recorded in LTX and LTC. The Pleistocene/Holocene transition is only recorded in LCH where it shows high ^{18}O values that give evidence of higher E/P and are interpreted as warmer conditions in the BM.

The beginning of the Holocene is characterized in LCH by a reduction of *Cupressus-Juniperus* pollen with an expansion of *Quercus*. A change in pollen composition assemblages from ca. 9.5 to 8 kyr is observed. A clear expansion of *Abies* in LCH records, along with low values in ^{18}O isotopes and evidence of glacial advances (3) points to a cooler short period in the BM. Low lake level in LCH is inferred (4), however, based on diatom data for this period. This conflicting evidence might indicate that lake levels and vegetation are reacting differently to modification in the water balance in the area during the early Holocene. During the mid to late Holocene an increase in lake levels is recorded in LCH and LTX by ca. 6/5 kyr. In LTC lacustrine conditions are re-established by ca. 3.5 kyr. The late Holocene pollen records in LCH, LTX and LTC shows a clear signal of human impact in the basin. Volcanic activity is recorded in pollen diagrams, charcoal, magnetic susceptibility and other proxies of the lacustrine sequences. Their impact varies from fires to important changes in lake levels like the event of 22.5 kyr in LCH when an increase in lake level is associated with the collapse of the volcanic cone of Popocatepetl (4). Vegetation composition in the BM is related to this intermittent volcanic activity. The environmental gradient between the relatively dry north and the moister southern areas was already present in the BM since probably ca. 16 kyr ago as shown by the trends in the records from LTC and LCH.

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HOLOCENE GLACIER HISTORY OF THE NORTH AMERICAN CORDILLERA

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Glacier fluctuations have been a traditional source of information about past climatic history in the North American Cordillera but the preserved glacier record has significant limitations. In most areas the maximum Holocene glacier extent was during the "Little Ice Age" and most surface evidence of earlier Holocene glacier events was eliminated. Therefore only the extent and timing of the LIA maximum and subsequent events can be reconstructed in detail. The record of earlier glacier history is fragmentary and based on three major lines of evidence. (i) Scattered sections found within LIA limits. Dating, where available, only provides maximum or minimum ages (which may not be closely limiting) for glacier advances and former glacier extent is poorly defined. (ii) Morainic evidence of older events may be preserved beyond LIA limits at a few, regionally anomalous, sites. Although documenting the presence and possibly providing dating of earlier glacier events, these examples cannot be used to define their regional characteristics. (iii) Cores or stratigraphic sections from present or former downvalley, ice-marginal or proglacial lakes that received sediment from the glacier. These often provide the most complete and best-dated records.

The incomplete nature of the earlier records, limited dating control and related uncertainties (e.g. in ^{14}C dating) make it difficult to distinguish (and correlate) events which are <2-300 ^{14}C years apart. As synchroneity is the key to the reconstruction of spatial patterns, these dating uncertainties limit the development of past climate scenarios. The climate signal of glacier records may also be ambiguous. Glacier dynamics are primarily controlled by mass balance relationships which involve both precipitation and temperature variables and may be significantly influenced by non-climatic factors such as surging or calving behaviour. Most of the examples used in the following discussion are glaciers with terrestrial, land-based termini (often in predominantly forested environments) that provide directly comparable, relatively well-dated records.

The Holocene glacial history is discussed for three timeframes: the Little Ice Age (most of the last millennium); mid-Holocene (Neoglacial) and early Holocene/Late Glacial. The best dating control and greatest volume of information is for the LIA. The data show multiple, often synchronous periods of glacier advance but the timing of the maximum LIA glacier extent differs between glaciers and between regions within the Cordillera.

In Alaska the LIA was usually the most extensive Holocene event. Land-based, non-surging coastal glaciers in Prince William Sound and adjacent areas overrode calendar-dated trees in the late 1200s/early 1300s and early 17th/early 18th centuries. Two subsequent major intervals of moraine construction are identified (early 18th and late 19th centuries) and glaciers were close to their maxima in the late 1800s. Tidewater calving glaciers show spectacular fluctuations (LIA maxima ranging from ca. 1250-1890 A.D.) that may or may not be synchronous with adjacent land-based termini. In Interior Alaska lichenometric ages for moraines in the Brooks Ranges cluster around ca 1200, 1570 and 1860 A.D. with the 1570 moraines being most widely distributed. In the Wrangell Mountains glaciers expanded ca. 1169-959 BP with four lichen-dated moraine phases ca 1500, late 18th-mid 19th, late 19th, early 20th centuries. However, the physical expansion of glaciers is limited by earlier Holocene moraines in this region and in the adjacent Yukon where the LIA maxima occurred in the mid-late 1800s. During the 20th century most glaciers have receded except for those in areas of high precipitation or some calving or surging glaciers.

In the Continental Interior sites of the Canadian Rockies the earliest LIA advances have been calendar dated by tree-rings at 3 sites to between 1200 and 1375 A.D. Little definitive evidence is available for glacier fluctuations during the 1400-1600 period. Based on data from ca 60 glaciers, two major moraine building periods occur in the early 18th and mid-late 19th centuries. The maximum regional extent of ice was probably ca.1850 A.D. though at many glaciers the 18th century was slightly greater. Several readvances occurred in the late 19th century to positions close to the maximum position. A recent summer temperature reconstruction based on tree-ring densitometry at the Columbia Icefield suggests strong summer temperature control of glacier fluctuations over the last millennium but contemporary (last 30 years) mass balance data indicate that decreasing winter accumulation is the primary contributor to recent negative mass balances. Available lichenometric dating from the Colorado Rockies suggests the oldest LIA moraines are late 17th-early 18th century, similar to the Canadian Rockies, although tree-ring dating from intervening sites in Glacier National Park, Montana show only mid-19th century moraines.

Evidence from sub-till dates and lacustrine episodes indicate that initial LIA advances in the Coastal Ranges of B.C. began 1000-600 ^{14}C yr BP. A few glaciers in the southern Coast Ranges and Bella Coola areas have maxima in the early 1700s but most have maxima between 1850 and 1900. These results indicate that, generally, LIA maxima in the B.C. Coast Ranges were slightly later than those in the Rockies. However, available dating from glaciers in the Cascades and Olympic Mountains show 16th-18th century moraines at Mount Rainier, Dome Peak and Blue Glacier as well as early-mid nineteenth century maxima.

In summary, despite a recurring temporal pattern to the LIA advances (1200-1300s, early 1700s, mid-late 1800s), the timing of the regional maximum extent varies considerably. There are also regional differences in mid-Holocene glacier events. The earliest Neoglacial moraines are dated to 5-6000 yr BP (Garibaldi Advance in BC, early advance on Mount Rainier) in the Coast Ranges but oldest advances in the Rockies postdate ca 3800 Yr BP. Several glacier advances are identified in the period ca 3300-1900 yr BP (Tiedermann advance in BC) and there is strong evidence for a regional event after 2800 yr BP in Canadian Rockies (Peyto Advance) and BC Coast. Several glaciers show evidence of multiple advances during this period and evidence for an event postdating ca 1500 yr BP occurs at Peyto and Tide Lake BC. There is some evidence of progressively more extensive Neoglacial advances. However, at most sites the evidence is not clear enough to distinguish whether there are several discrete events during this time frame or simply a period of continuous period glacier advance.

The early Holocene was a time of restricted glacier cover; valley-floor areas upvalley of the present snouts of Athabasca and Dome Glaciers in the Canadian Rockies were forest covered between ca 8230-7550 and 6120-6380 yr BP. The late glacial record has attracted considerable attention but there are few well dated sites. Recently the regionally identified Crowfoot Advance of the Canadian Rockies has been dated between 10,070±420 and 11,330±330 yr BP from lacustrine sediments. Similar dating control (>9970±80 ,<11,070±50) brackets moraine formation at Sky Pond in the Colorado Rockies. These two sites indicate a glacier advance during the Younger Dryas Chron that was of equivalent or slightly smaller extent than the LIA. The only Early Holocene moraines with bracketing dates (>8990±60,<9580±50>) are for the McNeeley 2 event on Mount Rainier.

LATE QUATERNARY VOLCANIC ACTIVITY AND ITS INFLUENCE ON LACUSTRINE SEDIMENTATION IN CENTRAL MEXICO

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During the last 40,000 years the lacustrine basins of Mexico and the Upper Lerma, in central Mexico, have witnessed intense activity from Popocatépetl and Nevado de Toluca stratovolcanoes. These two volcanoes are located at 70 km SE and 22 km SW from Mexico City respectively. The Upper Lerma and Mexico are two high altitude basins, once had large shallow water bodies around where early populations developed since ca. 7000 yr. BP. These lakes are now nearly dry due to water extraction but their sediments keep an excellent record of the volcanic activity and environmental evolution of the area.

The Upper Lerma Basin: At least five major eruptions of Nevado de Toluca volcano have occurred during Late Pleistocene: ca. 37,000; 28,000; 24,000; 15,000, and 11,600 years BP (Macías *et al*., 1997; Caballero *et al*., 1998). Ten meter deep cores in the basin record the last two events as an ashflow deposit and a plinian fallout layer respectively. This well constrained stratigraphy is also improved by a fallout tephra from the Tres Cruces volcano dated at ca. 8500 yr. Subaereal exposures suggest that an extensive lake existed in the Upper Lerma basin prior to ca. 24,000 yr BP. Palaeolimnological data indicate that during the last ca. 15,000 yr. a shallow, productive, freshwater lake has been present in the area. This lake experienced a period of shallower waters level by ca. 8500 yr BP after which lake levels recovered (Metcalfe *et al.*, 1991; Caballero *et al*., 1998).

The Mexico Basin: The present cone of Popocatépetl volcano has been constructed after a St. Helen's type eruption that occurred ca. 23,000 yr. ago. Popocatépetl became active at least 8 times since then at ca. 14,000; 11,000; 9000, 7000, 4800, 2100, 1700 and 1200 through the establishment of large plinian events (Siebe *et al*., 1997). Of these, the 14,000 yr old eruption blanketed the basin of Mexico with >10 cm of pumice. Only the 14,500 and the 5000 yr. BP are present in the Chalco basin (Lozano and Ortega, 1998; Caballero and Ortega, 1998) and the 11,600 yr BP fallout from Nevado de Toluca (Caballero and Ortega-Guerreo, 1998).

The 14,000 and 11,600 yr old eruptions of Popocatépetl and Nevado de Toluca volcanoes not only covered the water bodies of the basins with sand-to-gravel size pumice but also the surrounding highlands. Subsequent remobilization of this unconsolidated sediments by spring discharge, glacier melting and rainfall water generated secondary mud flows and intense fluviatile sedimentation depositing thick volcaniclastic sequences in the lake's periphery (Caballero, *et al*., 1998; Siebe *et al*., 1998).

Volcanic activity can also modify the lacustrine environments by changing the local hydrological network. One of the most important transitions in Lake Chalco correlates with the 23,000 yr. old St. Helen's type eruption of Popocatépetl. During this event the collapse of the cone favored the transition of Lake Chalco from a shallow saline to a fresh water lake. Limatic changes also modified the lacustrine environment at Chalco. Lake Chalco was a relatively deep lake during the last interstadial with a trend towards lower lake levels during the Glacial Maximum (ca. 20,000-18,000 yr BP). Slightly higher lake levels correlate with the end of the glacial period. The early Holocene is recorded as a shallow, saline interval after which lake levels recovered by ca. 5000 yr BP.

Therefore these two basins represent suitable sites to monitor climatic changes and the impact of volcanic activity to the palaeo-environmental conditions of the lakes during the last 40,000 years. Refinement of the stratigraphic record of the lakes will allow determining glacial or interglacial epochs that can be link to subaerial exposures showing secondary sedimentation. Therefore more detailed studies are necessary to document the full impact of this activity on the vegetation and the lakes of the area and their later recovery.

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CULTURAL INTERCONNECTIONS BETWEEN NORTHERN AND SOUTHERN HEMISPHERES

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This paper will deal with cultural aspects that related the northern and southern hemisphres in Prehispanic times.

Leaving aside problems of various origlns of the different varieties of maize between 6000 and 5000 B.C. both in Mesoamerica and Southamerica, by the third millennium B.C., a dynamic scenario of flows of successful hybridized cultigens, such as pumkins, squash, beans, chili peppers, bottle gourds, peanuts, sweet potatos and maniocs may have flowed between Mesoamerica and the Andean Region in both direct ions.

It is particularly in Western Mexico, where some archaeological traits, such as stirrup pots, shaft tombs, copper and bronze metallurgy suggest various contacts between this Mesoamerican region, and the Peruvian and Ecuatorian coasts. Manteño merchants have been suggested as the agents of this flow.

Some linguistic elements have furthermore been cited as independent data suggesting these contacts (the Tarascan language–a linguistic island in Mexico–is related to the quechua of the Andean Region).

On the other hand, Columbian gold metallurgy may have influenced Centralamerican goldsmithery, that show their impact in the Mayan Area.

FOREST ECOSYSTEM RESPONSE TO CLIMATIC CHANGES ON MILLENNIAL TIME SCALES IN THE WESTERN AMERICAS

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Today's striking similarities in landform, climate, and environmental gradients between temperate western North and South America invite comparison of their environmental histories. The question is how did these similarities affect the environmental histories in face of the markedly different floristic composition of the biota and different past hemispheric forcing, e.g. insolation, distribution of ice sheets, etc.

At present, conifers dominate the temperate flora of western North America, a flora which evolved and diversified during mid and late Tertiary times in response to long-term cooling and tectonism, that led to an intensification of summer-dry conditions and development of rainshadow regions (Barnosky, 1987). In contrast, the flora of temperate western South America is dominated by evergreen, small-leaved tree taxa, while conifers play only a minor role. This southern distinctiveness is attributed to low diversification and extinction rates since late Cretaceous times and an absence of major amplitudes of climate change in the Quaternary (Markgraf *et al.,* 1995). Today's distribution of temperate ecosystems in western North and South America is related primarily to seasonal patterns of precipitation in response to conditions in the Pacific Ocean and the interaction between tropics and extra-tropics (Lawford, 1996). Seasonal shifts of the westerly storm-tracks (poleward in summer and equatorward in winter), determine the duration of the dry season and are the principal parameters affecting distribution of temperate biota in the Americas (Veblen and Alaback, 1996).

The character of full-glacial environmental changes is comparable in both North and South America (Barnosky *et al*. 1987, Thompson *et al.,* 1993, Villagran and Armesto, 1993, Markgraf, 1991). High temperate latitudes became essentially treeless, replaced by tundra in Alaska, *Empetrum* heath and scrub-steppe in Tierra del Fuego and southern Patagonia. At comparable mid-latitudes in both regions open forest and parkland expanded in areas of present-day rainforest. In western North America subalpine tundra, and in western South America Magellanic Moorland was more widespread and occurred at lower elevations than today. Overall the west to east gradient across the mountains was markedly intensified during full-glacial time. Equatorwards in both hemispheres, in the transition from temperate to subtropical latitudes, woodland and montane conifers expanded down-slope to elevations that now support desert, steppe shrubland or sclerophyllous forest. These changes, comparable in both hemispheres' temperate regions indicate overall colder and drier conditions. However, the spatial extent and magnitude of these changes was far greater in North America than in South America. The primary reason for this difference is the impact of the Laurentide ice sheet on regional climates of western North America, causing displacement of the polar jet stream, stronger glacial anticyclones, and a steepening of the latitudinal temperature gradient. In South America, where there is no comparable mid-latitude ice sheet, the primary full-glacial forcing is related to the increased extent of circum-Antarctic sea-ice. As a consequence, the steepest segment of the latitudinal temperature gradient was at lower latitudes in North America than in South America. This in turn forced a 10° to 15° equatorward shift of the westerly storm-tracks in North America, compared to a shift of only 5° in South America.

Early Holocene conditions in temperate western North America are characterized by spread of spruce along the Northwest Pacific coast, expansion of Douglas fir and alder forest in the Pacific Northwest, and dominance of lodgepole pine forests in the northern Rocky Mountains. East of the Cascade Range warm-temperate steppe expanded to higher elevations and higher latitudes than today. Areas where charcoal analyses have been undertaken indicate that the fire frequency was higher in the early Holocene than at present. In contrast, in southwestern North America, simultaneous upward shift of the upper forest limit and downward shift of the lower forest limit suggest higher temperatures at high elevations and increased precipitation at low elevation. The difference in early Holocene climate in the two regions can be explained by variations in the seasonal cycle of insolation, and their effects on atmospheric circulation. In the Northern Hemisphere summer insolation between 14 and 7 cal ka was higher than present whereas winter insolation was lower than at present. GCM models suggest that the summer insolation anomaly directly led to increased temperature and decreased effective moisture. Indirectly, it strengthened the northeastern Pacific high pressure system, which intensified summer drought in the Pacific Northwest, and enhanced monsoonal circulation in the Southwest, leading to wetter summers (Thompson *et al.,* 1993, Bartlein *et al.,*1998).

In temperate southern South America early Holocene insolation was characterized by a reduced seasonal cycle, with warmer winters and cooler summers than today. According to GCM simulations, this insolation anomaly led to weaker summer monsoons, resulting in warmer and drier conditions in the lower temperate latitudes, and to a reduction of the strong seasonal latitudinal shifts of the westerly storm tracks, evident at present. Instead early Holocene storm-track posi-

tion remained at an equinoxial latitude (45 to 50°S) year-round (Markgraf *et al*,, 1992). In fact, vegetation distribution in the early Holocene shows high precipitation rainforest and Magellanic moorland only in the intermediate latitudes of 45 to 50° S, and drought-adapted forest or woodland both at the northern and the southern range of the temperate rain forest region. High fire frequency, documented in charcoal records, is characteristic of the early Holocene especially for the high latitudes (Markgraf and Anderson, 1994).

Hence, for the early Holocene, inter-hemispheric similarity of climate patterns occurred despite hemispheric differences in the seasonal cycle of insolation. In both hemispheres' high latitudes, the insolation anomaly brought drought conditions related to the expansion of the subtropical high pressure system. For the lower latitudes, however, the regional response to the specific insolation regime resulted in markedly different climates. In southwestern North America, enhanced monsoonal circulation led to increased precipitation, whereas in the lower mid-latitudes of South America, summer precipitation was essentially absent and even winter precipitation was reduced.

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ARCHAEOLOGICAL APPROACHES TO THE RECONSTRUCTION OF PALEOENVIRONMENTS: AN EXAMPLE FROM TEOTIHUACAN, MÉXICO

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Recent research in the Teotihuacan Valley in northeastern Basin of Mexico attempts to recover independent evidence for past environmental conditions. In this region, the development of the prehistoric city of Teotihuacan–the population of which reached at least 150,000 permanent residents around A.D. 500, extending over an area of 20 km^2–and the state system over which it held control, undoubtedly had a significant impact on the immediate valley as well as adjacent regions. Over the decades, many hypotheses concerning pre-urban as well as urban processes incorporated assumptions about the relationship between prehispanic populations and the environment: the location of communities with respect to resource availability; the agricultural potential of the region insofar as its capability to fulfill the urban center's needs; the role of irrigation in the state formation; and the possibility of over-exploitation of natural resources as a contributing factor to the fall of Teotihuacan, among others. All of these hypotheses suffered from the absence of direct evidence for paleoambiental conditions in the study region, although they stimulated years of intense discussion.

Objectives

1. Develop a suitable and replicable technique for the analysis of evidence for paleoenvironmental conditions in the Teotihuacan region at different moments in the past.

2. Detect and differentiate evidence for human impact on the environment from the effects of natural phenomena such as climate change and geomorphological processes.

Methodology

A pilot study was undertaken in order to determine the degree of preservation of direct evidence for paleoenvironmental conditions in the region as well as to develop an appropriate methodology for the analysis of data. A total of 24+ soil profiles were excavated between 1992-98. A NW-SE transect across the valley between Cerro Colorado and the Patlachique Range was complemented by additional profiles in the central alluvial plain, Cerro Gordo and other points in the Patlachique Range. In addition to physical-chemical analyses of the soils, pollen, phytolith and macrobotanical specimens were recovered from selected profiles. 78 radiocarbon dates were obtained, mostly from organic sediments including 69 conventional and 9 AMS determinations (from which $\delta\ ^{13/12}C$ ratios were also determined).

To look at landscape alteration in cultural terms, a preliminary division into 5 periods was established based on available radiocarbon determinations:

23,000-11,600 BP (Pleistocene/ Transition to Holocene)
8200-7000 BP (Archaic)
5500-3200 BP (Middle-Terminal Formative, starting with first permanent settlement of region by permanent agriculturalists)
3000-1900 BP (Teotihuacan period)
1200-300 BP (Fall of Teotihuacan-Beginning of Colonial period)

Preliminary Results

Probable buried soils have been identified from several profiles; additional laboratory analyses are underway to confirm their characteristics in order to evaluate their implications fro local processes. Pollen was poorly preserved in most contexts; phytoliths, on the other hand, were well represented. Phytoliths from Cerro Gordo, Cerro Colorado and the Patlachique piedmont indicate an overall predominance of grasses adapted to dry conditions. Phytolith evidence also supports the hypothesis that pine/oak forest was dominant on the peak of Cerro Gordo throughout most of the cultural sequence represented. Today, only a limited area of oak forest exists in this area. Profiles from the Patlachique Range, located in a stretch of gentle piedmont just above 2300 masl, revealed low frequencies of pine and oak phytoliths, possibly corresponding to sediments deposited from higher slopes. Both types of phytoliths are practically absent from samples from Cerro Colorado. Yet both are consistently present in sediments on the alluvial plain throughout the sequence, and particularly during the period of Teotihuacan occupation. $^{12/13}C$ ratio from buried A horizons in the piedmont zones of the Patlachique Range and Cerro Colorado indicate that succulent plants provided the source of carbon dates in samples from these areas, suggesting that the vegetation characteristic of these areas during the Formative period was probably xerophytic scrub. In general, the evidence suggests continuity in the types of vegetation characteristic of the region, including pine-oak forest on higher slopes, and especially xerophytic scrub and grassland, with changes in the distribution (extension) of communities

through time. Pollen evidence, however slight, supports this scheme. Macrobotanical materials largely reflect the modern seed bank and include opportunistic genera that are commonly found in the valley today: Amaranthaceae, Chenopodiaceae, Portulacaceae, Brassicaceae, Compositae, Cruciferae and diverse grasses.

In general, botanical evidence suggests that vegetation changes during prehispanic times in both the alluvial plain and surrounding piedmont are closely related to agricultural practices as would be expected. Soil evidence supports the hypothesis that major erosive processes occurred in more recent times, following Spanish Conquest, possibly associated with abandonment of prehispanic terrace systems. A few instances of inverted radiocarbon dates may reflect this process.

Discussion

From a chronological perspective, botanical evidence from radiocarbon dated strata suggests a predominance of dry conditions throughout the Formative period with a tendency towards increasing humidity beginning during the Terminal Formative and continuing during the Teotihuacan period, followed by a return to drier conditions around the time of the fall of Teotihuacan to the Colonial period. A zonal perspective suggests the influence of land use: dry conditions characteristic of surrounding slopes throughout the cultural sequence, with a slight increase in humidity in the Patlachique piedmont during the Teotihuacan period. In the high-water table zone of the alluvial plain, below 2290 masl, a tendency for increased humidity is evident from the Middle Formative through the Colonial period, although drier conditions seem to be indicated during the Archaic. In areas situated between 2290 and 2350 masl, dry conditions predominate with a slight decrease during the Teotihuacan period and a return to similar conditions following the fall of Teotihuacan.

RANCHING SONORAN RANGELANDS: USING THE PLEISTOCENE AS A MODEL

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The current use of Sonoran rangelands in Mexico is based on domestic herbivores, especially cattle, and, to a lesser extent, goats. However, neither species uses efficiently the forage that is produced on the range. In response, ranchers often clear large tracks of "useless" native thorn scrub to create adequate habitat for cattle, commonly establishing buffel grass (*Cenchrus ciliaris*). Although these pasturelands are regarded as a symbol of progress by cattle ranchers and many governamental officers, such habitat modification has many undesirable ecological effects.

A good alternative to cattle ranching is the use of wild herbivores, which are better adapted to local conditions, and often make a more efficient use of the food resources available. In the Sonoran Desert, this approach is limited by the few wild herbivores present: two species of deer (*Odocoileus hemionus* and *O. virginianus*) and javelina (*Dicotyles tajacu*) in the brushier areas, and the pronghorn antelope (*Antilocapra americana*) in more open areas.

In contrast, herbivore communities were quite diverse before the end of the Pleistocene, when they underwent massive extinctions. The reasons for these extinctions are still debated, but acceptance of Martin's (1973) hypothesis of anthropogenic overkill, exhibits the current low herbivore diversity as evolutionarily anomalous. Therefore, increasing the herbivore richness in these communities is quite reasonable, although great care should be exercised while doing so. A well planned re-diversification can improve use of the range, while avoiding the conservation problems derived from cattle and goats, and can also restore paleoecological processes that became non functional after the Late Pleistocene loss of herbivores (Mellink, 1991).

The establishment of complex, multispecific communities requires the introduction of exogenous species. Communities of exotic ungulates have often been established for hunting purposes. The species that compose them are selected for their merit as trophies. Contrariwise, a review of Pleistocene assemblages can provide a sounder base to establish such complex communities. So, Martin (1981) proposed that exogenous candidates be selected based on taxonomic affinities. A different perspective is that ecological rules, regardless of taxonomic affinities, should be used for such purpose.

Species in several Pleistocene faunal assemblages from Sonora show a good spacing along a size gradient, regardless of the particular species in the assemblage (Mellink, 1995). This corresponds with current ecological theory, and suggests that a minimal size difference (v.gr. Hutchinson's rate, 30%) allows species to coexist. It also suggests that ecological processes, rather than coevolutionary ones, were at play. When two habitats were present, species could be more similar in size, if the similar-sized species did not overlap spatially.

I tested the size-difference criterium with data from a ranch in central Sonora on which 13 ugulates occurr, most of them exotic. The four similarly-sized species that occupied close habitats did not overlap spatially. Species in open habitats differing in size by at least 30% did overlap extensively in the habitat they used. Three species of similar size, in this same habitat, that also overlapped in space use had a statistically different fecal pH, suggesting differences in diet.

Other similar-sized species coexisted through very clear different feeding strategies. On the other hand, microhistological fecal analysis for nine herbivore species showed that the species organized loosly along a grass - tree gradient, but that there was a great overlap among them in the species of plant consumed; even so among some herbivores that were of different size. Two suggestions can be derived: 1) there are fine-tunning mechanisms in the community, v.gr. involving differences in parts of plants used, and 2) at least during certain periods, competition might be high. Overall, however, assembling multispecific communities of large herbivores based on a size gradient appears to be a superior procedure than to the select species on a purely subjective bases, as is currently done on game ranches.

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HIGH RESOLUTION PALEOCEANOGRAPHY OF THE BAY OF LA PAZ, GULF OF CALIFORNIA, EVIDENCED BY RECENT RADIOLARIANS

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The Bay of La Paz, in the Gulf of California, México, is a basin relative shallow (depth < 450 m) and semiclosed by islands. In consequence, it is not common to observe within it, incursions of all the water masses which get into the Gulf of California from the Pacific Ocean, and the presence of subtropical waters predominate. In spite of it, the analysis of the radiolarian content in the kasten core "BAP96J-CP" (2.11 m long), collected in the bay, suggests that the oceanographic environment of the bay has fluctuated in concurrence with oceanographic changes observed in the mouth of the Gulf of California. Core "BAP96J-CP" shows laminated structure and a sedimentation rate of 1.9 mm per year. The down-core records of 3 radiolarian assemblages, defined through Q-mode Factor Analysis, suggest that the Bay of La Paz, has experienced three oceanographic changes conspicuous during the time considered in this study. From approximately 1014 to 720 years ago, both the eolic as the oceanic circulation were relative strong. This produced, in turn, strong upwelling events, vertical mixing and the flourish of *Hexacontium enthacanthum* Jorgensen. From approximately 720 to 360 years ago, an "stagnation" of Subtropical Water occurred within the bay. This promoted the flourish of *Tetrapyle octhacantha* Haeckel. Since approximately 360 years ago, the interchange of subtropical waters between the Bay of La Paz and the Gulf of California has been well evident. This has allowed to record some events of the oceanographic phenomenon: "El Niño", in the radiolarian down-core curves.

INTERHEMISPHERIC CORRELATION OF MILLENNIAL SCALE CLIMATE CHANGES DURING THE TERMINATION OF THE LAST ICE AGE: THE SOUTHERN ANDES, PENINSULAR FLORIDA, AND CENTRAL EUROPE

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Pollen records from Canal de la Puntilla, Huelmo, and Lago Condorito in the lowlands of the Chilean Lake District (CLD) (41° S) show the prevalence of glacial climate until 14.6 kyr (kyr =10^3 ^{14}C yr B.P.), with hyperhumid conditions and mean annual temperatures 6-7° C lower than today during the coldest episodes of the Last Glacial Maxi-mum (LGM). Pulses of *Nothofagus* expansion occurred at 20.2 kyr (26 kcal, kcal=10^3 cal yr B.P.) and 14.6 kyr (17.4 kcal), coeval with intervals of glacier recession after achieving LGM maxima at ~27 kyr (35.7 kcal), ~22.2 kyr (29 kcal), and ~14.6 kyr in the CLD and adjacent Isla Grande de Chiloé (1), and Heinrich events 1, 2, and 3 in the North Atlantic Ocean (NAO) (2). The 14.6 kyr (17.4 kcal) event represents the onset of an irreversible trend toward arboreal expansion and diversification, and the abrupt withdrawal of Andean ice lobes. We interpret these signals as an abrupt warming event that marked the onset of the last termination. This warming correlates with the Oldest Dryas-age glacier recession in the Swiss Alps (3), Scandinavian ice sheet (4), the first warming recorded in the δ^{18}O record from the Huascarán ice core (5), and the unidirectional decline in Northern Hemisphere (NH) ice volume as indicated by the δ^{18}O of benthic foraminifera from core TR163-31 in the eastern equatorial Pacific Ocean.

Expansion of thermophilous North Patagonian Rain Forest (NPRF) taxa ensued with pulses centered at 14.2 kyr (17.1 kcal) and ~13 kyr (~14.8 kcal), leading to the establishment of closed-canopy NPRF between ~13 and ~12.2 kyr (~14 kcal) in the lowlands of the CLD. Similar conclusions have been obtained from fossil beetle studies in the CLD (6). A reversal in trend followed with cooling events at ~12.2 and 11 kyr (12.9 kcal). The persistence of rain forest vegetation between ~11 and 10 kyr (~12 kcal) suggests that cooling did not exceed 3ºC. Small-scale fires occurred between 11 and 10 kyr in the CLD despite the predominant cool-humid climate in the region.

Pollen records (7) from Lake Tulane in Florida (30° N) show a remarkable series of oscillations in pine and oak/ragweed pollen, with Tulane pine peaks (TPPs) starting at ~65 kyr, ~50 kyr, ~40 kyr, ~27 kyr (~35.7 kcal), ~22.2 kyr (~29 kcal), 13.5 kyr (~16.1 kcal), and 11 kyr (~13 kcal). We interpret these records as representing alternations between cool-dry and warm-wet (TPP events) conditions. With the exception of the TPP event dated between 13.5 and 12.7 kyr (16.1 to 14.7 kcal), all TPPs begin slightly before the deposition of ice rafted debris (IRD) in the NAO (2) and cold phases of the Dansgaard-Oeschger events in Greenland ice cores (8); the implication is that warming preceded the massive fluxes of icebergs from the perimeter of the NAO. Termination of the late-glacial TPP event (i.e. onset of cool-dry conditions in Florida) coincided with meltwater pulse Ia (9), rejuvenation of North Atlantic Deep Water (NADW) production (10), and the Bølling-age warming in Greenland (8), Europe (11) and the CLD. The apparently delayed onset of the TPP at 13.5-12.7 kyr may be related to cooling of the Gulf of Mexico following large inputs of meltwater from the Laurentide ice sheet via the Mississippi river.

The TPP dated between 11 and 10 kyr (12.9-12 kcal) (and its equivalent in a core from nearby Lake Annie) coincided with Younger Dryas-age cooling in Greenland (8), Europe (11), New Zealand (12), and the CLD. It seems, then, that some of the critical climate changes in Florida were opposite in direction to those identified in Greenland ice cores and North Atlantic sediment cores. A similar pattern is observed in the Chilean data during the LGM.

High resolution data from core V29-191 (13) in the NAO show that IRD deposition and extreme sea-surface cooling during H1 interrupted a warming trend that had started at 14.8 kyr (~17.7 kcal). One implication of these results is that the onset of the last termination at ~14.7 kyr (~17.5 kcal) was near-synchronous in the mid-latitudes of the Northern and Southern Hemispheres, and that the H1 event represents the collapse of marine-based ice in the North Atlantic region in response to global warming. The flush of icebergs during H1 may have established a lid of cold fresh water in the NAO, causing a delay in Northern Hemisphere warming until the rejuvenation of NADW production during Bølling time. In contrast, the Chilean data show an irreversible warming trend that culminated with conditions approaching modern-day climate between ~13 and ~12.2 kyr (14.8-14 kcal).

An emerging pattern for the timing and structure of the last termi-nation in the southern mid-latitudes (1,4,12,14) suggests correlation of paleoclimate signals with records from central Europe, North Atlantic sediment cores, and Greenland ice cores (i.e. warming events at ~14.7 ~13, ~9.8 kyr, and cooling events at ~12.2 and ~11 kyr). However, regional controls including abrupt discharge of icebergs and/or melt-water from collapsing ice sheets may have altered the timing, direction, and magnitude of climate changes in certain regions of the NH. If supported by further studies, our results would imply synchronous and global extent of paleoclimate signals during the last termination.

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AS THE MACAW FLIES: MESOAMERICAN-ANASAZI TRADE ACROSS THE CHICHIMEC SEA

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Macaws, Amazon parrots, marine shells, copper bells, pseudo-cloisonné invested stone, wood, and basketry, platform mounds, column-fronted galleries, and other Mesoamerican traits are found at sites throughout much of the Anasazi area. Some of these traits also occur at Post-Contact Pueblo villages in the American Southwest. The context and implications of this situation are discussed with respect to long-term interaction among Mesoamerican and Pueblo peoples.

LATE QUATERNARY GLACIATION AND CLIMATE CHANGE IN THE TROPICAL ANDES

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Glacial and lake level records from Peru and Bolivia indicate that tropical Andean climates have varied significantly during the late Quaternary. These proxy records also indicate that there may have been important changes in the export of heat, moisture, and trace gases to higher latitudes. As a greater array of late Quaternary proxy records are gathered from the tropics it will be possible to further refine our understanding of global change mechanisms.

Glacial moraines provided some of the first direct evidence to suggest that the climate of the tropics has changed significantly on glacial-to-interglacial time scales (e.g. Rind and Peteet, 1985). Klein *et al*. (in press) have recently interpreted the more than 1000 m depression in equilibrium-line altitude associated with glacial maximum moraines in Peru and Bolivia to have been a function of 5°-9° C temperature depression. This is significantly greater than the estimates of tropical sensitivity to temperature change based on the sea-surface temperature reconstructions of CLIMAP (1981).

The variability of tropical Andean climates is also significant in the Holocene. By 10 ^{14}C kyr BP most montane valleys in Peru and Bolivia were nearly deglaciated (Mercer, 1984; Seltzer, 1992). Glaciers had retreated to within several hundred meters of the locations of the modern glacier termini. In general, there is little evidence for renewed glacial activity until about 3.5 ^{14}C kyr BP. In the late Holocene glaciers expanded at most a couple of hundred meters downvalley from their modern limits. There were probably at least three phases of glaciation in the late Holocene (e.g. Rodbell, 1993), although it is not possible to unequivocally trace these from valley to valley. Since the middle of the nineteenth century glaciers have been retreating in the Peruvian Andes (Broggi, 1943) and most recently this retreat may be accelerating (e.g. Brecher and Thompson, 1991).

The significant lack of glacial activity during the early to mid Holocene suggests a drier climate during this time period. Lakes that received meltwater directly from these glaciers, especially during the dry season, appear not to have been buffered by this source of moisture during the mid-Holocene (e.g. Abbott *et al*., 1997a), which may indicate that some of the valleys became completely deglaciated at this time.

Sedimentary records from lakes located in intermontane basins of the Andes provide a continuous record of late Quaternary climate change. Lake Titicaca, located on the border of Peru and Bolivia, was as much as 100 m lower than present in the early to mid-Holocene (Seltzer *et al*., 1998; Cross *et al*., in review). The lake transgressed rapidly starting about 3.6 ^{14}C kyr BP (Abbott *et al*., 1997b). In a similar setting Lake Junin, located in central Peru, has an isotopic record from authigenic carbonates extending from 13.5 to 0.5 ^{14}C kyr BP that shows major enrichments in del^{18}O and del^{13}C during the late glacial and early Holocene (Seltzer, Rodbell, and Burns, unpub. data). Superimposed on this trend are major isotopic shifts. The oxygen isotopic record is interpreted to reflect much drier conditions in the late glacial and early Holocene.

Many of the late glacial and Holocene records in the Peruvian and Bolivian Andes may be attributed to a decrease in seasonality of insolation at this time. A decrease in summer insolation would result in less convective precipitation and therefore glacial retreat and low lake levels. However, abrupt changes in these systems and some evidence for glacial advance and high lake levels in the late glacial (e.g. Mercer, 1984; Clapperton *et al*., 1997; Servant *et al*., 1995) are not entirely consistent with this hypothesis.

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PUTTING A NEW FACE ON THE FIRST AMERICANS

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Studies of several 9000 year old human remains from the northwest region of the United States have identified a high incidence of Caucasoid physical traits that appear to distinguish the Pleistocene and Early Holocene populations from the modern northern Asians and American Indians. Furthermore, new data from a genetic marker called lineage X suggest a possible ancient link between Eurasian and Native Americans. These developments underscore the complexity of documenting the origins of the First Americans and lead to speculation that some of the earliest populations into North America may have come from Europe.

SYNCHRONOUS CHANGES IN FIRE HISTORY AND EL NINO IN THE SOUTHWESTERN UNITED STATES, AND NORTHERN PATAGONIA, ARGENTINA

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We compared multi-century tree-ring reconstructions of fire history and El Niño-Southern Oscillation (ENSO) indices in two widely-separated, ENSO-sensitive regions of North and South America. We also compared 20th century observational data sets of regional fire activity and climate. Similar responses of both seasonal rainfall and wildfire regimes to ENSO provide a basis for evaluating inter-hemispheric changes in forest ecosystems and climate. We report here our preliminary observations of synchronous changes in regional fire frequency during the 18th and 19th centuries, and suggest that these fluctuations are indicative of decadal-scale shifts in the modal frequencies or amplitudes of the Southern Oscillation.

Tree-ring reconstructions of fire histories in both regions were based on sampling and analyses of hundreds of widely distributed fire-scarred trees. The Southwestern US fire history network is composed of fire-scarred tree collections from more than 60 forest stands distributed over the states of Arizona and New Mexico. The Argentina network is composed of collections from 5 stands in northern Patagonia. The importance of region-wide climate effects (e.g., droughts) on past fire activity in both regions is indicated by the repeated occurrence of highly synchronous fire events among trees and stands within both regions over the past several hundred years.

Actual fire spread between most of the stands was unlikely because of distance and barriers (e.g., rivers and deserts), hence, synchroneity (or asynchroneity) is a measure of regional (e.g., climate) versus local controls (e.g., topography, chance, etc.) over burning. Likewise, fire frequency variations that are synchronous in both the Southwest and Patagonia suggest inter-hemispheric climatic controls. Decadal-scale fluctuations in the frequency of regional fire years are broadly similar between the two regions. Relatively low frequency periods occurred in both regions before ca. 1675, from ca. 1780 to 1830, and after ca. 1880. Relatively high frequency periods occurred in both regions from ca. 1700 to 1750, and from ca. 1840 to 1880.

We propose that frequent inter-annual switching (i.e., high climate variability) from wet to dry on ENSO time scales is a key to frequent and synchronized regional fire years. Conversely, reduced amplitude of this switching, i.e., fewer or weaker El Niños and/or La Niñas, over decadal periods results in reduced regional fire frequencies. This supports a similar conclusion about climatic variability and fire frequency by Markgraf and Anderson (1994) in a review of Holocene-length pollen and charcoal sediment studies in Patagonia. Based on the established linkage of ENSO, precipitation, and fire dynamics in these regions in the 20th century, and the independent evidence from other proxy records, we interpret a reduction in frequency of regional fires in both the Southwest and Patagonia as an ecosystem response to a reduction in frequency and/or amplitude of the ENSO system during the period ca. 1780 to 1830. Reconstruction and comparison of climatic and ecological variables (e.g., rainfall, ENSO indices, and fire frequency) in distant regions provides multiple lines of evidence converging on interpretations that are more robust and have more important implications than provided by single variable reconstructions.

CHRONOLOGY OF GLACIATION IN THE OLYMPIC MOUNTAINS, WASHINGTON: REGIONAL CONTROLS AND POSSIBLE HEMISPHERIC CORRELATIONS

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Few well-dated alpine glacial records span the last glaciation, hampering efforts to understand first- and second-order climatic fluctuations in terrestrial settings. The glacial sequence in the coastal lowlands of the western Olympic Peninsula has yielded a radiocarbon chronology of multiple advances during the last glaciation. When linked to pollen-based temperature inferences, the glacial chronology permits assessment of controls on regional moisture transport. Furthermore, the temporal pattern of ice advances suggests correlation with southern Hemisphere alpine glacial advances and with North Atlantic cooling cycles.

Glaciers descending the Hoh and Queets valleys delivered large quantities of sediment to the coastal plain, repeatedly damming the valleys with voluminous end moraines. The result is a detailed stratigraphic and geomorphic record of glacier fluctuations with abundant datable organic matter. The sequence records six distinct glacier advances during the last (Wisconsinan) glacial cycle. The Lyman Rapids drift records the most extensive Wisconsinan advance. Stratigraphic and chronologic evidence suggest that the advance occurred after the last-interglacial sea-level highstand (oxygen isotope stage 5e) and prior to middle Wisconsin time (isotope stage 3). The Hoh Oxbow and Twin Creeks drifts document five Hoh valley advances. The advances, in approximate order of diminishing glacial extent, occurred shortly after ca. 39,000 ^{14}C yr BP (Hoh Oxbow Ø), between 29,000 and 27,000 ^{14}C yr BP (Hoh Oxbow I), and between ca. 23,000 and 19,500 ^{14}C yr BP (Hoh Oxbow II). The Twin Creeks drift records two readvances, one between 19,100 and 18,300 ^{14}C yr BP (Twin Creeks I) and another (Twin Creeks II) for which chronologic data are lacking.

The dominant control on the extent of western Olympic glaciation appears to have been moisture delivery. Correlation of the glacial record with a temperature curve derived from local pollen records (Heusser, 1972, 1974) and spanning the last glacial (and possibly interglacial) cycle indicates an inverse relationship between glacial extent and stadial temperature depression: the inferred colder stadial events in the pollen records were associated with the less extensive of the six documented glacial advances. Conversely, the warmer stadial events correspond to greater glacial extent. Of particular note is the relatively small extent of the Twin Creeks I advance, which was correlative with the global Last Glacial Maximum (oxygen isotope stage 2). This advance occurred during a cold, dry period and was substantially less extensive than the earlier Lyman Rapids and Hoh Oxbow Ø, I and II advances. These relationships indicate strong glacier dependence on Pacific moisture sources.

Climate model results described by Thompson *et al*. (1993) provide a framework for understanding these relationships. At the LGM, their model suggests that a glacial anticyclone associated with the Laurentide and Cordilleran ice sheets brought dry, easterly winds to the region. Cold, dry conditions are well documented in pollen records from across the region (e.g., Heusser, 1972, 1974; Barnosky, 1984). Dry easterly winds would have inhibited the delivery of Pacific Ocean moisture to the Olympic Mountains, in turn inhibiting glacier growth. Prior to the LGM, the Laurentide and Cordilleran ice sheets were not at their maximum positions in the northern United States, and would not have brought dry anticyclonic winds to the Pacific Northwest. Thus, the extensive Olympic ice advances during oxygen isotope stages 5(?) through 3 occurred during "strong moisture stades," while weaker moisture delivery kept the LGM advance relatively small.

The Olympic radiocarbon chronology permits correlation with detailed southern Hemisphere glacial chronologies and, hence, permits preliminary evaluation of interhemispheric synchroneity of glacial advances. The Hoh Oxbow I and II advances are coincident with 26,940 and 21,000 ^{14}C yr BP Llanquihue advances in the Chilean Andes described by Lowell et al. (1995). The Hoh Oxbow Ø advance may correlate broadly with a Llanquihue advance $\geq$ 33,500 ^{14}C yr BP. The Olympic sequence does not, however, record distinct advances correlative with 29,600 or 23,060 ^{14}C yr BP Llanquihue advances in the higher-resolution Chilean record.

Finally, the pattern of Olympic glacial advances during oxygen isotope stages 3 and 2 suggests correlation with North Atlantic Bond cooling cycles and Heinrich events. Hoh Oxbow Ø and I glacier expansions into the middle Hoh valley, taken as the dates of initial outwash deposition (ca. 39,000 and 29,200 ^{14}C yr BP, respectively), occurred approximately two-thirds through successive Bond cycles (Bond *et al.*, 1993). The ca. 26,700 ^{14}C yr BP Hoh Oxbow I culmination coincides with the culmination of the corresponding Bond cycle and thus with Heinrich event 3 (H3). The correspondence of the Hoh Oxbow Ø ice expansion with a Bond cooling cycle suggests the culmination of the advance correlated with H4. Timing of the Hoh Oxbow II advance phase is also unconstrained. However, minimum dates suggest that the advance occurred between 23,000 and 19,500 ^{14}C yr BP and may thus have corresponded with H2.

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TREE-RING CHRONOLOGIES AND ENSO IN NORTHERN MEXICO

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The El Niño-Southern Oscillation (ENSO) has been detected in instrumental climate records from northern Mexico and large sectors of North America. Subannual tree-ring chronologies of earlywood and latewood width have recently been developed from ancient Douglas-fir at higher elevations of the Sierra madre Occidental in Chihuahua and as far south as the Tropic of Cancer in Durango. Winter-Spring precipitation is the dominant climatic influence on these Mexican chronologies, and both winter precipitation and tree growth tend to be enhanced during warm ENSO events. The strongest ENSO influence on climate over subtropical North America occurs during the boreal cool season when ENSO events in the Equatorial Pacific typically mature. The earlywood chronologies are significantly correlated with cool-season precipitation (November-March in Chihuahua and Durango), and some 30% of the variance in earlywood growth chronologies exhibit is linked with the Tahiti-Darwin Southern Oscillation Index (SOI) during winter. The latewood chronologies are strongly correlated with summer precipitation (June-August), the monsoon season when some 80% of the annual rainfall occurs over this portion of the Sierra Madre Occidental. The latewood chronologies also exhibit significant decadal variability, and provide an unambiguous record of the Mexican Monsoon rainfall for the past 300 to 600 years. These Mexican tree-ring proxies provide a unique long-term perspective of the past variations in ENSO forcing during winter and monsoon rainfall during summer, two of the major and potentially predictable modes of precipitation variance over subtropical North America. Precipitation reconstruction from some of the longest Mexican chronologies, indicate that the drought of the late 16th century (1566-1593) may have been the most intense and prolonged drought of the past 600 years in northwestern Mexico. We are also working in the Sierra Madre Oriental and have developed a couple of precipitation-sensitive chronologies of Montezuma Cypress (*Taxodium mucronatum*) from Tamaulipas and San Luis Potosi. These cypress chronologies are some of the longest tree-ring chronologies yet developed in the tropics and may provide some insights of the ENSO influence on precipitation in northeastern Mexico.

HIGH VERSUS LOW LATITUDE GLACIAL CLIMATE SENSITIVITY IN THE AMERICAS: RESULTS FROM PMIP SIMULATIONS AND NASA-GISS SENSITIVITY EXPERIMENTS

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One of the most persistent challenges in paleoclimate modeling has been to accurately simulate the climate of the Last Glacial Maximum (LGM; 21,000 yr. B.P.) using known boundary conditions and external forcing. Central to this challenge has been understanding the role the ocean has played in either modulating or enhancing LGM climate. Until recently, paleoclimate reconstructions for the LGM consistently indicated that there was significant cooling over most of the land and the mid-to-high latitude oceans, significant cooling over land in tropics, but little direct evidence for changes in tropical sea surface temperatures. From the paleoclimate modeling perspective, the last glacial maximum reconstruction of five degree cooling at sea level from Sr/Ca ratios and $\delta^{18}O$ measurements in Barbados corals, and from concentrations of dissolved noble gases in ground water from northeast Brazil, are intriguing because these data imply a significant tropical cooling at sea level. In contrast to CLIMAP SST reconstructions, the five degree cooling appears reconcile the recognized differences in the terrestrial and oceanographic records of low latitude glacial temperatures.

As part of the Paleoclimate Modeling Intercomparison Project (PMIP), simulations of the LGM climate have been completed for nine atmospheric general circulation models (AGCMs) with prescribed CLIMAP LGM sea surface temperatures (SSTs), and for five AGCMs using modern ocean heat transports (OHTs). All the PMIP simulations used the same paleoclimate boundary conditions and external forcing (e.g. insolation, greenhouse gas concentrations, ice sheet distributions and topographies). In this study we focus on high versus low latitude climate sensitivity within the America's (90°N to 90° S, 20° W to 165° W) over land and the adjacent oceans. Among the PMIP simulations, although there are broad similarities in the response of individual models to LGM forcing, there are significant differences in the latitudinal distribution of the responses. The nine simulations with prescribed CLIMAP LGM SSTs exhibit more consistent responses at both high and low latitudes (1° to 2° C cooling in the tropics), whereas the five simulations with modern ocean heat transports and calculated SSTs show a greater range in responses at all latitudes (1° to 4° C cooling in the tropics).

We have also run a series of LGM paleoclimate sensitivity experiments using the NASA-GISS Model II to examine the role of different configurations of ocean heat transports (OHTs), and associated ocean heat convergences (OHCs), amongst otherwise LGM boundary conditions. The five sensitivity experiments include simulations with OHTs calculated for 1) a modern climate but with glacial land-sea distributions, 2) a glacial climate with CLIMAP LGM SSTs, 3) a glacial climate with CLIMAP LGM SSTs minus 2° C everywhere, and 4) a cool tropics glacial climate with all CLIMAP LGM SSTs greater than 18° C assigned an average of the SST value and 18° C. Our results indicated that the dominant atmospheric feedback contributing to LGM global surface air temperature cooling was regulated by evaporation over the subtropical Pacific, a significant source of atmospheric water vapor today. The steep gradient of CLIMAP LGM SSTs between the subtropics and mid-latitudes of the Pacific gave rise to high OHCs in the subtropics relative to modern. Evaporation rates increased in the subtropics to balance the increased CLIMAP LGM OHCs, and this increase in evaporation over the subtropical Pacific compensated for decreases elsewhere, moderating changes in atmospheric water content in response to cooler glacial conditions. In contrast, maintaining modern OHTs under LGM boundary conditions greatly reduced OHCs and evaporation in the subtropical Pacific, supplied less water vapor to the atmosphere, and effectively cooled the mid to low latitudes. The cool tropics LGM experiment showed enhanced cooling related to decreased evaporation over the tropical oceans, and a comparable reduction in atmospheric water content. The CLIMAP LGM SSTs minus 2° C exhibited moderate cooling related to the balance between cooler SSTs and reduced evaporation over the tropical ocean, and the persistence of the steep gradient of SSTs between the subtropics and mid-latitudes resulting in enhanced OHCs and evaporation over the ocean.

CHRONOLOGY AND ECOLOGY OF VERTEBRATES: WHO WENT WHEN

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The Great American Interchange was triggered by emplacement of the Isthmian Land Bridge, the corridor that allowed wholesale movement of terrestrial biota between North and South America. Although this critical link was established in what is now Panama, only a small proportion of the evidence regarding interamerican vertebrate connections comes from Central America. The best records bearing on this history have been developed in temperate North America and temperate South America. This paper reviews the chronology of the interchange, the taxonomic composition of the northern and southern cohorts, some ecological aspects of their distribution, and the subsequent patterns of their evolution and extinction during the Quaternary.

The best stratigraphic framework for observing the onset of the full terrestrial interchange is the Anza-Borrego Desert in Southern California. There a succession of some 4,000 meters with several interbedded tuffs and excellent magnetostratigraphic control provides a long continuous sample of land mammal faunal history. The first appearances of several South American mammals cluster at the beginning of the Gauss (Chron 2R), dated at 2.6 ma. Another succession with excellent mammal records and good magneto-stratigraphy is the classic coastal section near Mar del Plata in Argentina. These great cliffs produce a cluster of first records of North American taxa also near Chron 2R. Clearly the interchange began in the late Pliocene.

The strongest evidence that the land bridge was fully emplaced is the large scope of the reciprocal interchange once it began. The first legions of South American terrestrial taxa to reach the north consisted of ground sloths, armadilloes, possums, caviomorph rodents and gigantic phororhachid birds; while the first legions of North American mammals to reach the south featured llamas, horses, sabercats, bears, peccaries and field mice. Most of these early arrivals (late Blancan in North America; Uquian in South America) represent grazing or mixed-feeding herbivores, along with a few associated large carnivores. Their geographic ranges spanned the tropics, extending either from north temperate to south temperate or the reverse. Taken as a whole, the mammal evidence indicates a vast interamerican highway (or mobil mosaic) of predominantly savanna habitats. Additional records in the early Pleistocene (Irvingtonian in North America; Ensenadan in South America) represent a similar pattern. Most northern groups traversed the Andean high road; others moved along the Amazonian low road, presumably at times when the rainforest was relatively restricted and the savanna corridors were expansive. In North American, some more xeric-adapted groups (*Nothrotheriops* and *Myrmecophaga*) spread up the western side of the Rocky Mountains, whereas some more mesic adapted groups (*Eremotherium* and *Holmesina*) spread only around the Gulf of Mexico and up the Atlantic Seaboard.

Although the earliest waves of northward and southward distributions of mammalian immigrants were about equal in diversity, subsequent diversification during the middle and late Pleistocene was drastically different on the two American continents. The South American contingent did not increase its diversity, whereas several taxa of North American origin diversified considerably in South America. The Cervidae and Canidae diversified into five genera each. The cricetid rodents radiated explosively, producing some 40 genera endemic to South America.

During the later Pleistocene a tropical phase of the interchange took place. In this second phase, a large number of tropically restricted mammal groups, especially ceboid monkeys, tree sloths, and some caviomorph rodents, spread from the Amazon Basin northward through Central America. The results of this phase of the interchange were the opposite of the earlier, more temperate phase of the interchange. The majority of tropical species spread northward; whereas very few northern species spread southward. Presumably the explanation lies in the relative areas of tropical versus temperate landscapes in North American and South America. The narrow strip of tropical land in Central America could not generate a tropical biota as diverse as could the great breadth of lowland rainforest in South America.

The final phase of this history of the Great American Interchange features the devastating losses of large mammals due to late Pleistocene extinctions. The large mammal extinctions both in North and in South America numbered two to three dozen, and in many cases (e.g. *Equus, Smilodon* and *Eremotherium*) these were large mammal genera that had spread between the Americas during the Late Pliocene or Early Pleistocene. In one sense, however, the South American extinctions were the more devastating, for they removed every single one of the native ungulates (such as *Toxodon* and *Macrauchenia*) as well as all of the ground sloths and all of the glyptodonts.

One remarkable feature that summarizes the history of this great interchange is the fact that more than half of South America's living mammal genera came from North America since the Late Pliocene. Great radiations of several mammal groups, most notably cricetid rodents, took place there within the Quaternary. The major feature of the northward reciprocal part of the interchange is that many rainforest-adapted groups, such as ceboid monkeys, spread from the Amazon Basin into Central America. All in all, 19 families of mammals spread north and 17 families spread south, in the 2.6 ma since the Great American Interchange began.

THE LAST MILLENNIUM OF OCEAN-ATMOSPHERE VARIATIONS ALONG THE WESTERN COAST OF THE AMERICAS INFERRED FROM TREE-RINGS AND GLACIER RECORDS

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Comparison of proxy records for past ocean-atmosphere variations from the coastal ranges of the Gulf of Alaska and northern Patagonia reveals common interhemispheric climate patterns. Such comparisons will provide insights into the relative roles of the tropical and extra-tropical Pacific Ocean in short-term, decade scale and longer-term climate changes. The climate proxy records are based on variations in tree rings and glacier termini over the past millennium.

Temperature series derived from tree-rings and integrated temperature and precipitation signals inferred from fluctuations of glacier termini are compared to examine the decade to century-scale climate variations common to these high-latitude Pacific proxy records. The temperature-sensitive tree-rings from the Gulf of Alaska (60° N) and from northern Patagonia (41° S) are significantly correlated over the past 400 years. Both records show the documented AD 1976 transition from cold to warm conditions in the tropical Pacific. Spatial correlation patterns of sea surface temperatures (SST) and tree rings mimic the primary features recognized in correlation fields based on land surface and SST comparisons. These correlations and overall patterns are considered to be an indication of common climate forcing.

Cross-spectral analyses of a compilation of tree-ring data over the past 400 years suggest that decadal temperature variations for the two regions were generally stronger and more coherent prior to AD 1850. After this time the decade-scale mode of the Pacific has been weaker and less coherent between regions. The cause for this change during the decades of the mid-1800s is unknown. However, the change corresponds with the initiation of widespread ice retreat and with a reported increase in the energy of the El Niño-Southern Oscillation.

Tree-ring cross-dating of glacially overrun forests with living trees at glacier forefields in the northern Gulf of Alaska region reveal a consistent and widespread early 13th century and middle 17th to early 18th century Little Ice Age glacial advance. Dates from moraines delineate two main periods of moraine building. The earlier interval (early 18th century) overlaps with the later time of glacial advance identified from overrun forests, and therefore dates the culmination of the mid Little Ice Age advances. A later period of moraine formation (late 19th century) dates the most recent Little Ice Age.

These intervals represent primarily multi-decade temperature depressions, although the relative role of increased precipitation forcing these ice advances is uncertain. This northern Gulf of Alaska glacial history provides an internally consistent record with which to compare records from the southern South America.

Patagonian glacial histories are based on radiocarbon-dated trees overrun by ice expansions, moraine dating and historical observations. Initial interhemispheric comparisons show an early advance from Patagonia in the early to mid 14th century that occurs significantly later than the mid 13th century advance recognized in coastal Alaska. A cluster of ice expansions from both regions during the mid 17th century suggest a near-synchronous advance at this time. The most recent general glacial pulse is dated decades earlier in Patagonia than in coastal southern Alaska. Both peak during the 19th century.

Tree-ring records from the Gulf of Alaska and northern Patagonia are sensitive records for SST variations from the extra-tropical Pacific. With their companion glacial geologic records, interhemispheric comparisons allow for determination of the relative roles of the tropicaland extra-tropical Pacific Ocean in forcing higher latitude climate variations. The development and analyses of longer tree-ring series and better-dated glacier histories will help evaluate the timing of glacier expansion suggested here and put the advances of the Little Ice Age and the recent warming into the context of long-term ocean - atmosphere variability.