



Modelling the Geomorphological Effects of Till Redistribution: Assessing a Dynamic Theory for Rogen Moraine Formation and Drumlin Formation

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SESSION NO. 18, 1:30 PM

Friday, July 25, 2003

S13. Millennial-scale Correlation Between Ice-core and Marine Sediment Records (Posters)

Reno Hilton Resort and Conference Center, Pavilion

18-1 BTH 29 Shackleton, Nicholas J.

MILLENNIAL-SCALE CLIMATE VARIABILITY: THE REPLICABILITY OF MARINE RECORDS
SHACKLETON, Nicholas J.¹, DE ABREU, Lucia², BLUMBACH, Petya¹, CHESHIRE, Heather¹, VAUTRAVERS, Maryline², GRIMALT, Joan³, MARTRAT, Belen⁴, THOUVENY, Nicolas⁵, and THOMAS, Lucy⁶. (1) Godwin Laboratory for Quaternary Studies, Cambridge Univ, Cambridge, CB2 3SA, United Kingdom, njs5@cam.ac.uk, (2) Godwin Laboratory, Univ of Cambridge, New Museums Site, Pembroke Street, Cambridge, CB2 3SA, United Kingdom, (3) Department of Environmental Chemistry, Institute of Chemical and Environmental Research (CSIC), Jordi Girona, 18, Barcelona, 08034, (4) Institute of Chemical and Environmental Research (CSIC), Barcelona, 08034, Spain, (5) Centre Européen de Recherche et d'Enseignement de Géosciences de l'Environnement, CEREGE, Univ Aix-Marseille and CNRS, BP 80, Europôle de l'ARBOIS, Aix en Provence, 13545, France, (6) School of Geography, Univ of Leeds, Leeds, LS2 9JT, United Kingdom

One of the objectives of the 2001 coring campaign off Portugal aboard Marion Dufresne (funded by ec through the POP project) was to obtain records that would document the replicability of records such as that published by Shackleton et al. (Paleoceanography, 2000) from core MD95-2042. Here we demonstrate some of the results of these tests noting first that the cores are readily correlated using magnetic susceptibility data. Particularly important features that we have replicated include 1: the relationship between vegetation (through pollen) and marine climate (through isotope data) records of the Last Interglacial and of Marine Isotope Stage 3 interstadials; 2: the relationship between temperature and the benthic isotope record in Marine Isotope Stage 3; 3: the relationship between benthic and planktonic isotope records in Marine Isotope Stage 3; 4: the details of the early part of Marine Isotope Stage 3 in relation to the Greenland ice core records; 5: the radiocarbon age of each interstadial in relation to its Greenland ice core model age; 6: the details of Marine Isotope Stages 6 to 9; 7: the number and relative magnitude of distinct ice rafting events.

18-2 BTH 30 Shackleton, Nicholas J.

THE DEEP-WATER TEMPERATURE COMPONENT OF THE NORTH ATLANTIC BENTHIC $\delta^{18}\text{O}$ RECORD ACROSS TERMINATIONS I AND II: THE EFFECT OF NADW - AABW EXCHANGE ON THE APPARENT TIMING OF MARINE ISOTOPE STAGE BOUNDARIES
SKINNER, Luke C. and SHACKLETON, Nicholas J., Earth Sciences, Cambridge Univ, Godwin Laboratory, New Museums Site, Pembroke Street, Cambridge, CB2 2SA, United Kingdom, njs5@cam.ac.uk

Paired measurements of Mg/Ca and $\delta^{18}\text{O}$ in benthic foraminifera from two well-dated deep-sea cores (MD99-2334K, 3146m; MD01-2444, 2637m) recovered on the Iberian Margin (37°N, 10°W) permit the estimation of the deep-water temperature (DWT) component of the benthic $\delta^{18}\text{O}$ record across the last two glacial terminations. The glacio-eustatic component since ~20 ka BP is well constrained by sea-level estimates, allowing the marine $\delta^{18}\text{O}$ signal to be completely de-convolved across Termination I. An abrupt drop in DWT during the Younger Dryas indicates a collapse in North Atlantic Deep Water (NADW) supply to the North Atlantic at this time. Hence a significant component of the benthic $\delta^{18}\text{O}$ record of Termination I is in fact an expression of local deep water-mass exchange, probably between high- $\delta^{18}\text{O}$ NADW and low- $\delta^{18}\text{O}$ Antarctic Bottom Water (AABW). This interpretation is corroborated by benthic $\delta^{13}\text{C}$ values and ^{14}C -ventilation ages, which indicate the incursion of a highly 'aged' high-nutrient (cold) water-mass during the Younger Dryas. The inferred NADW collapse and associated AABW incursion during the Younger Dryas results in a lead of North Atlantic benthic $\delta^{18}\text{O}$ over both ice-volume change and deep Pacific benthic $\delta^{18}\text{O}$, that is due to local deep water-mass effects only. A similar pattern of events has also been reconstructed for the penultimate glacial termination. Deep-water temperature fluctuations across Termination II imply a significant component in the benthic $\delta^{18}\text{O}$ record that is not attributable to DWT change and, by analogy with Termination I, probably represents the effect of local water-mass exchange. This has a direct bearing on the discrepancy previously identified between the beginning of the Eemian interglacial (based on pollen evidence for terrestrial climate) and the base of Marine Isotope Stage 5e (based on benthic $\delta^{18}\text{O}$). The observed lead of benthic $\delta^{18}\text{O}$ with respect to terrestrial climate may thus be due to local water mass effects rather than a delayed surface-climate response with respect to ice-volume drop. These results demonstrate the important role of thermohaline circulation in millennial-scale climate change and its impact on marine isotope stratigraphy.

18-3 BTH 31 Cacho, Isabel

HEINRICH EVENT RELATED CHANGES IN THE ALBORAN SEA WATER PROPERTIES
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Millennial scale climate variability during the last glacial period had a strong impact in the Mediterranean region, particularly in the surface water properties of the Alboran Sea (the westernmost basin of the Mediterranean Sea). The combined approach of parallel measurements of Mg/Ca and $\delta^{18}\text{O}$ in different species of planktonic and benthic foraminifera permits a detailed reconstruction of water properties (temperature, sea water $\delta^{18}\text{O}$ /salinity) at different water depths. Here we study the last glacial interval in core MD 95-2043 from the Alboran Sea, the resolution of which is good enough to resolve centennial scale changes. HEs at this location, away from the deposition of IRD, are identified by sharp cooling events recorded in the alkenone SST estimates and the concurrent presence of the polar foraminifer *N. pachyderma* (s). These SST cold events are also confirmed by the Mg/Ca record from *G. bulloides*. However, while the warming phase at the end of HEs match in both timing and intensity, the onset cooling phase is less pronounced in the Mg/Ca record, as a result of the relatively cold temperatures of the previous interstadials. These differences in shape and also absolute values between alkenone and Mg/Ca SST records are interpreted in terms of seasonal differences, suggesting a more abrupt cooling phase for the cold season. Detailed analyses of the different temperature and isotope records

across HEs 1-5 illustrate the consistent occurrence of a complex three-phase pattern during HEs. This pattern is particularly pronounced in those records related to the thermocline and deep waters masses whose properties are modelled by climatic/oceanographic conditions in the Mediterranean region. In particular, sea water $\delta^{18}\text{O}$ reconstructed by *N. pachyderma* (d) evolves following an enrichment-depletion-enrichment sequence. This middle HE light isotopic phase of the thermocline is synchronous with a very short warming of the deep water mass as indicated by Mg/Ca in *Cibicides* and is also coincident with a very short intra-stadial warming event recorded in Greenland ice $\delta^{18}\text{O}$ records. These results show a complex HE evolution and outline the rapid responses and links between properties of the different Mediterranean water masses.

18-4 BTH 32 Chapman, Mark

CONTRASTING PATTERNS OF CLIMATE VARIABILITY IN THE MID-LATITUDE NORTH ATLANTIC DURING THE LAST 3 GLACIAL PERIODS

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Numerous investigations suggest that the subpolar ocean has experienced considerable variability in sea surface temperature (SST) associated with iceberg discharge events during the last glacial-interglacial cycle but, at present, little is known about the significance or amplitude of SST climatic fluctuations in previous glacial-interglacial cycles. We have generated a suite of detailed palaeoenvironmental measurements spanning the last 3 glacial periods from cores SU90-03 and MD99-2253, recovered from the northern margin of the subtropical gyre and the subpolar gyre respectively. The chronology for the cores are derived from ^{14}C dates and $\delta^{18}\text{O}$ measurements made on the foraminifers *Globigerina bulloides*, *Cibicides wuellerstorfi* and *Uvigerina* spp. Past SST conditions were estimated from compositional changes in the planktonic foraminiferal assemblages and compared to a history of ice rafted detritus (IRD) input provided by counts of lithic particles. The impact of the northward surface transfer of heat on the return flow of North Atlantic Deep Water are evaluated from benthic $\delta^{13}\text{C}$ measurements.

A series of IRD depositional events are documented throughout the length of both cores, with most intervals of enhanced IRD input readily recognisable at both 40°N and 56°N. In general, short-term coolings appear to match the pattern of IRD variations. However, a major amplification of the IRD signal and an increase in the frequency of IRD events appears to have occurred during the last glacial period compared to the previous glacials. This pattern is matched to a large extent by the characteristics of the palaeotemperature records through MIS 8, 6, and 4-2. Well-defined millennial-scale fluctuations in surface water temperatures are less frequent during MIS 6 and the amplitude of SST variability during MIS 8 appears to be of a lesser magnitude (3-4°C) compared to the last glacial period (6-8°C) at the southern site. Significant differences are also evident when comparing SST variability and patterns of IRD variation through MIS 7 and 5 and the last 3 deglacial transitions. Results from these North Atlantic cores reveal a complex pattern resulting from differences in the timing and the strength of mid latitude temperature gradients which accompanied the phases of ice sheet growth and decay over the last 300,000 years.

18-5 BTH 33 Marchitto, Thomas

VENTILATION INFLUENCE ON BAJA CALIFORNIA OXYGEN MINIMUM ZONE STRENGTH SINCE THE LGM: CONSTRAINTS FROM BENTHIC FORAMINIFERAL Mg/Ca
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Organic matter concentrations in a sediment core from the oxygen minimum zone (OMZ) off southern Baja California (705 m water depth) vary in concert with Dansgaard/Oeschger climate oscillations. A measure of sediment color (the third principal component of the diffuse spectral reflectance) displays a particularly striking similarity to Greenland ice core temperature records over the past 50 kyr. High organic matter concentrations during interstadials and during the Holocene may have been caused by increased productivity and/or increased preservation due to reduced OMZ ventilation. Changes in ventilation could have been caused by competition between warm, salty, low-oxygen (tropical) intermediate waters and cool, fresh, high-oxygen (North Pacific) intermediate waters. Such fluctuations, if significant, should be recorded by benthic foraminiferal Mg/Ca (temperature) and $\delta^{18}\text{O}$ (temperature plus salinity).

We present high resolution records of *Uvigerina* Mg/Ca and $\delta^{18}\text{O}$ spanning the past 16 kyr. $\delta^{18}\text{O}$ displays two apparently abrupt decreases superimposed on the deglacial ice volume trend: one at the time of the Bolling warming, and another at the end of the Younger Dryas. Mg/Ca remains flat across the start of the Bolling, and actually suggests a slight cooling at the end of the Younger Dryas. These results suggest that the $\delta^{18}\text{O}$ is dominated by salinity changes, with freshening occurring at the starts of the Bolling and the Holocene. For the latter, the coincidence of cooling and freshening implies a shift toward more North Pacific-like intermediate waters. Since neither transition is consistent with reduced ventilation as a driver of organic matter increases, productivity was likely the dominant influence. Additionally, there is an abrupt shift toward cooler, fresher waters after ~5 ka that is not obviously reflected in organic carbon content. We also consider the possibility that *Uvigerina* Mg/Ca is complicated by environmental factors other than temperature.

18-6 BTH 34 Kido, Yoshiaki

MILLENNIAL-SCALE VARIABILITY OF SURFACE PRODUCTIVITY IN THE JAPAN SEA BASED ON HIGH-RESOLUTION ANALYSIS USING XRF MICRO-SCANNER
KIDO, Yoshiaki¹, TADA, Ryouji, MINAMI, Ikue, WATANABE, Satoko, and IRINO, Tomohisa². (1) Earth and Planetary Science, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, Japan, kido@sys.eps.u-tokyo.ac.jp, (2) Earth and Planetary Science, University of Hokkaido, Hokkaido, Japan

Fine-grained sediments with distinct alternations of dark-light colored layers in the Japan Sea during the last glacial period were considered to reflect the drastic changes of paleoceanographic conditions in the sea in response to millennial-scale climatic changes known as Dansgaard-Oeschger (D-O) cycles. However, the detail characteristics of the millennial-scale variability are not clarified because of the limitation of resolution in previous analyses.

We tried to apply our new XRF micro-scanner method to wet sediment cores MD01-2407, 08 obtained from the Japan Sea to conduct high-resolution (1.25 cm interval) quantitative analysis of major elements. Our new method estimates the water content for the individual XRF scanning area, and corrected XRF intensities for absorption effect of interstitial water using the estimated water content. With this method, we can conduct quantitative analysis of Al, Si, K, Ca, Ti and Fe concentrations less than ~2.7 wt%.

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Biogenic silica, biogenic carbonate, and terrigenous material contents are estimated from Si, Ca, and Al concentrations assuming constant Si/Al and Ca/Al ratios, and constant Al concentrations in the terrigenous material. The concentrations of biogenic silica and carbonate show several hundred to thousand years scale variations during the last 150ky. Especially, the pattern of biogenic carbonate contents shows variability that closely match with D-O cycles with higher contents in the interstadial dark layers, whereas the biogenic silica and terrigenous material contents show higher contents in the stadial light layers during the last glacial period (MIS 2 to 4). The relationship between the dark layers and carbonate content is reversed during MIS 1 and 5, whereas opal and terrigenous contents do not have consistent relationship with the dark and light layers.

Dark layers during the MIS3 probably reflect the increase in the carbonate productivity as a result of increased influx of the nutrient-rich East China Sea Coastal Water (Tada et al., 1999). Whereas low biogenic carbonate in the dark layers during the MIS5 probably reflects combination effects of the increased productivity of biogenic silica, the increased flux of terrigenous material, and dissolution of carbonate.

18-7 BTH 35 Tada, Ryuji

DARKNESS OF THE JAPAN SEA SEDIMENTS AS A PROXY FOR HIGH-RESOLUTION RECONSTRUCTION OF EAST ASIAN SUMMER MONSOON VARIABILITY

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Asian monsoon is a regional phenomenon of global significance. More than 1/3 of world population lives in the area under the influence of Asian monsoon. Their lives are strongly influenced by the summer monsoon precipitation not only because it is the major source of their water resources but because it occasionally causes floods. The East Asian summer monsoon brings a large amount of precipitation in southeastern margin of Asia that influences surface water salinity and nutrient in East Asian marginal seas. Recent oxygen isotope study of stalagmite from Hulu Cave in China revealed millennial-scale variability of the summer monsoon intensity in association with the Dansgaard-Oeschger Cycles [DOCs] (Wang et al., 2001). However, the record is only 70 ky long, and there is no good proxy for longer term high-resolution reconstruction of East Asian summer monsoon intensity beyond 70 ka. The Pleistocene to Holocene fine-grained sediments in the deeper part of the Japan Sea are characterized with centimeter- to decimeter-scale alternations of darker, organic-rich, laminated layer and lighter, organic-lean, bioturbated layer. Deposition of the individual dark layer is synchronous and correlatable basin-wide. Tada et al. (1999) suggested that these dark and light layers were formed in association with DOCs with dark layers corresponding to interstadials. They speculated that deposition of the dark layers was resulted from increased contribution of the lower salinity and nutrient-enriched East China Sea Coastal Water [ECSCW] during interstadials of DOCs. Present oceanographic data suggests that the discharge from the Yangtze River significantly contributes the formation of ECSCW, and that more than 70 % of the water from the Yangtze River flows into the Japan Sea. Nutrient budget calculation of the sea also suggests that approximately the same amount of phosphorous discharged from the Yangtze River is buried as organic matter in the Japan Sea. Thus it is likely that the Japan Sea act as a trap of nutrients discharged from the Yangtze River. Because the Yangtze River discharge is strongly controlled by the summer monsoon precipitation, the organic matter burial in the Japan Sea, and the gray scale of its sediments, could be an excellent high-resolution proxy for the East Asian summer monsoon and DOCs.

18-8 BTH 36 Nagashima, Kana

EAST ASIAN MONSOON/WESTERLY INTENSITY VARIATIONS DURING THE LAST 150KY BASED ON EOLIAN DUST GRAIN SIZE AND ITS N-S CONTRAST IN THE JAPAN SEA
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The hemipelagic sediments of the Japan Sea contain significant amount of eolian dust derived from dry areas in inland Asia. The eolian dust grain size is controlled by the distance from the source area and the speed of transport wind, whereas the eolian flux is controlled by the distance and size of the source area as well as intensity of the transport wind. There are two possible paths for eolian dust transport to the Japan Sea. One is through winter monsoon surface winds, and the other is through the westerly jet. For both cases, the distance and size of the source area are influenced by the summer monsoon intensity. Whereas the wind speed is controlled either by the winter monsoon intensity or by the speed of westerly jet. In order to reconstruct the temporal variability of the atmospheric circulation in East Asia, we examined the grain size, content, and composition of eolian dust within the sediment cores from northeastern (KT94-15-PC5; 40°09'00"-f36°00'N-C138°00'-12°-f05°00'E) and southern (IMAGES MD01-2407; 37°04'00"-f06°00'N, 134°00'-f00°00'-hE) parts of the Japan Sea. The results revealed millennial-scale variability in eolian dust grain size and content in harmony with Dansgaard-Oeschger Cycles in both cores during the last 150 ky with larger eolian dust median diameters and contents during stadials. We also examined temporal variations of the N-S differences in the eolian dust grain size between the two sites. Eolian dust grain size in the southern site tends to be larger during MIS 1, early MIS 3, MIS 5.1, 5.3, and early MIS 5.5, and smaller during other periods showing oscillations of ca. 20 kyrs periodicity. In addition, N-S difference in eolian dust grain size shows millennial-scale variability with smaller grains size in the southern site during glacial stadials. Based on the comparison of the mineral and elemental compositions between eolian dust of each site and desert and loess of inland Asia, we attributed the cause of the temporal variations in N-S differences in Kosa grain size to the N-S shift either in the dust source area transported by the westerly jets or in the southern limit of dust transport by winter monsoon surface wind.

18-9 BTH 37 Nielsen, Simon Harder Holm

SOUTHERN OCEAN DEGLACIAL AND HOLOCENE CLIMATE INFERRED FROM DIATOMS
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The site TN057-17 (50°S 6°E) from the Atlantic sector of the Southern Ocean is today located on the Antarctic Polar Front (APF), and therefore is in an ideal position for reconstructing past APF changes. By combining the sedimentary records of a trigger and a piston core from TN057-17, we reconstructed a high-resolution record of changes in summer sea surface temperature (SSST) and sea ice cover since the Last Glacial Maximum, based on diatom transfer functions. With 13 14C-AMS and 1 U/Th dates from both TN057-17 cores, the resulting record is capable of resolving the high-frequency deglacial and Holocene climate variability.

The record displays reduction in yearly sea ice presence from an LGM at 21.5 cal. kyr. BP. This was interrupted by a reversal between 14.5-12.5 cal. kyr. BP. Reduction commenced again into the Early Holocene. From 11 cal. kyr. BP, sea ice cover reappeared, increasing gradually to a maximum at 4.3 cal. kyr. BP. In the Late Holocene, sea ice presence has been fluctuating, but

generally decreasing. Our deglaciation record correlates well with that of Vostok and Byrd ice cores, and that of core TN057-13PC4 (53°S, 5°E).

The SSST record shows a 6000-year cyclicity, with fast warming occurring at 18.5, 12.5 and 4 cal. kyr. BP. The first two warmings followed by slow (3-6 ka) cooling. A cold reversal between 13.6-12.5 cal. kyr. BP seems offset from the sea-ice record, closer to the Indian Ocean Cold Reversal. The coldest interval of the Holocene is centered at 4.3 cal. kyr. BP, a millennia later than the Neoglacial around Antarctica. Apparently, this part of the record shows more affinity to a North Atlantic record of SSST and Greenland ice core records.

The record gives evidence for an oceanic climate controlled mainly by the influence of insolation on the atmospheric circulation. This is overlain by prominent, possibly solar-driven, cycles with multicentennial- and millennial-scale periods. The hemispherical polarity of the SSST changed hemisphere to hemisphere from northern to southern hemisphere summer insolation at least 3 times since the Last Glacial Maximum, perhaps indicating a fluctuating influence of the thermohaline circulation on the climate of the Southern Ocean.

SESSION NO. 19, 1:30 PM

Friday, July 25, 2003

S17. Paleoseismology in the Twenty-first Century: A Global Perspective (Posters)

Reno Hilton Resort and Conference Center, Pavilion

19-1 BTH 38 Biasi, Glenn P.

RUPTURE LENGTH AND EARTHQUAKE MAGNITUDE ESTIMATES FROM PALEOSEISMIC MEASUREMENTS OF DISPLACEMENT AT A POINT

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Paleoseismic investigations are a primary means for discovering pre-instrumental earthquake behavior of a fault. Individual paleoseismic excavations necessarily recover only data at a point on the fault. However, fault length and earthquake magnitude are necessary in order to apply paleoseismic findings to earthquake hazard estimation. Thus a challenge for paleoseismology is to extend results from a point to some estimate of rupture length and magnitude. A leading complication is that observed surface slips tend to vary greatly within a single rupture, so one cannot say whether measured offsets are representative of the paleorupture, or whether they are larger or smaller than the average. In addition detailed studies suggest that sites such as minor transtensive step-overs best suited for the preservation of dating information can hide or distribute slip, leading to underestimates of slip and earthquake size.

We have developed a means of estimating the magnitude and rupture length of a paleo-earthquake in a probabilistic way given a point estimate of slip. Hemphill-Haley and Weldon (BSSA, 1999) show that by scaling slip distributions by rupture length and average displacement, well-mapped ruptures have some common features. Their normalized variability plots can be inverted for a probability distribution of possible earthquake magnitudes given point displacement after they are scaled using magnitude-length and magnitude-surface displacement regressions from the literature. Beside paleomagnitude estimates, the inverse probabilities provide quantitative help in assessing whether events at adjoining paleoseismic sites are likely to correlate, and thus complement radiocarbon evidence that might not be compelling on its own. We are presently applying these relationship to assess event correlations among paleoseismic sites on the southern San Andreas fault.

19-2 BTH 39 Michetti, Alessandro M.

AN INNOVATIVE APPROACH FOR ASSESSING EARTHQUAKE INTENSITIES: THE PROPOSED INQUA SCALE BASED ON SEISMICALLY-INDUCED GROUND EFFECTS IN THE ENVIRONMENT

MICHETTI, Alessandro M.¹, ESPOSITO, Eliana², MOHAMMADIOUN, Bagher³, GÜRPINAR, Aybars⁴, PORFIDO, Sabina², ROGOZHIN, Eugene⁵, SERVA, Leonello⁶, TATEVOSSIAN, Ruben⁵, VITTORI, Eutizio⁶, and AUDEMARD, Franck⁷, (1) Dipartimento di Scienze, Università dell'Insubria, Via Valleggio 11, Como, 22100, Italy, alessandro.michetti@uninsubria.it, (2) CNR-IAMC, Istituto per l'Ambiente Marino Costiero, Calata Porta di Massa, Interno Porto di Napoli, Napoli, 80133, Italy, (3) Robinswood Consultant, 2, Rue des Saulx, St. Martin de Nigelles, 28130, France, (4) Engineering Safety System, Int'l Atomic Energy Agency, P.O.Box 100, Wagramer Strasse, Vienna, 5A-1400, Austria, (5) Joint Institute of Physics of the Earth, Russian Academy of Sciences, B. Gruzinskaya 10, Moscow, 123995, Russia, (6) Technological and natural risk, APAT, Italian Agency for Environmental Protection and Technical Surveys, via Vitaliano Brancati, 48, Rome, 00144, Italy, (7) FUNVISIS, P.O. Box, Apartado Postal 76.880, Caracas, 1070-A, Venezuela

The debate originated within the Workshop of the Subcommittee on Paleoseismicity held during the XV INQUA Congress in Durban, August 1999, emphasized the importance of developing a multi-proxy empirical database on earthquake ground effects that can be used by, and incorporated into, seismic-hazard assessment practices. The Subcommittee selected this task as the primary goal for the past inter-congress period. An interdisciplinary Working Group (WG) was established, including geologists, seismologists and engineers, in order to formalize the collected data into a new scale of macroseismic intensity based only on ground effects: the proposed new INQUA scale.

This paper illustrates the results of the research conducted by the WG, introduces the INQUA scale, and discusses major issues related to this innovative approach to the intensity assessment. The INQUA scale first draft is due to Leonello Serva, based on the compilation and comparison of the three most commonly used intensity scales, i.e., the Mercalli-Cancani-Sieberg (MCS), Medvedev-Sponhauer-Karnik (MSK) and Mercalli Modified (MM). Eutizio Vittori, Eliana Esposito, Sabina Porfido and Alessandro M. Michetti produced a revised version, after (a) integration with the revised MM scale of Dangler and McPherson (1993) and (b) checking the scale against the description of coseismic ground effects and intensity assessments for several tens of historical and instrumental earthquakes in the world. The last version of the INQUA scale, to be presented during the INQUA Congress, is a joint contribution of the WG including new data, editing, comments and scientific discussion from Bagher and Jody Mohammadioun, Eugene Rogozhin, Ruben Tatevossian, Aybars Gürpınar, Franck Audemard, Shmulik Marco, Jim McCalpin, Nils-Axel Möner, and Valerio Comerci. Also, the newly revised MM scale for New Zealand (Hancox, Perrin and Dellow, 2002), kindly provided by Graeme Hancox, has been also taken into account in this last version.

The outstanding progress of paleoseismological and Quaternary geology research in the past decades makes available an entirely new knowledge for understanding the response of the physical environment to seismicity, thereby providing the basis for the proposed INQUA intensity scale.

19-3 BTH 40 Nakata, Takashi

HANDY GEOSLICER: A NEW SAMPLING METHOD AND TOOL FOR QUATERNARY STUDIES
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We introduce completely new sampling method and tool for Quaternary studies. The tool named Handy Geoslicer enables us to easily extract undisturbed wide thin sections of unconsolidated sediments that allow us to observe sedimentary structure and to collect datable materials. Handy Geoslicer has a very simple structure. It is made of stainless steel and is composed of a sampling box and its shutter. For sampling, we firstly intrude the sampling box vertically down into the ground by using a hammer or body-weight and then its shutter sliding along the thin slits attached to the both sides of the box, and pull out the tool containing samples. Extracted sediments that form a monolith and are surprisingly undisturbed and show almost same features as previously observed on trench walls excavated close to the extraction sites. This method is far more effective than the conventional sampling method such as boring sticks, hand augers and extracted monolith allows us to observe three-dimensional structures of the sediments. The standard Handy Geoslicer extracts samples 10cm long, 3cm thick and 150cm long. When we use a vibrator, we can collect samples as deep as 300cm. We successfully collected samples from alluvial lowlands, sand dunes, tidal flats, swamps and even from lake bottoms. Collected sections can be taken to a laboratory in the sampling box for close examination or can be displayed at a meeting or even stored for future re-examinations. In order to get deeper and wider outcrops by this method, we made a long Geoslicer employing sheet piles commonly used at construction sites as sampling boxes. Although this sampling method is still to be improved for perfect performance, we realize that this is the most practical sampling method to obtain extensive vertical soil sections of the unconsolidated Quaternary sediments.

19-4 BTH 41 Kaneda, Heitaro

PIT EXCAVATION ON A MOUNTAIN SLOPE: A POSSIBLE PALEOSEISMIC INVESTIGATION FOR SHORT AND LOW SLIP-RATE FAULTS WITHOUT SUITABLE SITES FOR TRENCHING
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Paleoseismology has developed mostly based on studies of major active faults with high slip rates, but low slip-rate faults are also potential sources of catastrophic earthquakes. Especially in regions under tectonically undeveloped regime where many short and low slip-rate faults accommodate regional strain, such faults should be much more important for seismic hazard assessment. We believe that further understanding of low slip-rate faults and tectonically undeveloped regions is one of the important directions of paleoseismology in the 21st century.

One big challenge about low slip-rate faults would be difficulty in obtaining paleoseismic data, because there are fewer suitable sites for trenching along them. In particular, most of low slip-rate strike-slip faults occur within mountainous regions and therefore traditional trenching is much less effective for these faults. Here, we propose pit excavation on a mountain slope as a possible paleoseismic investigation for such faults. By excavating a pit across a small uphill-facing fault scarp on a mountain slope and analyzing the sediment trapped by the scarp, we possibly estimate timing of recent paleoseismic events on the fault.

We carried out two test excavations (pits D1 and D2) on a fault in intraplate Japan for the purpose of evaluating application and problems of this method. The tested fault is the Daguchi fault, one of the short strike-slip faults within the Nosaka mountains north of Lake Biwa, southwest Japan, which is typical of intra-montane low slip-rate faults lacking available trench sites. Pit D1 on the northern segment of the fault successfully reveals evidence of latest two surface-rupturing events. Coupled with the extremely small catchment area upstream of the pit site that precludes recycling of detrital woods, identification of species and portion for wood fragments from the trapped sediment allows accurate estimation of the timing of the paleoseismic events. Pit D2 on the southern segment also reveals evidence of multiple paleoseismic events, but lack of wood fragments in the sediment prevents accurate age control. Pending results of pollen analysis, tephra analysis, and radiocarbon dating should provide constraints on the approximate timing of paleoseismic events and the cause for lack of woods.

19-5 BTH 42 Bacon, Steven N.

PALEOSEISMIC DISPLACEMENT MEASUREMENTS FROM LANDFORMS SUBJECTED TO PERIGLACIAL PROCESSES: OBSERVATIONS ALONG THE JARAI GOL FAULT NEAR THE TAMYN AM HILLS, DARHAD DEPRESSION, NORTHERN MONGOLIA

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The Jara Gol rupture (Khil'ko et al. 1985) is located along a west-facing escarpment of the Sayan Mountains, at 51° 25'N, 99° 50'E in the Darhad depression of northern Mongolia. The fault trace is located east of two prominent, latest Pleistocene end moraine complexes known as the Tamyn Am Hills. A reconnaissance-level investigation primarily using morphostratigraphic position revealed that the fault deforms lateral and ground moraines as well as an inset (?Holocene) recessional outwash plain composed of multiple terraces heavily modified by icings (aufeis), but does not deform younger fluvial terraces located near the flood plain of the Jara Gol ('gol'=river).

Observations along 6 km of the trace indicate that motion on the ~N10°W striking Jara Gol fault is oblique normal left-lateral. Motion is determined by tectonomorphology. The trace is composed of west-facing, ~N-S striking an echelon faults that are connected at left-steps by N30-40°W striking faults forming releasing bends. The entire trace contains well-formed troughs, pressure ridges, and depressions, characteristic of lateral motion. Ground moraines have multiple-event scarp heights of ~7.0-7.7 m with a far-field slope of ~18-20° and single-event scarp heights of ~2.3-3.6 m with maximum scarp slopes of ~33-35°. The younger (?Holocene) outwash plain has a single-event scarp with a height of ~3.6 m and maximum scarp slopes of ~40°.

Moraine and outwash plain landforms did not display any lateral offsets. Piercing points on the footwall of the outwash plain, in the form of terrace treads and risers do not cross the fault onto the hanging wall. The surface of the hanging wall is gently sloping and ~3-5 m lower in relief than the footwall. This surface is armored by tightly packed well-rounded cobbles that locally exhibit 1-2 m wide cobbly linear mounds that are ~0.5 m in relief resembling portions of stone polygons or nets, features typical of patterned ground. It appears that continual frost action has obliterated the

original surface morphology and stratigraphy of the outwash plain on the hanging wall by heaving and inversely grading cobbles. This phenomenon presents difficulties in performing paleoseismic investigations (e.g. lateral displacement measurements or trenching) in regions that are subjected to periglacial processes such as northern Mongolia.

19-6 BTH 43 Phillips, Fred M.

DIRECT DATING OF FAULT SCARPS IN UNCONSOLIDATED SEDIMENT USING COSMO-MORPHOLOGICAL EVOLUTION

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Morphological dating, using fitting of scarp topographic profiles to solutions of the geomorphic diffusion equation, has long been a mainstay of paleoseismology. Unfortunately, large variability in geomorphodiffusivity limits quantification of ages using this approach. The precision of morphological dating can potentially be enhanced by combining it with measurement of cosmogenic nuclide accumulation in materials beneath the scarp. In order to test this approach, we have measured in situ ³⁶Cl in depth profiles beneath two apparent single-event scarps of known age: a Holocene terrace-riser scarp at Cajon Pass in southern California and a Late Pleistocene fault scarp in western Nevada, and a previously undated multiple-rupture scarp in central New Mexico. Comparison of the measurements for the Cajon terrace scarp with preliminary predictions based on the known scarp age and topographic profile show good agreement. The agreement is also good for two cosmogenic profiles at the Nevada scarp, but the (apparent) hanging wall profile shows a deficit of ³⁶Cl, rather than the expected excess. This may have resulted from sampling across a minor splay rather than the main rupture. At the New Mexico scarp, cosmogenic ³⁶Cl measurements correspond well with stratigraphic indicators of multiple ruptures and has enabled establishment of a rupture chronology. These results are encouraging for routine application of cosmogenic nuclide accumulation as a complement to standard morphological dating.

19-7 BTH 44 Azuma, Takashi

PARAMETERIZED DATABASE OF ACTIVE FAULTS AND SIMULATION SYSTEM FOR THE FUTURE EARTHQUAKES

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The datasets of the earthquakes from the active faults has a long history and there are many type studies of them. To estimate the timing and magnitude of the future events from these datasets, we should compile them by using uniform basis and make them into the database. In this presentation, I'd like to propose and discuss the idea of the parameterized database of active faults and the simulation system to estimate the future earthquakes based on that database.

In this presentation, I call the field survey data as the primary data, such as location, length of the fault, slip rate, timing of the event, and recent activity of the small earthquakes. These data are represented by the numerical datasets. The data, which is obtained from the calculation with the primary data, is called as the secondary data, such as the magnitude of the earthquake deduced from the fault length or amount of slip per event, the peak acceleration of ground motion, and the deformation pattern of crust. On the simulation system, we can search the parameters from the database of primary data and select a formula to obtain the secondary data.

For a start, I construct the parameterized database of active faults in Japan. And I will seek the opportunity to link the system to the other active fault database in other countries.

19-8 BTH 45 Clark, Dan

AUSTRALIAN PALEOSEISMOLOGY: TOWARDS A BETTER BASIS FOR SEISMIC HAZARD ESTIMATION

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In this presentation we review the limited history of paleoseismological investigation in Australia and discuss the potential contribution of active fault source data towards improving our understanding of intraplate seismicity. The availability and suitability of Australian active fault source data for incorporation into future probabilistic hazard models is assessed, and appropriate methods for achieving this proposed.

Perhaps the most important realisation from the paleoseismological data collected to date from half a dozen Quaternary faults is that the methods employed to include active fault source zones into hazard assessments in countries such as New Zealand and the United States may not be appropriate for the Australian context. The data suggest that surface rupturing events on Australian Quaternary faults are separated by tens of thousands of years or more. If future investigations confirm this indication, each fault, when considered in isolation, is unlikely to contribute significantly to the hazard for normal structures. However, if other active faults are present in a region, as is certainly the case in many parts of Australia, then the hazard is proportionately larger.

In the western and central parts of Australia there is also an indication that the concept of recurrence of a 'characteristic' or 'maximum probable' magnitude event on a single fault may not be applicable. In this vast region there is no paleoseismological evidence, nor evidence in the landscape, of more than 2-3 surface rupturing events on any given fault. In this context, estimates of hazard must be driven by an understanding of the patterns in migration of seismicity, and on a knowledge of the distribution of potentially seismicogenic faults. Faults active in the Quaternary may not themselves contribute to the hazard, but can provide critical information on the long-term character of the seismicity in an active 'region'.

There are many known Quaternary faults in Australia which have not yet been investigated in detail. Because of the sparsely inhabited nature of the Australian continent it is very likely that more Quaternary fault scarps will be found (despite high scarp degradation rates over much of arid Australia). Some of these fault scarps may even be related to historic events.

19-9 BTH 46 Clark, Dan

THE POTENTIAL FOR PALEOLIQUEFACTION STUDIES TO CONTRIBUTE TO AUSTRALIA'S EARTHQUAKE HAZARD MAP

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Australia has a low rate of modern seismicity and a short historical record of earthquakes. Both of these factors combined make it difficult to lead to large uncertainties construct regarding an earthquake hazard map for Australia in which we can have complete confidence. The current hazard map is based exclusively on historical and instrumentally recorded seismicity. It is an open question whether this is a valid characterisation of seismicity over the long term. Recent neotectonic investigations in areas of low topographic relief, for example, indicate that seismicity must be transitory in both space and time over large parts of Australia.

One approach to address the problem of sparse seismicity in intraplate regions like Australia is to use paleoliquefaction studies to constrain the occurrence of prehistoric earthquakes. Liquefaction has been observed following large historic earthquakes in South Australia and Victoria, and numerous 'sand blows' were observed following the 1968 Meckering earthquake (Ms 6.8) in Western Australia. It therefore seems likely that earlier, prehistoric earthquakes would have also induced liquefaction in these areas, as well as other areas which are geologically prone to liquefaction but have not experienced an historical earthquake.

We have identified 4 target areas for paleoliquefaction studies: (1) the Perth region, a major urban centre situated in a large sedimentary basin near the South West Seismic Zone; (2) the Murchison river area about 500 km north of Perth, which lies near the epicentres of two large historical earthquakes; (3) the southeastern tip of South Australia, site of pronounced liquefaction associated with a large (Ms 6.5) 1897 earthquake; and (4) the Goulburn river near the Cadell fault in Victoria, whose banks consist of poorly consolidated fluvial sediments and lies near a fault known to have experienced slip in the Quaternary. In this presentation, we will discuss why we have chosen these sites as having high potential for paleoliquefaction studies, and hope to present some results from preliminary surveys at of the four target areas.

19-10 BTH 47 Langridge, Robert

THE WELLINGTON-MOHAKA FAULT: UPDATED PALEOSEISMOLOGY, SLIP RATE, AND HAZARD
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The Wellington fault represents NZ's greatest seismic risk. The fault extends ~170 km from Cook Strait at the southern end of North Island, through the urban corridor of the national capital, to the Manawatu gorge, where it continues north as the Mohaka fault for ~290 km to the Bay of Plenty. These dextral faults accommodate the oblique component of motion across the Hikurangi subduction margin. The faults are postulated to show a decreasing rate of slip from S to N related to a decrease in locking across the margin and increasing influence of extension in the Taupo Volcanic Zone. No historical earthquakes of $M > 6$ have occurred on this fault system. Therefore recently, greater attention has been given to their slip rate and paleoearthquake records. The 75 km long Wellington-Hutt Valley segment of the Wellington fault (W-HV) is the best studied with a slip rate of 6-7.6 mm/yr. The last 2 events occurred on it between 1640-1440 AD and 1290-940 AD, yielding an average recurrence interval of 500-700 yr. The W-HV segment has the potential to deliver a $M=7.6$ earthquake with SED of ~4.2 m to the Wellington region. The next segment north of the W-HV is the Tararua Ranges (TR) segment, which traverses those ranges for ~53 km. No slip rate and very few paleoearthquake data exists for this mountainous, bush-covered segment. An estimate of total dextral offset of 7 ± 1 km comes from displaced river drainages. A pulse of aggradation at Totara Flats (1650-1480 AD) has a similar age to the MRE on the W-HV segment. North of the TR segment 7 trenches at 4 paleoseismic sites on the straight, 43 km Pahiatua-Woodville (P-W) section have yielded at least 3 distinct paleoearthquakes during the last 2500 yr. Two new slip rate measures of 4.6-7.2 and 3.6-4.9 mm/yr for this section come from trench data combined with surveys of offset streams. New work on a 27 km section of the southernmost Mohaka fault gives a slip rate of 5-7 mm/yr. Trenching studies show that 3 paleoearthquakes have occurred on it at similar times to the P-W section. In summary, the paleoearthquake results from 3-4 segments of this fault system yield similar slip rate along strike to the north, and similar (overlapping) event ranges for the last 2-3 events. These results have significant implications to our treatment of the seismic hazard from future surface-rupturing earthquakes of $M > 7$ in southern North Island.

19-11 BTH 48 Hsiao, Chien-Li

RELEVANT DEBATE OF HISTORICAL TAIWAN EARTHQUAKES

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Earthquake parameters determination from macroseismic data is a procedure, the reliability of whose results can be impaired by many problems related to quality, number and distribution of data. Such problems are common with ancient, sketchily documented events, but affect even comparatively recent earthquakes. In order to figure out the relationships between historical earthquakes and the associated faults, the historical documents from 1604 to 1897 are restudied. We made some important improvements in the method of editing and supplemented many new materials. Accompanying anomalous phenomena before and after earthquake occurrence were included in the description of earthquake phenomena. Comparing the isoseismal map and the trajectory of surface faulting with relocated epicenters, it can be found that results of this study may be more reasonable than the previous studies. The following points are noted: 1. seven of earthquake tsunamis (1683, 1721, 1781, 1792, 1866, 1867) occurred in the western and northern Taiwan; 2. there are several features suggest that the two earthquakes (1683, 1846) were induced by meteorites but has not been reported before; 3. nine of the surface ruptures (1604, 1661, 1662, 1694, 1720, 1792, 1816, 1867, 1882) occurred in Taiwan, but five ruptures (1683, 1694, 1720, 1792, 1816) reinterpreted associated with earthquake faults. According to the paleo-map and archaeological studies of the 1694 earthquake; the Kanshi Taipei Lake is caused by earthquake faulting is witnessed.

19-12 BTH 49 Imaizumi, Toshifumi

DIGITAL ACTIVE FAULT MAP OF JAPAN AND ITS APPLICATION

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The location of active faults is one of the most important data for large seismic activities in the past, earthquake prediction on land and the relevant seismic hazard mitigation. Even in an earthquake country Japan, danger of active faults was not well understood among the people before 1995 Kobe earthquake. In order to provide the fundamental information regarding active faults such as their distribution and characteristic activities, we have re-interpreted air-photographs in Japan and depicted the detailed location of active fault traces together with related information. Active faults we mapped are mostly based on distinctive fault-related features, and therefore are defined as faults that have been repeatedly moved during the last several 100,000 years and will move again in future generating large earthquakes. Many new active faults were found in one side, and many previously recognized faults were regarded inactive in the other side mainly due to detailed interpretation of large-scale air-photographs. The 1:25000 map scale maps containing the active faults amount to 1300 GIJ toposheets and they were not easily published as printed sheets. In order to provide the data to the public in the form that many people can easily utilize, we digitized the data and burned on DVD with GIS map as background, and publish it as *ENDigital Active Fault Map of JapanEU*. This map reveals types of active faults and frequency in their regional distribution, activity (average slip rates) of fault zones, strain rates under the present stress field, relation between active faults and land use especially public buildings such as school and hospital etc. The

map still needs much improvement, but we hope this map will be used not only in the academic fields but also in the land use planning to avoid dangerous setting of structures.

19-13 BTH 50 Goto, Hideaki

TIMING AND DISPLACEMENT OF THE MOST RECENT SURFACE FAULTING ALONG THE MEDIAN TECTONIC LINE IN SHIKOKU, SOUTHWEST JAPAN

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An active fault system extends for about 190 km along the Median Tectonic Line (MTL) in Shikoku, southwest Japan. The MTL is an arc-parallel, right-lateral strike-slip fault related to the oblique subduction of the Philippine Sea plate beneath the Eurasian plate along the Nankai trough. It is one of the most active inland faults in Japan. However, the long-term seismic risk of the MTL has been poorly understood, because of insufficient paleoseismological data, especially the timing and amount of displacement associated with the most recent surface faulting along the fault zone.

In order to better define seismic potential of the MTL, we carried out a trench excavation survey across the Hatano fault in central Shikoku. We excavated two trenches across the fault trace and two trenches parallel to the fault trace to expose stratigraphic evidence for horizontal displacement associated with the past earthquakes. The sediments exposed on the trench walls contain evidence for two faulting events in the past 3500 years B.P. The most recent surface faulting along the Hatano fault occurred between 1510 cal A.D and 1630 cal A.D. This is the first paleoseismological data, which precisely constrain the timing of the most recent faulting event of the MTL. We have also estimated 2.0-3.0m right-lateral displacement and 0.3-0.5m vertical displacement up on the north during the most recent faulting event based on offset of paleo-channel deposit.

Detailed analysis of large-scale aerial photographs led us to identify numerous geomorphic and artificial features that are offset during the most recent faulting along the MTL. These features include terrace risers, streams, roads, and rice-paddy dikes. We have made detailed geomorphic maps using an EDM and measured the amount of offset at each site. The amount of offset ranges from about 7 meters in eastern Shikoku and 2-3 meters in western Shikoku, which is concordant with geologic slip rates. This implies that the characteristics earthquake model proposed by Schwartz and Coppersmith (1984) is applicable to the MTL active fault system.

19-14 BTH 51 Shishikura, Msasnobu

Holocene Subducted Plate Motion Along the Sagami Trough, Central Japan, Revealed from Paleoseismological Study

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Sagami Trough extending NW-SE off South Kanto is convergent plate boundary where the Philippine Sea Plate subducts beneath the North American Plate. Two major historical earthquakes of the 1703 Genroku Kanto Earthquake (M 8.2) and the 1923 Taisho Kanto Earthquake (M 7.9) occurred along the trough. As a result of the coseismic crustal movements associated with these earthquakes and repeated pre-historic earthquakes, Holocene emerged shoreline indicators (e.g. emerged wave-cut bench, fossilized mollusk etc.) are distributed on about 10 or more levels along the coast of the Miura Peninsula and the Boso Peninsula. The height distributions of lower two levels of them in the Miura Peninsula indicate more than 1 m of uplift during both the 1703 and 1923 events. In the Boso Peninsula, although geodetic data show up to 2 m of uplift during the 1923 event, historical documents and the height distribution of emerged shoreline indicators suggest that the coseismic crustal movement during the 1703 event had resulted steep northward tilting accompanied with uplift of more than 5 m in the southernmost area and subsidence of ca. 1 m in the central area. According to above results, it is inferred that the fault source model of the 1703 event is composed of dual fault system (fault A and B). The fault A is same as the model of the 1923 event which has already been estimated by Ando (1974). The uplift of the Miura Peninsula (both the 1703 and 1923 events) and the Boso Peninsula (only the 1923 event) can be explained by about 6.7 m slip of the fault A. The fault B is low angle dip thrust located off the southeast of the Boso Peninsula. The unique 1703 coseismic crustal movement in the Boso Peninsula has been derived from about 12 m slip of the fault B. 14C ages of the older paleo-shorelines above two recent levels indicate that the characteristic earthquake generated from the fault A has been occurred repeatedly about every 400 years. Basing on the feature of emerged shoreline topography, one of several events is the 1703 type earthquake accompanied with the slip of fault B. Recurrence interval of this type is estimated to be 2000-2700 years. Therefore, the slip rate of these faults are estimated to be 16.8 mm/year (fault A) and 5.2 mm/year (fault B) respectively. These value are greatly different each other and smaller than the recent back-slip rate (30 mm/year) estimated from GPS data.

19-15 BTH 52 Sugito, Nobuhiko

SLIP DISTRIBUTION DURING THE LATEST TWO EARTHQUAKES ON THE SEKIDOSAN FAULT ALONG THE SOUTHEASTERN MARGIN OF THE OUCHIGATA PLAIN, CENTRAL JAPAN

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We report nearly characteristic behavior during the latest two surface-faulting events on the Sekidosan fault in central Japan. The Sekidosan fault is a NE-trending, 33-km-long active reverse fault along the southeastern margin of the Ouchigata Plain, an elongated NE-trending tectonic lowland whose northwestern and southeastern sides are bounded by reverse faults. A vertical slip rate of 0.8 - 1.0 mm/yr has been estimated based on vertical separation of the top of a peat layer dated at approximately 6,000 years B.P. However, there is no historical record that indicates surface-faulting events along the fault. In order to clarify the activity of the Sekidosan fault during the Holocene, we conducted the following geological and geomorphological investigations.

First, we reexamined the precise location of the fault traces by interpreting aerial photographs on scales of 1/10,000 to 1/40,000. We then carried out 33 topographic profiling across the tectonic scarps on geomorphic surfaces younger than the last glacial maximum. Among the profiles, 15 profiles are interpreted to represent the vertical offset during the most recent surface-faulting event. As a result, we were able to reconstruct the slip distribution associated with the most recent surface-faulting event along the middle and northeastern part of the Sekidosan fault. The amount of vertical offset along the middle part is fairly constant along the trace (2 - 3 m). In contrast, the amount of vertical offset along the northeastern part is 1 - 2 m and tapers off toward the northeastern end. The amount of vertical offset along other 10 profiles nearly equals to twice the amount of offset during the most recent surface-faulting event, indicating that the amount of offset at individual sites along the Sekidosan fault was almost the same during the latest and penultimate earthquakes.

Subsurface stratigraphy and radiocarbon ages revealed by drilling survey across a flexure scarp 4 - 5 m high on geomorphic surfaces of Holocene age suggests that more than two surface-faulting events occurred after approximately 6,000 years B.P.

19-16 BTH 53 Mathew, George

LUMINESCENCE CHRONOMETRY OF TECTONIC LANDFORMS IN KACHCHH, W. INDIA : EVIDENCES OF LATERAL EASTWARD PROPAGATION OF THE KACHCHH MAINLAND FAULT
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 Consequent to continent-continent collision and flexing of the Indian lithosphere, the paleo-rift basin of Kachchh (Kutch), western India experienced several tectonic episodes along the major E-W faults. The 2001 Bhuj earthquake was the most recent evidence for a continued seismicity along Kutch Mainland Fault (KMF). The present contribution is a maiden attempt to reconstruct event chronology of the tectonic landforms in the northern hill range along KMF. Blue green stimulated luminescence (BGSL) ages on quartz extracts were used to infer the rates of river incision. Under a reasonable assumption that the climatic control on incision in such a hyper arid area was minimal.

The fluvial incision rates in the region bounded by N23°19' - E69°41' (Bhuji) to N23°19' - E70°11' (Devisar) were estimated using, a) channel fill deposits on incised bed rocks and b) valley fill terraces cutting across rising asymmetrical anticlines. BGSL ages indicate bed rock incision during 15 ka to 5 ka followed by aggradation between 5 to 0.5 ka and another incision since 500a. This implies two episodes of uplift, at 15 ka and 500a. Rates of Incision of ~1.5 mm/a on the strath bedrock terrace during 15 to 5ka, and 9.0mm/a during the past 500a on valley fill terraces are inferred. Geodetic measurements since 2001 have provided an uplift rate of 12mm/a in eastern KMF. A systematic decrease in the BGSL ages of channel fill deposits towards east [15ka(Bhuji) - 12ka (Jawaharnagar) - 7.6 ka (Khrisara)], indicate eastward propagating fault related folding of KMF. Deflection of drainage around the nose of plunging fold, the presence of water gaps and decrease in topographic relief further support this inference. The 2001 Bhuj earthquake was probably manifestation of this deformation, now active in the eastern zone of KMF.

19-17 BTH 54 Juyal, Navin

CHRONOMETRIC EVIDENCES OF QUATERNARY EXTENSION ALONG TRANS-HIMADARI FAULT IN CENTRAL HIMALAYA, INDIA

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The tectonic activity of Trans-Himadri fault (THF, equivalent of the South Tibetan Detachment System) during the late Miocene (20-11 Ma) has been documented. However in the absence of chronologically constrained field evidences, activation of THF during the Quaternary has been debated. In this contribution new evidences suggesting tectonics activity during the Quaternary are presented. Presence of knick zones, perched glacial valleys, deformed lacustrine sediments, incised outwash gravels and scree cones in two lacustrine (Garbyang and Goting) and one glaciated basins (Goriganga) in the vicinity of THF, conjunctively suggest episodic tectonic activity during the Quaternary. The older tectonic events resulted in the formation of knick zones (deep gorges) and perched glacial valleys associated with the footwall of THF. Dating of terminal moraines in Gangotri basin suggest that the maximum extent of valley glaciation in the region occurred at ~64 ka. (Sharma and Owen, 1995), the Presence of moraines in Garbyang at identical elevations and at the base of lacustrine sediments abutting against the THF places the timing of gorge incision to > 64ka. Deformed lacustrine sediments located on the subsiding hanging wall provide evidence of younger tectonic events. Optical dating of lacustrine sediments and outwash gravel suggests three major tectonic events during 22-17 ka, 14-13 ka and <11 ka. Linear extrapolation of the ages places onset of lacustrine sedimentation at ~65ka. This is consistent with the minimum age of the underlying moraines. Based on the genetic relationship of seismicity between MCT and THF, the evidences suggest an ongoing activity on the THF that has been synchronous with movements along the MCT. The present results support the steady-state model of Himalayan orogeny.

19-18 BTH 55 Haynes, Jeremy

GROUND-RUPTURING EARTHQUAKES AT THE ARCHAEOLOGICAL SITE OF QASR TILAH, DEAD SEA TRANSFORM, JORDAN

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The Qasr Tilah archaeological site is located along the northern Wadi Araba fault portion of the Dead Sea transform about 8 km south of the escarpment to the Dead Sea Ghor. The site contains a fort, a water reservoir (birkeh) with aqueducts leading to it from the adjacent Wadi Tilah, and aqueducts leading from the reservoir to agricultural fields. Charcoal collected from the foundation mortar and upper wall mortar of the birkeh reveal that the water reservoir at this site was built ca. 641-687 A.D. (Niemi, 2000; 558-776 A.D. in Klinger et al., 2000), indicating its use in the Late Byzantine to Umayyad period. Repairs to the upper northwest corner wall of the birkeh that is built over the active fault suggest that seismic subsidence occurred on the fault possibly during construction of the structure. Recent detailed archaeological excavations in 2001 and 2003 and mapping of stratigraphic sections revealed evidence for at least three earthquakes that postdate construction of the reservoir and aqueduct. The most recent earthquake clearly cuts through sedimentary layers that are very near to the surface indicating a very recent age of faulting. At least two faulting events cut sedimentary layers full of mortar, charcoal, building blocks, and other tumble debris from the collapse of the birkeh. These data indicate that there are at least three earthquakes that post-date the collapse of the birkeh wall. Several earthquakes are known from historical records to have occurred in the vicinity of the southern Dead Sea, Kerak, and Wadi Araba. These include the earthquakes of A.D. 31, 363, 659/60, 1068, 1212, 1293, and 1456-59 1588 (Ambraseys et al., 1994; Amiran et al., 1994). At this time, we do not have enough age control to assign any of the known historical earthquakes to this section of the fault. However, radiocarbon samples collected from key stratigraphic horizons and ceramic analyses of potsherds collected in archaeological context should enable us to date the individual seismic events identified in the trenches.

19-19 BTH 56 Niemi, Tina M.

ARCHAEOSEISMOLOGY OF OFFSET RUINS ALONG THE SOUTHERN DEAD SEA TRANSFORM, JORDAN

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The field of archaeoseismology is the study of ancient earthquakes based on their effects on human constructions found in the archaeological record. Archaeological sites that are built over active faults are unique because of their potential to yield the precise date and magnitude of individual historical earthquakes. Furthermore, the age and areal distribution of earthquake-damaged features can help refine the epicentral location of past earthquakes. The main objective of the Wadi Araba Earthquake Project is to use detailed archaeological excavation and mapping to define and date archaeological structures that have been offset by earthquake motion in order to better our understanding of ancient earthquake sources, develop models of earthquake recurrence, and improve our understanding of future seismic hazards along the Dead Sea Transform faults in Jordan. Our paleoearthquake data from trenches excavated across the active faults in Aqaba indicate repeat motion on the faults with the latest scarp forming around A.D. 1045-1278 (probably in the historical earthquakes of 1212 or 1068). The ancient Islamic walled city of Ayla is known from Arabic historians to have been completely destroyed in the earthquake of March 18, 1068. Archaeological excavations at Ayla revealed walls that were tilted, slumped, and shifted completely off their foundations and evidence for liquefaction. Recent excavations of a monumental Byzantine mudbrick church structure indicate that a portion of this building collapsed in the earthquake of May 19, 363 A.D. This date is derived from over 100 coins of Constantius II (337-361 A.D.) found beneath tumbled mudbrick walls. Subsequent inhabitants repaired wall joint separations and fissures in the standing walls. These fissures were later faulted to the surface of the cultural debris and sediments dated to the 7th-8th century. One 4th century wall at the south end of the site appears to be offset by at least two earthquakes. These data indicate primary tectonic faulting in Aqaba in the 4th and 11-13th century. Our excavations at the Qasr Tilah archaeological site that is built over the Wadi Araba fault south of the Dead Sea indicate at least three post 7th Century earthquakes. These data clearly show that both slip and earthquake chronology data can be gleaned from key archaeological sites.

19-20 BTH 57 Hermanns, Reginald L.

PALEOSEISMICITY DEDUCED FROM LAKE SEDIMENT DEFORMATIONS IN THE CALCHAQUI VALLEY, NW-ARGENTINA

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Vestiges of at least two strong earthquakes occur in lake sediments of a former rock-avalanche dammed lake in the Calchaqui valley at the transition from the Cordillera Oriental to the Sierras Pampeanas tectonic provinces of the NW Argentine Andes. Two reverse-fault offsets with buckle faults in the foot wall and slump faults in the hanging wall indicate that these earthquakes took place while the lake sediments were water saturated and therefore during the lake phase. Within strike of these faults overturned folds occur in a lake sediment segment 1-km-long. Perpendicular to the folds are two deformation horizons with convolute bedding interpreted as seismites. These seismites horizons occur in various sub-basins of this former lake but are restricted to well sorted deposits of silty to sandy composition. No seismites occur within the center of the former lake characterized by clayey to silty composition. The age of the earthquakes causing lake sediment deformation is bracketed by preliminary cosmogenic nuclide ages of surfaces of three rock-avalanche deposits and breakaway scarps, two of them having minimum ages of ~ 13.5 ka and the other one of ~ 4.5 ka. While the older rock-avalanche deposits dammed the valley and formed this lake the young rock avalanche fell in a sub-basin of the lake which was followed by dam erosion and lake-dry out. In addition, one seismites horizon could be AMS carbon-14 dated to 7,500 +/- 70 a "CAL BP" by organic material. This age coincides with the age of a cluster of 4 simultaneous landslides dated by a combination of cosmogenic nuclide dating and tephrostratigraphy to have occurred at about the same range of time (7 - 7.5 ka ago). These data spanning several thousand years differ from the historic seismic record of the past 200 years and the instrumental record of the last 40 years which indicate, respectively, that no earthquakes of intensity MM > 6 or no earthquake of magnitude M > 4 has occurred in this area. Therefore, paleoseismic investigations indicate that the seismic hazard in this area is stronger than suggested by the historical and instrumental seismic records and that strong earthquakes do occur with a recurrence interval of a few ka.

19-21 BTH 58 Lalinde Pulido, Claudia Patricia

PALEOSEISMIC EVIDENCE AT LICEO TALLER SAN MIGUEL, PEREIRA-ARMENIA REGION, COLOMBIA - SOUTH AMERICA

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The Pereira-Armenia region -located in the west flank of the Colombia Cordillera Central- is crossed by the Romeral fault system, which is an active LLSS fault with a secondary thrust component in the Eje Cafetero zone (4-5° N latitude). The ground were sits the Liceo Taller San Miguel, located 9 km south of Pereira, is carpeted by over 2 m-thick volcanic ash falls of less than 30 ka. This locality has been affected by both N40°E and E-W trending faults that correspond respectively to thrust faults or folds and normal-RLSS faults in the tectonic model for the zone. Specifically, field evidence of two types on the E-W faults were found at "Canchas": (1) the 50°N tilt of the Late Quaternary interbedded sequence of volcanic ash falls and 3 paleo-soils and (2) an about 1.70 m vertical throw affecting the sequence. The activity of the N40°E trending faults is attested by a normal offset of about 0.65 m at "Parqueadero". This latter faulting does not comply with the stress tensor proposed for this region; thus this deformation could be interpreted as being the consequence of flexural slip induced by a NE-SW striking blind thrust, where reverse faulting along bedding at depth turns into normal faulting at surface.

Such measured offsets can have generated an event of at least Mw 6.6 for the NE trending fault; and at least Mw 6.9 for the E-W trending fault. These two recently-identified faults are now named Puerto Samaria Fault (NE-SW) and Cestillal Fault (E-W). Up to now, fault and its seismogenic potential determinations in this region had been based solely on morphologic evidence. Maximum seismic magnitude estimated for this region was between 6.2 and 6.6 for seismic

sources at 35 km away. Seismic magnitudes like the one calculated in this work (Mw 6.9) used to be estimated for source-site distances greater than 50 km. This work brings field evidence that leads to a better understanding of the seismic activity of this region in the last 30 ka and confirms that local Mw 6.5 seismic events have occurred in this region. Although volcanic ash falls smoothens and eventually hides the geomorphic evidence of active deformation, it is a perfect chronometer of its activity when active deformation is revealed, like in this case. After the Armenia 1999 event, it has become a must to revise the seismic hazard studies in this region in terms of local crustal seismicity.

Financed: Banco Republica, COLCIENCIAS, INQUA

19-22 BTH 59 López, Myriam C

EVIDENCE OF HOLOCENE COMPRESSION IN THE VALLE DEL CAUCA, ALONG THE WEST FOOTHILLS OF THE CENTRAL CORDILLERA OF COLOMBIA

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In the west foothills of the Central Cordillera of Colombia, east of the town of Tulúa, a series of north-south trending scarps affecting the surface of Quaternary alluvial deposits and a large number and variety of drainage anomalies attest to the recent activity of imbricated north-striking thrust faults that emerge along bedding planes of Miocene units. Some of these faults eventually cut across unconformably-overlying Quaternary alluviums and overthrust some paleosoils. At the north Tulúa motorway exchanger, these paleosoils have been particularly dated at 12,840 ± 40 and 17,800 ± 660 ka BP; in another scarp southwest of this place, there are paleosoils in a coluvial wedge with ages of 22,000 ± 160, 21,000 ± 140, 17,000 ± 130 and 7,460 ± 330 Ka BP.

West-facing flexural scarps in association with blind thrusting (produced by fault propagation folding), north-south elongated pressure ridges bounded by antithetic and synthetic reverse faults and some anticline emergences in the recent alluvial deposits are clear evidence of the primary west vergence of the fold-thrust belt of these Central Cordillera foothills whose youngest activity used to be thought as Tertiary in age.

Deflections and interruptions of (1) the NNE trend of the Tertiary units by the ENE right-lateral strike-slip system, (2) the trend of the reverse faults, (3) the axial trend of some anticlines, and their spatial configuration suggest that shortening in the western foothills of the Central Cordillera is mechanically and kinematically connected with the ENE RLSS system, at least in this section of the Valle del Cauca.

Project: "Paleoseismic Investigations in the Valle del Cauca – Toward the Seismicity Model in the SouthWest of Colombia" developed by Seismologic Observatory of Southwest Colombia -OSSO- Valle University and EAFIT University with the cooperation of COLCIENCIAS and CORPORACION OSSO.

19-23 BTH 60 Mörner, Nils-Axel

HIGH PALEOSEISMIC ACTIVITY DURING DEGLACIATION DATING AND RECORDING OF 50 EVENTS IN SWEDEN

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Sweden, today an area of low to moderately low seismic activity, was, in Late Glacial time, characterized by a very high paleoseismic activity; both in seismic magnitude and in seismic frequency. This period, or mode, of exceptionally high seismic activity is recorded by multiple criteria: primary faults, bedrock deformation, sedimentary deformations, rock and sediment slides, liquefaction, sorting by shaking, tsunami waves, a number of geomorphic expressions, paleo-magnetic disordering as well as ordering. Most of the events are dated by means of varve chronology providing a time resolution as to a single year. The sharp dating control allows reconstruction of the spatial distribution of individual liquefaction events, by this providing new means of estimating magnitudes. By applying multiple criteria, it was possible to establish a paleoseismic catalogue for Sweden which, for the moment, includes 50 separate events. When plotted against time, more than 50% of the events fall within the period 9000–11,000 BP when the rate of uplift was in the order of some to several 10s of cm per year or 0.4–1.4 mm per day (quite remarkable rates, recently confirmed by observational data). A causal correlation between high seismicity and peak rates of uplift is therefore advocated. The same seems to apply for the entire Fennoscandian region. Within the Mid to Late Holocene, there are a number of significant events, too. In three areas, it has been possible to establish the recurrence time and pattern of paleoseismic events; viz Hudiksvall (7 events), Mälardalen (14 events) and the Swedish West Coast (12 events). The practical implications of a high deglacial seismic mode, is that all efforts of making long-term safety estimates based solely on available instrumental records will totally fail to provide any meaningful information. We are in Fennoscandia facing a major paradigm shift; from a concept of general stability to 21st century concept of an exceptionally high seismic activity during the phase of deglaciation.

19-24 BTH 61 Magyari, Árpád

LATE QUATERNARY TRANSPRESSIONS SOUTH OF LAKE BALATON, HUNGARY
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The Somogy Hills is a hilly area, located immediately south of Lake Balaton, Hungary. The region has two well defined valley systems. 1.: few tens of kilometres long and nearly parallel „transversal” valleys with N-S to NNW-SSE direction. 2.: „longitudinal” valleys of NE-SW – E-W strike. We analysed Quaternary and directly underlying Upper Miocene (Pannonian) outcrops by structural, tectono-morphological and sedimentological methods to quantify the main fault directions; to separate mass movements from faulting and folding; and to separate earthquake-induced sediment deformations from other (e.g. periglacial) effects. Quaternary outcrops showed several consistent directions of faulting, and co-depositional seismic activity (seismites). Three different Mohr-sets of faults could be differentiated in Quaternary sediments. In Pannonian outcrops four different sets were separated, three of which are common to the Quaternary ones. The three sets are considered Late Quaternary since all cut young loess sections and have sharp morphological expressions. In the transversal valleys NNE-SSW striking en echelon folds, normal and Riedel faults can be detected. Both affect the present day surface. Riedel faults can be seen as renewed small valley-opening from the last decades until today. On the basis of the fault and fold patterns this movement refers to a marked left lateral transpression along the transversal valleys. NE-SW – E-W longitudinal valleys show right lateral strike slip motion at the same time. This research was supported by the Hungarian National Research Fund (OTKA T-037593).

19-25 BTH 62 Guerrieri, L.

THE INTERMOUNTAIN BASINS WITHIN THE APENNINES (ITALY): LANDSCAPES RESULTING BY REPEATED STRONG EARTHQUAKES

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The epicentral areas and the most relevant ground effects of strong historical to modern earthquakes that occur in the Apennines – with typical hypocentral depths of 5 – 15 km – are systematically located within the intermountain extensional basins that characterize the landscape of the inner part of Central and Southern Italy. This study aims at showing A) why we can assume that these basins are the result of repeated strong earthquakes over a geologic time interval, that is the last ca. 3 Ma, B) how this assumption can be used for seismic hazard assessment in Italy, and C) on which basis this approach should be used for understanding the seismic potential of others regions of the Earth. In particular, we focus here on the Fucino, Colfiorito, Bojano and Rieti basins, where our analysis clearly indicate that several geologic and geomorphic features, including the size of the basin and the thickness of the filling deposits, appear to be directly related with the source parameters of the associated "typical" earthquake, that is the dominant seismic event in the recent seismic history of the area. This indicates that the growth of the Apennines intermountain basins is due to the repeated occurrence of "characteristic" surface faulting earthquakes along the causative normal fault segments. Thus, a relation exists between seismic potential, length and displacement of the surface rupture (paleoseismic evidence), fault slip-rates, and dimensions of the associated intermountain basin. This relation, or "seismic landscape", is apparent for all the Quaternary normal fault basins of the Apennines, also where local factors such as very high rates of depositional/erosional processes due to the drainage network (Rieti basin) or pre-existing structural complexities (Bojano basin) tend to mask the real shape and size of the growing geologic structure. Conversely, this is no more true for older, Pliocene basins, located on the Tyrrhenian side of the Apennines belt, which show a much more subdued seismicity and low-energy geomorphic relief. In this line, we propose a model illustrating the expected occurrence and characteristics of coseismic ground effects for the Fucino-like (M7) and the Colfiorito-like (M6) "seismic landscapes", which summarize the basic criteria for evaluating seismic hazards in the extensional setting of the Apennines.

19-26 BTH 63 Guerrieri, L.

ACTIVE DEFORMATION OF THE NORTHERN ELSINORE FAULT ZONE: IMPLICATIONS FOR THE QUATERNARY EVOLUTION OF SANTA ANA RIVER, SOUTHERN CALIFORNIA

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Quaternary geologic mapping, soil geomorphology, morphometric analysis, and borehole stratigraphy are used to assess the influence of Quaternary active tectonics on the geomorphic evolution of the Santa Ana River (SAR) in Santa Ana Canyon (SAC) in the southeastern Los Angeles Basin. The reach is situated between the Puente-Chino Hills (PCH) and Prado Dam where the Elsinore fault splits into the Whittier and Chino faults. Soil B horizons on mapped units are well developed, > 2 m thick and reddened to 6.75 YR on Upper Pliocene-Lower Pleistocene fan units and <50 cm thick and reddened <7.5YR on the oldest Holocene fluvial deposits. Geomorphic analyses included detailed longitudinal and cross-valley profiles and the evaluation of geomorphic indices, such as stream length-gradient and transverse topographic symmetry. Results indicate a strong asymmetric distribution of relief (uplift) across the PCH and spatial variation in the relative degree and magnitude of deformation across major structural zones. The right-lateral Chino fault results in slight southwest deflection of stream channels and valleys on the east flank of the PCH. Boreholes containing prominent dark, organic-rich layers suggest episodic ponding upstream of SAC. Available data do not directly support coseismic ponding-events along the Chino fault, however, deposit age suggests possible ponding in response to regional flooding events in the SAR drainage. Greatest long-term uplift occurs northwest of the Elsinore-Whittier faults (EWF) where it passes through SAC and is reflected in the magnitude of SAR terrace uplift. The SAR long profile and distribution of terraces through SAC also reflect strike-slip motion along the EWF. Unlike other large fluvial systems in the same area, the Santa Ana River has persisted in its present course since the PCH uplift began, principally controlled by the tectonic boundary between the maximum uplift in the PCH to the north and uplift of the Santa Ana Mountains along the restraining bend south of the canyon.

19-27 BTH 64 Scharer, K. M.

THE WRIGHTWOOD PALEOSEISMIC RECORD, DOUBLED

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At the Wrightwood, California paleoseismic site, the combination of local patterns of paleo-earthquake deformation and an excellent stratigraphic record preserve a long (~4,000 year) record of prehistoric earthquakes on the San Andreas fault. Previous evaluation of the event series indicates a 105-year average recurrence interval over 14 paleoearthquakes. This series shows a weakly time-predictable behavior that, nonetheless, can not be distinguished from a Poisson distribution. Because uncertainty in the recurrence behavior at this site is largely controlled by the length of the event series, we initiated this study to extend the event series and robustly characterize the recurrence behavior of the San Andreas fault in the San Gabriel mountains. Here we present event evidence for ~12 earthquakes that predate and lengthen the existing record. Strong evidence of paleoearthquakes is preserved as fissures and growth strata across structural features like meter-scale thrust faults, mini-grabens, and broad folds. Moderately compelling evidence is expressed by consistency of upward terminations at a depositional horizon. Preliminary carbon-14 dates of the older section indicate ~10 of these events occurred between 2,000 and 4,000 14C years BP. In order to characterize the peat layers in the older section, we present dates from the humic and humin fractions of 21 layers, and when possible, compare these to macrofossil ages. The older event series is compared with previous calculations of 30-year conditional probabilities given Poisson and lognormal models.

19-28 BTH 65 Zhang, Hongwei

PALEOSEISMOLOGY OF THE NORTHERN SAN ANDREAS FAULT AT VEDANTA MARSH SITE, OLEMA, CALIFORNIA

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At Vedanta marsh located in Olema, CA, 60 km north of San Francisco, well-defined stratigraphy and abundant in situ organic material allow the determination of the first long, high-resolution multiple event record for the north coast segment of the San Andrea fault. During the 1906 San Francisco earthquake, the ground ruptured along the northeastern edge of the Vedanta marsh where historical offset measurements near the site were about 5m. Subsidence of the marsh was also observed at the time of the 1906 earthquake as a lane of water ponded against the rupture trace (Lawson, 1908). Eight trenches have been excavated across the fault during the past two field seasons. The main fault zone consists of a 2-m-wide zone of upward-branching fault splays within the marsh stratigraphy. A secondary fault zone located 5m to the east juxtaposes older sediment (>25 ka) against colluvium in apparent normal separation. The marsh stratigraphy consists of major peat layers interbedded with marsh clay and silt that interfinger eastward with colluvial gravels. A clear, vertical transition from predominantly fine-grained marsh deposits to coarse clastic sediment occurs at a depth of approximately 1 m. AMS radiocarbon dating of peat, macrofossils, and charcoal collected throughout the section provide excellent age control for event horizons. At least ten pre-1906 events were identified by evidences of outward-splaying, upward fault terminations and fissure fills. The 1906 earthquake ruptures a portion of the upper gravel and a possible late 19th century road fill. Deformation within each of the laterally correlative, upper three peat layers deposited about 300, 700, and 1100 yr B.P. exposed in all the trenches provide age constraints on the timing of four pre-1906 earthquakes. Earlier events were exposed in the one deep excavation and are confined between the section dated to approximately 1200 to 2500 yr B.P. Most of the event horizons terminate in or near major in situ peat layers that provide excellent organic material for radiocarbon analysis. Correlation among trenches and radiocarbon dates indicates a range of recurrence intervals between paleoearthquakes. Further analyses of the radiocarbon data will help us to clearly define the dates of these paleoearthquakes.

19-29 BTH 66 Vittori, Eutizio

NEW INSIGHT ON THE OWENS VALLEY FAULT ZONE (EASTERN CALIFORNIA, U.S.A.) FROM DETAILED QUATERNARY FAULT MAP

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Owens Valley is a 170 km long late Neogene graben at the boundary between the Sierra Nevada and Basin and Range Provinces that extends southward from Bishop to the Owens Lake-Coso area. It also lies in the narrow Eastern California Shear Zone (active geodetic strain rate ~6-8 mm/yr). In 1872, during a M 7.4-7.6 earthquake, a 116 km segment of the Owens Valley fault zone (OVFZ) ruptured with up to 10 m dextral-slip locally.

Field studies and interpretation of 1:12,000 scale, low-sun angle aerial photographs, augment earlier work to show both the extent of the 1872 rupture, and the broader setting of numerous Quaternary faults in the surrounding graben. The low-sun angle aerial photographs cover nearly all the valley floor permitting detailed mapping of the ruptures and relative age classification of scarps. Fault scarps are classified into four age groups based on the age of the youngest deposit offset by the fault and on their aerial photo and field appearance: 1) 1872 rupture, 2) Holocene, 3) Late Pleistocene, and 4) Pleistocene or older. The 1872 rupture, dominantly strike slip, runs mostly in the valley center, while earlier faulting, mainly concentrated in the slopes, displays a strong normal component. In addition, the location of apparently Pleistocene lake shorelines are shown, as some prominent scarps at the SE edge of the lake formerly interpreted as lake highstands are in reality fault-controlled.

The 1872 rupture terminates at late Quaternary basaltic volcanic fields (Big Pine and Coso) at right-steps of the OVFZ. Our map shows that the 1872 scarp terminates south of Dirty Socks Springs near Red Mountain, further south than shown by previous work. Sections of the 1872 rupture with lengths of 34, 11, 10.5, and 10 km show pure transient displacement. Four east-steps, two of which have been documented as restraining bends by recent MSc studies, link the rupture sections. The northern section at the termination of the 1872 rupture shows significantly greater oblique slip. The occurrence of restraining bends on east-steps of a right lateral fault suggests strain partitioning with rotation of small blocks between the range front normal faults and the OVFZ. The pattern of faulting around and within the Owens Lake playa indicates that it is a pull-apart basin, controlled by a right-step of the main NNW right-slip fault zone.

19-30 BTH 67 dePolo, Craig M.

THE WARM SPRINGS VALLEY FAULT SYSTEM, A MAJOR RIGHT-LATERAL FAULT OF THE NORTHERN WALKER LANE, WESTERN NEVADA

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The Warm Springs Valley fault system (WSVFS) is one of three major right-lateral faults in the northern Walker Lane. The system has well-developed, late Quaternary tectonic geomorphology over 35 km, but may be up to 95 km long with potential extensions in Warm Springs and Honey Lake Valleys. The system is typically made up of two or more fault traces in parallel and anastomosing patterns. The WSVFS is a quintessential transtensional fault with a strong tendency to step to the right at large and small scales, creating extensional areas. The WSVFS traverses several sedimentary environments, and has different geomorphic expression in each. In the basin sediment of Warm Springs Valley, fault scarps, vegetation lineaments, and small push-up features created by the last few events along the fault are visible (short-term geomorphic expression), and there are large areas where alluvial processes are young or active, and there is no convincing tectonic expression. Long-term geomorphology (mid to late Quaternary) is buried or not sustained. In the alluvial fan environment, long-term geomorphic expression, such as linear ridges, is nearly continuous, whereas expression of the last few events is subtle and sparse, and commonly is buried, eroded away, or indistinct. In the bedrock environment, long-term geomorphic expression is abundant and continuous, including linear ridges, valleys, and drainages, sidehill benches and swales, fault scarps, oversteepened hillslope bases, and fault facets. Similar to the alluvial fan environment, short-term geomorphic expression is sparse.

Four trenches excavated along the southern portion of the WSVFS expose at least three, and potentially more, latest Pleistocene paleoearthquakes. Evidence includes offset deposits, fault-fis-

sure deposits, colluvial-wedge deposits, liquefied and laterally spread deposits, and a sandblow. One of these paleoevents appears to have occurred while Warm Springs Valley was inundated with water, possibly the high stand of Lake Lahontan, a latest Pleistocene pluvial lake.

19-31 BTH 68 Thelen, Weston

GEOPHYSICS AND PALEOSEISMOLOGY: THE SIGNATURE OF ACTIVE FAULTS IN THE GREAT BASIN

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We show examples of locating and estimating the relative ages of suspected fault strands using three simple and inexpensive geophysical methods. In the east Gardnerville basin, Nevada, we used shallow seismic reflection, total-field ground magnetics, and resistivity to define the three-dimensional geometry and characteristics of poorly characterized recent fault strands. Locating the strongest magnetic and resistivity anomalies focused further surveys on the most potentially active fault strands. We used a sledgehammer seismic reflection profile to image faulted Cenozoic stratigraphy below the anomalies. The signal arising from each technique varies regionally among faults and locations so it is important to integrate methods. Combining electrical resistivity, ground magnetics, and high-resolution seismic imaging can identify the more recent and active strands within a fault zone. Such signatures have been found, by similar field campaigns, to occur on normal and strike-slip faults in other areas in the Great Basin including Warm Springs Valley, Pahump Valley and the Virginia Range of Nevada. This combination of geophysical signatures provides an additional tool for paleoseismic investigations in the Great Basin and abroad. The implications of such a set of techniques include improved seismic hazard analyses, particularly on the outskirts of urban areas, and more efficient targeting of paleoseismic investigative trenches.

19-32 BTH 69 McCalpin, James P.

PALEOSEISMIC INVESTIGATIONS IN THE RIO GRANDE RIFT, USA, 1978-2003

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The Rio Grande rift trends north-south for 1000 km between northern Chihuahua, Mexico, and central Colorado, USA. In the past 25 years most of the major rift-bounding faults have been subjected to paleoseismic study. At the northern end, late Quaternary fault scarps were first discovered in 2002 on the Williams Fork Mountains fault, on the east side of the Williams Fork Mountains. Discontinuous late Pleistocene fault scarps exist on the western side of the Upper Arkansas Graben (Sawatch Fault), which was trenced in 1978. South of Poncha Pass the symmetry of the rift reverses, and the 120 km-long Northern Sangre de Cristo fault bounds the large San Luis Graben on its eastern side, and is tentatively divided into 3 segments. Trenches on this fault in 1980 and 2002 document the MRE at about 7.6 ka, and the PE between 10-15 ka. South of Taos, New Mexico the symmetry of the rift reverses again, with major displacement shifting to the western margin (Pajarito Fault). The accommodation zone is occupied by the sinistral Embudo Fault, which displaces Quaternary but not late Quaternary deposits. The Pajarito Fault forms a 75-130 m-high escarpment in a plateau formed by the 1.2 Ma Bandelier Tuff, yielding a long-term slip rate of about 0.1 mm/yr. Since 1997 at least 20 trenches have been dug in this fault zone, which bounds the Los Alamos National Laboratory. Recurrence on the Pajarito Fault tends to be about 20 ka, with the latest event in the mid-Holocene. Normal faults in the Albuquerque-Belen Basin are typified by large (25-100 m-high) fault scarps across old (500-1200 ka) geomorphic surfaces west of the Rio Grande, and by much smaller scarps at the base of the Sandia Mountains. South of Albuquerque the Hubbell Springs fault bounds the eastern rift margin and was trenced in 2000. At the latitude of Socorro the Socorro Mountain fault bounds the western side of the rift. Trenches in 1999 showed a Holocene MRE. Farther west the longer La Jencia fault was extensively trenced in the 1980s, and a recurrence interval of 20 ka was estimated. In southern New Mexico the Alamogordo and Organ Mountains faults have been trenced in a preliminary fashion. Finally, the southernmost part of the rift at El Paso is composed of the East Franklin Mountains fault, which was trenced in 1996. The MRE there was ca. 10ka, but there are questions about slip rate and recurrence.

19-33 BTH 70 Olig, Susan S.

LATE QUATERNARY PALEOSEISMICITY OF THE CENTRAL HUBBELL SPRING FAULT AND IMPLICATIONS FOR STRAIN PARTITIONING IN THE CENTRAL RIO GRANDE RIFT, NEW MEXICO

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The Hubbell Spring fault (HSF) is near the eastern margin of the Albuquerque-Belen basin in the central Rio Grande rift, and is one of the most active faults in the region. Recent mapping and geophysical studies indicate that the fault geometry is more complex and longer than previously thought, with two dominant west-dipping splays (western and central) extending for over 40 km south of Albuquerque. An eastern splay (also referred to as the Meadow Lake fault) is buried along its southern 2/3 and appears to be older than late Quaternary. Our paleoseismic investigation of the Carrizo Spring trench site on the central HSF revealed structural, stratigraphic, and pedologic evidence for at least 4, and probably 5, large earthquakes that occurred since deposition of piedmont deposits on the Llano de Manzano surface about 83 ± 6 ka. All of these events included warping across a broad deformation zone, whereas the 3 largest events also included discrete slip across five fault zones. Behavior appears non-characteristic, with preferred vertical displacements per event ranging from 0.4 to 3.7 m. Fault-related deposition was dominated by eolian rather than colluvial sedimentation, similar to previous trench studies in the area. The total down-to-the-west throw of piedmont deposits is 7.3 ± 0.5 m, yielding an average vertical slip rate of 0.09 ± 0.01 mm/yr. Luminescence ages suggest that the 3 largest faulting events on the central HSF may correlate to the three youngest events on the western HSF, but additional ages are needed to confirm this. Two smaller warping events on the central HSF do not appear to correlate to any events on the western HSF. We estimate that over 90% of the late Quaternary strain on the HSF occurred as coseismic rupture of the western and central splays. Additional investigation is needed to determine how this may relate to paleoseismicity on other adjacent, subparallel Quaternary faults along the eastern rift margin.

19-34 BTH 71 Barron, Andrew D.**LONE MOUNTAIN: AN ILLUSTRATIVE EXAMPLE OF RANGEFRONT MORPHOLOGY ALONG AN ACTIVE NORMAL FAULT**

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Lone Mountain provides a particularly illustrative example of range front morphology controlled by active normal faulting. Located in the western Great Basin 25 km west of Tonopah, the mountain reaches 2770 m elevation. The northwest flank of the mountain is bounded by a normal fault which is traceable for about 30 km. Displacement along the fault has produced at least three offset and now abandoned alluvial and pediment surfaces which show progressively greater offset with age. The oldest of these surfaces sits about 10 m above current grade and are characterized by deeply dissected fan remnants and pediments with rounded crests. Intermediate aged surfaces are moderate to deeply dissected and sit about 5 m above current grade with well developed pavements and a medium to dark varnish. The youngest surfaces are not dissected, and not far out of active stream grade. In sum, the geomorphic evolution of abandoned alluvial surfaces with time is well demonstrated at Lone Mountain. Additionally, there exist numerous youthful appearing single-event scarps ranging from 0.25 to 0.75 m high which locally cut Late Pleistocene pluvial lake deposits adjacent to the Range. Thus, the most recent movement has been active post-Late Pleistocene and probably late Holocene.

19-35 BTH 72 Levson, Victor M.**ESTIMATING LIQUEFACTION SUSCEPTIBILITY OF LATE PLEISTOCENE AND HOLOCENE DELTAIC DEPOSITS USING CONE PENETRATION TESTS AND THREE-DIMENSIONAL QUATERNARY GEOLOGY MAP DATA: IMPLICATIONS FOR PALEOSEISMOLOGICAL STUDIES**

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Regional earthquake hazard evaluations of deltaic deposits in three areas of southwest British Columbia are used to illustrate the utility of cone penetration tests and three-dimensional Quaternary geology data for evaluating liquefaction susceptibility. The west coast of BC is the most seismically active region in Canada and the SW corner of the province is home to about 2 million people. One method of mitigating the seismic hazard in the region, is through the use of earthquake hazard maps that show variation in liquefaction susceptibility. These maps are designed for emergency and land-use planning and are based on local site conditions such as the thickness, age and distribution of Quaternary stratigraphic units. Surficial geology maps, geotechnical borehole databases, water well logs and other subsurface data are used to define map units. Quantitative techniques such as cone penetration tests are then used to measure parameters required for liquefaction assessments of each unit. We combine the Seed method for determining liquefaction susceptibility with the probabilistic seismic model developed for the NBC, to provide a quantitative assessment of the liquefaction hazard that can be compared between different maps units and areas.

The Quaternary geology of deltaic deposits in the three illustrative case study areas is complex and there are a variety of stratigraphic units that contribute to the liquefaction hazard. Normally consolidated Late Pleistocene deltaic sands and gravels are the oldest deposits of concern for liquefaction. In general these deposits are relatively dense and have a low liquefaction susceptibility but late-stage surface channels with perched water tables locally pose a significant hazard. In contrast, many facies of Late Holocene delta deposits of the Fraser River such as top-set channel sand facies, are highly susceptible to liquefaction. An intermediate liquefaction hazard, between these two end members, is presented by parts of the Fraser River delta proximal to the mountains. Early Holocene deltaic sediments there are comparatively gravely and have a lower liquefaction susceptibility than sandier downstream reaches. The liquefaction assessments confirm paleoseismological studies of the different deltaic facies and highlight prospective areas for further study.

19-36 BTH 73 Nelson, Alan R.**EARTHQUAKE HISTORY OF REVERSE FAULTS AND FOLDS IN TRENCHES ACROSS ALSM-IMAGED SCARPS IN THE SEATTLE FAULT ZONE, PUGET LOWLAND, WASHINGTON STATE**

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The Seattle fault zone—a 70-km-long, east-west belt of young reverse faults—is one of several fault zones in the Puget Lowland that accommodates 4-7 mm/yr of north-south shortening resulting from northward migration of forearc blocks along the Cascadia convergent margin. Like crustal faults in similar densely populated basins, the faults may pose a greater earthquake hazard than do much longer but more distant plate-boundary faults. Airborne Laser Swath Mapping (ALSM, also known as LIDAR mapping) of the Puget Lowland reveals previously unknown scarps beneath the forest canopy along some young reverse faults. From complex exposures of reverse faults and folds in trenches across the scarps we reconstruct the earthquake history of the Seattle fault zone for regional hazard assessment.

Trenches display stratigraphic and ¹⁴C evidence of early Holocene as well as late Holocene earthquakes on the Seattle fault, but trench logs differ considerably in lithology and genesis of stratigraphic units, styles of faulting and folding, and numbers of surface-deformation events identified. Five trenches across 1-to-6-m-high scarps on a 2.6-km-long, north-dipping backthrust to the Seattle fault about 12 km west of Seattle on Bainbridge Island reveal folds and faults, liquefaction features, and forest A horizons buried by hanging-wall-collapse colluvium that record three, or possibly four earthquakes, between 2.5 ka and 1.0 ka. The most recent 1.0 ka earthquake is probably the same earthquake that raised marine terraces and triggered a tsunami in Puget Sound. Two of three trenches on a similar 1-to-5-m-high, south-facing, en echelon scarp 3 km to the southwest at Waterman Point display hanging walls of Oligocene sandstone and mudstone thrust over forest soils developed in drift during a large earthquake about 1.0 ka. In the third trench, a second, post-1.0-ka earthquake is recorded by a forest soil developed on slope and hanging-wall-collapse colluvium from the 1.0-ka earthquake that is also overthrust by the hanging wall. At Vasa Park on the west shore of Lake Sammamish about 16 km east of Seattle, excavations at two sites across a low scarp show evidence for an earthquake likely between 10.5 and

4.5 ka. Surface folding and faulting of about 1-2 m per earthquake, estimated from stratigraphic and surface offsets, suggest magnitudes near M7 for Holocene earthquakes.

SESSION NO. 20, 1:30 PM**Friday, July 25, 2003****S20. Human-environment Interactions: Past and Present (Posters)****Reno Hilton Resort and Conference Center, Pavilion****20-1 BTH 74** Smyntyna, Olena V.**HUMAN-ENVIRONMENT INTERACTION IN SCIENTIFIC AND HUMANITARIAN THOUGHT AT THE END OF XXTH CENTURY: CAUSES OF PLURALITY**

SMYNTYNA, Olena V., Department of Archaeology and Ethnology of Ukraine, Odessa I.I. Mechnikov National Univ, 2, Dvoryanska str, Odessa 65026 Ukraine, smyntyna@mail.ru. Environmental approach to human history remains one of the most alluring and unequivocal since its origin in ancient times. At the beginning of XXIst century complicated interdisciplinary studies of cultural history where contemporary methods of instrumental analysis are used are often bringing us to the necessity to take environmental issues into account when conceptualising local peculiarities of cultural evolution. Three main approaches of human-environment interaction in historical retrospect could be distinguished in contemporary humanitarian and scientific thought. One of them known as "geographical determinism" is concentrating around environmental impact on human history. During the second half of XXth century most powerful among its concepts becomes adaptation theory, which is discussed in the frameworks of "New" and behavioural archaeology, environmental psychology, phenomenological and processual schools of culture etc. The second approach, concerning with human agency in nature development, becomes popular alongside with global reconsideration of human role in the Universe took place at the times of scientific revolution. Among theories and concepts developed in its frameworks attention should be paid to environmental archaeology, geoarchaeology, palaeoeconomic modeling, local and regional palaeoecological approach, landscape history, cultural landscape school, concept of anthropogenic landscape, theory of landscape as artifact and others. Adepts of third approach tend to interpret human-environment interaction as integrated system all elements of which are of equal importance and are engaged into complicate reciprocal influence. In this context attention should be paid to general and ecological stresses theories, concepts of social and ecological resilience, regulation and sustainability, to co-evolution theory, to geosystem notion as well as to wide spectrum of post-modern concepts. Such theoretic plurality appears to be positive when trying to create exhaustive picture of human-environment interaction in past and present.

20-2 BTH 75 Dodson, John R.**HOLOCENE ENVIRONMENT AND HUMAN IMPACT AT DINGNAN, CHINA**

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A pollen analysis of peat at Dingnan in southern Jiangxi Province, a temperate region of eastern China, contains a record of vegetation and landscape change covering the full Holocene. The record opens with an Alder woodland with a mix of Oak and grassland. In the mid Holocene the vegetation becomes more complex suggesting a moist and warm environment and little if any human impact. About 4-5000 years ago there is a collapse in forest cover and a fernland with low tree cover forms. This region is subsequently converted into a predominantly rice production area, fire becomes an important part of the management cycle in the system and some Pine plantations are developed.

The record of agricultural development is slightly younger than is known for regions further north in the Lower Yangtze Basin.

20-3 BTH 76 Lang, Andreas**LAND DEGRADATION IN BRONZE AGE GERMANY - AN EXAMPLE FROM FRAUENBERG AT WELTENBURG, BAVARIA**

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Human impact on landscapes was intense in the early settled regions of Central Europe. This paper examines the effects of early agriculture and land use in the vicinity of a Bronze Age fortress at Weltenburg, Germany. Sediments and soils found below archaeological structures are compared with sediments and soils surrounding these structures. A chronology is established using relative archaeological dating, C14 dating of charcoal fragments, TL dating of heated objects, and OSL dating of sediments. Results demonstrate dramatic environmental changes that occurred as early as the Bronze Age. Erosion resulting from agriculture stripped away most Holocene soils and Pleistocene sediments, transforming the natural landscape into a severely degraded cultural landscape. Since the Bronze Age, only minor changes have occurred because agricultural is limited on the degraded soils and the clay-rich soil remnants are resistant to further erosion.

20-4 BTH 77 Lagerås, Per**HUMAN IMPACT AND FIRE-REGIMES IN SOUTHERN SWEDEN INTERPRETED FROM TERRESTRIAL MACROSCOPIC CHARCOAL**

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In spite of its great potential, terrestrial macroscopic charcoal from soil profiles are rarely used in palaeoecological studies of human impact and land-use practises. The main reason for this may be that soil profiles usually are disturbed by bio-turbation, and that each piece of charcoal therefore has to be individually radiocarbon-dated in order to get reliable chronologies. Among the advantages of terrestrial macroscopic charcoal, in comparison to microscopic charcoal from lake and peat sequences, is that it is of very local origin and that it can be wood-anatomically identified to species or genera.

In connection to a series of archaeological excavations in southern Sweden, macroscopic charcoal was sampled from soil profiles in areas with traces of Iron Age agriculture. The sampled charcoal was wood-anatomically identified, and all together 150 pieces were radiocarbon-dated

within the project. The results give new information on the long-term fire-history of southern Sweden, from early-Holocene natural fires in *Pinus* woodlands, to anthropogenic fires in cultural landscapes. It gives new and detailed in-sights into the process of agrarian expansion and, in particular, the role of fire in forest clearances and in the maintenance of semi-open pastures and cultivated plots. The result show that the use of fire during the Iron Age can be divided into two succeeding phases: expansion and maintenance. In the expansion phase, fire was used to turn semi-natural *Quercus*-woodland to open land used for grazing and cultivation. In the following phase, fire was used primarily to keep pastures open by clearing secondary-succession trees and shrubs of *Betula* and *Corylus*. By comparing the results with local and regional pollen diagrams it is possible to link specific pollen zones to Iron Age land-use practises and fire-regimes.

20-5 BTH 78 Lagerås, Per

SCIENCE AND ART IN PALAEOENVIRONMENTAL RECONSTRUCTIONS

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In the project 'Man and environment in the Småland Uplands during the last 6000 years', the long-term landscape development of a forested region in southern Sweden was investigated using an inter-disciplinary approach. Within the project, the medieval hamlet Axlarp with its predecessors was studied in detail by pollen analysis, archaeological investigations, and the study of old documents and maps. Based on the results and interpretations from Axlarp – as well as information on topography, hydrology, and the distribution of Quaternary deposits – landscape reconstructions for selected time-slices were painted in water-colour by a professional artist. Stimulating discussions between scientists and the artist during the reconstruction process raised new questions about past landscape types, and highlighted information-gaps in the data. The paintings are presented on the poster together with some of the background data. Details in vegetation and land-use are graphically linked to corresponding sequences in pollen diagrams, radiocarbon dates, etc, and some of the possibilities and limitations of the palaeoecological and archaeological records are discussed.

20-6 BTH 79 Plater, Andrew J.

A MULTIDISCIPLINARY APPROACH TO DATING LATE HOLOCENE LAKE SEDIMENTARY RECORDS

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Chronologies of climate and human impact on lake sedimentation during the Late Holocene have been established for field sites in California and South Africa using a suite of techniques. The multidisciplinary approach taken has had to overcome mismatches between the period of record and established radiometric dating techniques, as well as problems with low activity samples resulting in considerable analytical uncertainty. The primary focus has been on determining chronological marker horizons using pollen data in combination with documented introductions of exotic species for reasons of health, economic development and environmental management. Down-core trends in inorganic geochemical and magnetic data have been used to identify potential pollution chronologies, or changes in the nature of sedimentation resulting from changes in lake level and/or sediment provenance linked to land-use activity and aperiodic flooding. Organic geochemistry has also been used to establish pollution chronologies based on the recent use of agrochemicals such as DDT. In California the established chronology reveals a switch from minerogenic sedimentation to biological productivity in Pinto Lake during the 1950s without any significant change in the rate of sedimentation. The upper part of the record then preserves catchment flooding events as pulses of minerogenic inwash (which may be linked to El Niño magnitude/frequency). In South Africa, recent human impact has resulted in a significant increase in the delivery of topsoil-derived material to the floodplain wetlands of the Mkuze River, KwaZulu-Natal, as a consequence of changing land-use and increased sensitivity to runoff since the 1960s.

20-7 BTH 80 Gunnell, Yanni

CRACKING THE CODE OF BUDDHIST COSMOLOGY THROUGH THE ANALYSIS OF HOLOCENE PALEOENVIRONMENTAL ARCHIVES: A PRELIMINARY RECONSTRUCTION OF PALEOLAKE BOROBUDUR (JAVA, INDONESIA)

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The 9th century world-heritage Buddhist monument of Borobudur (Java, Indonesia) stands above the floor of a dried-out paleolake, but it remains uncertain as to whether it was ever constructed on a lake shore. Here we reveal through new chronological, geomorphological and paleoenvironmental data on the extant sediment record of the area that Borobudur intentionally stood by an existing natural lake with a life history spanning at least 20,000 years.

Our study combines surface and subsurface data to generate time-sliced maps of paleolake Borobudur. Ground-checked aerial photographs were used to map the surface geology and drainage. The stratigraphy and contours of the paleolake were plotted and correlated after completion of an electrical resistivity and Very Low Frequency electromagnetic survey. Textural, mineralogical and pollen analyses were performed on lacustrine claystone roof exposures and two 50 m-deep cores in order to establish environmental fluctuations, sediment provenances and flooding events. Radiocarbon ages have allowed to age-bracket some of these events and set the claystone stratigraphy, and therefore the history of Borobudur, in a new chronological time frame.

The configuration of the fluctuating lake was intermittently influenced by far-field volcanoclastic deposits conveyed by turbid rivers from the active volcanoes in the north and east (Merapi, Merbabu, Sumbing, Sindoro), and by near-field clearwater runoff from the eroded Tertiary volcanic terrain (Menoreh Hills) in the south. Our findings support the interpretations of the Dutch artist W.O.J. Nieuwenkamp, who in 1932 visualized the edifice as an aquatic lotus symbol upon which the young Buddha was seated. Initially dismissed by scientists, these views are considerably more consistent with Buddhist cosmology than if Borobudur had never stood by a lake. Seasonal lakeshore fluctuations, although not detectable in the sediment record, probably played an important part in conferring on the temple a semi-aquatic character, especially towards the end of the annual rainy season within this "mesopotamian" environment. In this perspective, the sudden shift of the Borobudur-based Mataram government to East Java after 1006 AD may have been caused by chronic water-related diseases around Borobudur rather than any given volcanic hazard.

20-8 BTH 81 Heijnis, Hendrik

LAM PHRA PHLOENG DAM, THAILAND - A HIGH RESOLUTION RECORD OF HUMAN ACTIVITY AND CLIMATE VARIABILITY

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Lam Phra Phloeng reservoir is one of the most seriously affected by soil erosion related sedimentation in Thailand. Clearing in the catchment from 1974 to 1985 reduced forest area by about 70% (from 531 sq.km to 160.25 sq. km). The dominant crops in the upper catchment are sugar-cane and cassava. After the crop has been harvested the land is tilled and becomes sensitive to sheet erosion. The area suffers periodically from floods as well as draughts. Because of these rapid changes there is an increased sediment load in rivers draining into the reservoir. As a direct result the Lam Phra Phloeng reservoir has become very shallow at the point where major streams enter.

The measurement of sedimentation rates in Lam Phra Phloeng Dam (Water supply catchment Dam) is the co-operative research between the Royal Irrigation Department, Ministry of Agriculture, the Office of Atoms for Peace, Ministry of Science and Technology and the Australian Nuclear Science and Technology Organisation. During a fieldsampling campaign in June 2002, several sediment cores were taken from the Lam Phra Phloeng reservoir. These sediment have been analysed at high resolution for sedimentation rates using the radioisotopic techniques (Pb-210). Also investigated were climatic records and sediment characterisation such as grain size, in order to estimate the rate and nature of sediment accumulation in the reservoir. Comparison of the data obtained with climatic and hydrological data revealed the relationship between sediment accumulation rate, seasonal changes in rainfall and sub-decadal climate variability. These findings show that a revised life-span of the reservoir as water storage body is necessary and a more permanent crop is advisable to tackle soil-erosion issue, without compromising the economic status of the farmers in the catchment.

20-9 BTH 82 Elias, Scott A.

THE BERINGIAN BARRIER TO HUMAN DISPERSAL DURING THE LATE PLEISTOCENE

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The occupation of Beringia remains one of the most complex problems in human paleoecology. The archaeological evidence suggests that human occupation of Beringia did not begin until at least 18,000-15,500 cal BP, and firmly documented sites are not present until the Late Glacial (14,000-13,000 cal BP). Hoffecker and Elias (2003) address the question of why humans did not occupy Beringia before this time.

Beringian climates during the LGM were cold and dry, but temperatures in many regions were not significantly lower than modern levels. Increased aridity seems to have been the chief difference between LGM and modern climates. During the warmer phases of OIS 3, climates and forest cover in western Beringia were similar to today. Modern humans successfully occupied very cold, dry, and treeless regions of Eastern Europe and southern Siberia during late OIS 3 and the early LGM, using technologies similar to those of recent Arctic peoples. The latter inhabit areas such as the "Pole of Cold" (i.e., Yukagir) where temperatures are lower than they were in many parts of Beringia during the LGM. Therefore environmental conditions alone seem insufficient barriers to human dispersal through Beringia.

We believe that the principal barrier to human dispersal across Beringia was their warm-climate morphology, derived from their recent African ancestors. The humans who first colonized northern Eurasia retained this morphology until the later phases of OIS 2. Skeletal remains from Europe dating to 40,000-24,000 cal BP exhibit high brachial and crural indices, lengthened extremities, and other features found in present-day populations of the equatorial zone. People living at the Sungir' site (56° N) in Russia had skeletal features indicating that this warm-climate morphology was still present in subarctic Asia during the early LGM. Despite the use of technology broadly comparable to that of recent subarctic and arctic peoples, modern humans were unable to occupy areas of Northeast Asia above latitude 60° N prior to 24,000 cal BP. Moreover, as LGM climates reached their peak intensity at 24,000-21,000 cal BP, they abandoned the cold-east parts of Europe and Siberia for several thousand years.

20-10 BTH 83 Heyvaert, Vanessa

THE RECONSTRUCTION OF HISTORY AND ENVIRONMENT OF THE MESOPOTAMIAN PLAIN DURING THE MIDDLE AND LATE HOLOCENE

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In the framework of an interdisciplinary project, the interaction between the middle and late Holocene palaeoenvironment on the one hand, and the development of the social, political, and economic institutions of the populations in Mesopotamia on the other hand is investigated. In order to study such a complex picture of one of the oldest civilization of the world, a synthetic treatment is necessary from a varied and extensive array of data coming from different disciplines, i.e. geo-sciences, archaeology, philology and history.

This poster presents the results of the investigation of the natural and anthropogenic landscape of the archaeological site Sipar-Ammanum (Tell ed-Der) and its surroundings, located between the rivers Tigris and Euphrates at about 30 km South of Bagdad (Iraq). On the basis of remote sensing, supported by field surveys, palaeochannels and related irrigation systems were reconstructed and integrated with the archaeological chronostratigraphy. Lithologically based facies analyses of about 250 hand-operated gouge augers resulted in the identification of natural and anthropogenic units, together with the setting up of the further development of the fluvial environment during human occupation. A geological and geomorphological map of the 'archaeological sterile' subsoil of the study area has been created in a GIS.

Financial support for this research was provided by the Interuniversity Attraction Poles Programme - Belgian State -Federal Office for Scientific, Technical and Cultural Affairs.

20-11 BTH 84 Bondesan, Aldino**LATE HOLOCENE PALAEOENVIRONMENTS AND HUMAN IMPACT IN THE ARCHAEOLOGICAL AREA OF CA' TRON, AT THE MARGIN OF THE LAGOON OF VENICE (ITALY)**

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The palaeoenvironmental evolution of the Ca' Tron area, in the alluvial plain near the shores of the Lagoon of Venice, has been investigated within the framework of a geoarchaeological project started in 2000, funded by *Fondazione Cassamarca*. The prominent archaeological feature in the study area is a stretch of the Roman road *Via Annia*, built in the 2nd century B.C., but archaeological evidences span since the Iron Age to the Middle Age. The main upbuilding of the alluvial plain took place during the last glacial maximum. The post-glacial deposits belong to the Late Holocene. In the 2nd millennium B.C., a high energy river of alpine origin, the Piave River, crossed the study area following the course of the underground water-fed Sile River, and flowed into the lagoon. At that time, the lagoon was less extended towards the mainland. It reached the maximum extension, bordering the study area, only in Medieval times. Apart from this event, the Late Holocene palaeohydrographic network was mainly related to minor rivers originated in the plain, fed both by underground water and local runoff. They usually followed the larger, Late Pleistocene palaeochannels. Fossil pollen in the muddy, organic-rich infilling of one of these abandoned channels, the *paleoalveo della Cannà*, has been studied. The bottom of this ca. 15 m wide and 2.5 m thick sedimentary body, has been radiocarbon dated to 795 - 390 cal BC. The sub-vertical banks and almost rectilinear planform of the palaeochannel suggest human intervention on the river, possibly already in pre-Roman times. Pollen analysis shows that during the Iron Age up to the beginning of the Roman Age the land was used for farming practices (evidences of *Hordeum*, *Avena-Triticum*, *Plantago lanceolata* pollen), grazing animals and cultivating fruit- and nut-bearing trees and shrubs (*Juglans*, *Corylus*, *Rosaceae Maloideae*, *Vitis*). Human activities did not reduce the broadleaf plant communities (arboreal pollen percentage ranging from 30 to 55 % of the total upland plant pollen). Aquatic plant communities were formed by typical marsh and swamp freshwater species. The *paleoalveo della Cannà* was crossed by the Roman *Via Annia* by means of a stone bridge, while in the Middle Age a small wooden bridge existed in the same location (archaeological excavations are being carried out by under the direction of F. Ghedini).

20-12 BTH 85 McAndrews, John H.**HUMAN IMPACT AT CRAWFORD LAKE, ONTARIO, CANADA: THE SEDIMENT RECORD OVER THE LAST MILLENNIUM**

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Here we present results from a varved 80-cm sediment sequence from Crawford Lake (Ontario, CA). High-resolution sampling, multi-proxy analyses and an accurate age model, based on varve counts and over 20 AMS 14C dates, allow us to document the ecosystem response to regional climate change and human impact periods over the last 1000 yrs. Pollen analysis records farming periods, forest succession and climate change.

Poaceae, Zea and Ustilago distinguish farming periods. The Iroquoian Indian period, 1274-1516, also has domestic Helianthus and Cucurbita and weedy Portulaca; eight Iroquoian villages are within two kilometers of the lake. The charcoal-laden sediment of the Canadian period, 1820-2000, features introduced Rumex acetosella and native Ambrosia. Forest biomass reconstructed with R-values shows succession of Acer-Fagus deciduous forest to Acer-Quercus forest during Iroquoian period and since 1650 mixed forest of Acer, Quercus, Pinus and Tsuga. In the Canadian period, Betula and Ulmus flourished after logging. Since 1960, Ulmus declined due to disease. Transfer functions indicate temperature and precipitation peaked during the Iroquoian period. O-isotope analyses of inorganic CaCO₃, a proxy for temperature, confirm a cooling trend from 1500-1900.

Sedimentation rates and C-isotope values increased dramatically at the initiation of the Iroquoian period - and then remain high - indicating prolonged ecosystem impact. In the Canadian period, organic C increased, while CaCO₃ and its C-isotope values decreased.

Diatom assemblages shift during both periods. Stephanodiscus peaks at the start of the Iroquoian period. Assemblages were more complex in the Canadian period where initial peaks of Cyclotella michiganiana and Synedra nana gave way since 1970 to Asterionella formosa and a return of Cyclotella bodanica v. lemanica, a species largely absent since the Iroquoian period. Overall diatom abundance and rotifer abundance (five species) peak during both periods of human disturbance, indicating enhanced nutrients. Interestingly, there is a lag between diatom abundance and sedimentological changes at the start of Canadian period, indicating that lakes having experienced a degree of cultural modification may be less susceptible to further anthropogenic perturbations than pristine environments.

20-13 BTH 86 He, Xiubin**RESPONSE OF SOIL EROSION TO ENVIRONMENTAL CHANGES AND HUMAN ACTIVITIES DURING QUATERNARY, LOESS PLATEAU, CHINA**

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In evaluating modern soil erosion and foretelling soil erosion characteristic of the future under the background of global changes, we are facing a great number of questions that can only be answered through a better knowledge of the past. This paper analyzed structures and characteristics of soil erosion systems on the Loess Plateau during Quaternary. Based on stratigraphical, archaeological evidence, written historical records and previous works, the history of soil erosion in Quaternary was reconstructed. The soil erosion in the transitional period between dry-cool periods and wet-warm periods was more intensive than that in the dry-cool period or the wet-warm period. A chronological analysis of soil erosion on the loess plateau during Quaternary is presented. The intensive soil erosion occurred at 2.4M.a.B.P., 1.48M.a.B.P., 0.56M.a.B.P., 0.25M.a.B.P.,

0.14M.a.B.P. and 0.01M.a.B.P.; and during the Holocene, the periods of intensive soil erosion were 7500a.B.P.-7000a.B.P.; 200BC-0AD; 1000AD-1600AD; and the 30's, 50's and the later 60's of this century. Under the background of paleoenvironmental reconstruction, it shows that the influence of geo-ecological environmental changes on soil erosion was obvious, especially during the transitional periods. The soil erosion, however, was not serious during geological periods due to the self-control mechanism of the system. The serious accelerated soil erosion has occurred in recent 2500 years because of the man-made devastation of vegetation and other human disturbance to geo-ecological environment.

20-14 BTH 87 Fogel, Marilyn L.**WHAT HAPPENED DURING THE AUSTRALIAN MEGAFUNAL EXTINCTION: TROPHIC LEVEL UPSET, ECOSYSTEM CHANGE, OR HUNTING PRESSURE?**

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Stable carbon and nitrogen isotopes in the organic fraction of dated, fossil eggshells from emu and an extinct bird, Genyornis, reflect the diet of these birds and record changes through time. Data from three geographically distinct sites provides evidence that large-scale changes in the ecosystem happened on the Lake Eyre basin to Southern Australia after megafauna went extinct at 45-50 kA. Carbon isotopic shifts record diminishing C-4 grasslands; nitrogen isotopic shifts at Lake Eyre and Darling Lakes, NSW, record increasing aridity. Isotopic compositions of Genyornis and fossil emu will be compared to the C and N isotopic compositions of >500 modern plants collected in the continental rainfall gradient from 100-1500mm/year. In South Australia, N isotopic compositions of plants growing in very dry conditions reach values of +10 per mil, whereas in high rainfall regions N isotopes are as low as -2 per mil. Shifts in rainfall that affect the N isotopic compositions of plants can explain most of the changes measured in the eggshells over time. Genyornis eggshells were typically collected along side lakeshores and other water courses, often in great abundances indicating that they might have been colonial nesting birds. Multiple eggshells from the same nest are compared with different nests to determine whether these birds were capital breeders, relying on a stable, year-round food source. Both factors may have contributed to their demise from human predation, relative to the emu, solitary nesters that rely on recently ingested food for egg-laying.

20-15 BTH 88 Avni, Yoav**NATURAL ONGOING DESERTIFICATION IN THE ARID AND SEMI-ARID REGIONS OF THE MIDDLE EAST**

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In the arid and semiarid regions of the Middle East, gully incision erodes alluvial sediments and loess soils deposited during the Upper Pleistocene along the valleys. This phenomenon becomes critical in the arid region of the Negev Highlands of southern Israel where the land carrying most of the natural biomass and which has agricultural value is limited to narrow valleys. These fields, cultivated during the Iron Age (3000 years BP) and the Roman-Byzantine Age (1800-1400 BP), were irrigated by runoff harvesting techniques. The semi-nomadic population in the region continues to cultivate parts of these fields today. During flood events, the runoff penetrates the alluvial cover of the valleys, forming vertical headcuts, which gradually retreat up the valleys. The formation of deep and narrow gullies within the valleys concentrates the runoff into narrow channels, preventing the floodwater from irrigating the whole width of the valleys. The sharp change in irrigation efficiency is reflected in a sharp drop in biomass, up to 80%. This phenomenon continues downstream along the gullies, almost without recovery. The annual migration rate of the headcuts in the study area exceeds several meters up to 100 m. The ongoing stripping of the valleys floor has severely reduced the agricultural potential of the region and the vegetative biomass available for pastoral herds and other grazing animals. This phenomenon causes ongoing degradation of soil and biomass, leading to the increasing desertification of the region. OSL dating of alluvial units, as well as the position of archeological sites relative to the gullies, indicates that gully incisions initiated during the Early Holocene. It is concluded that desertification, caused by gully incision and headcut migration, is an ongoing process, which has been active in the Negev Highlands for the last few millennia. The loess sediments, deposited during the late Pleistocene within the drainage basins, are being eroded and removed during the Holocene. This process is related to the long-term re-adjacent of the geomorphologic system to the Holocene climate. Similar processes of gully incision and ongoing desertification are active in wide regions of the Middle East, as well as in other semiarid and arid regions worldwide, such as southern Africa, central Asia and northern China.

20-16 BTH 89 Starkel, Leszek**COINCIDENCE OF CLIMATIC AND ANTHROPOGENIC FACTORS ACCELERATING THE SOIL EROSION AND FLUVIAL ACTIVITY**

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The role of climatic factor in the rate of denudation and deposition is discussed in the literature since long time. Generally it prevails the opinion that deforestation, soil cultivation and overgrazing accelerate the soil erosion by 2-4 orders, what documented in dozens of profiles of lake, proluvial and alluvial sediments. But in Holocene sequences of Central Europe we reconstruct much higher frequency of various kinds of heavy rainfalls, reflected not only in higher rate of deposition, but also in glacial advances and debrisflow activity in high mountains, landslide activity in flysch mountains, rise of lake water level, calcareous tuffa precipitation in limestone plateaus and finally in avulsions of river channel and their tendency to braiding. These phases were dated at 8.5 -8.0, 6.5-6.0, 5.4-4.9, 4.5-4.1, 3.3-3.0, 2.8-2.7, 2.2-1.8 kyr 14C BP and V-VI c.AD, Xlc.AD and Little Ice Age. Several phases of increased human activity coincide with above presented, the others not. The transition Atlantic-Subboreal is expressed by high soil erosion due to activity of late Neolithic farmers, replaced by shepherds. The Bronze age soil erosion has no expression in the humidity increase. On the contrary humid Roman phase of extensive agriculture is expressed in aggradation going downstream upto lower course of the Vistula river. The abundance of farming causes that 5-6 th century humid phase is not visible in accelerated erosion. Opposite picture we get in 11-th century and especially during the Little Ice Age, when the extensive agriculture is dominating.

20-17 BTH 90 HiraKawa, Kazuomi

DRASTIC CHANGE OF FLUVIAL ENVIRONMENT IN RESPONSE TO FOREST CLEARANCE SINCE LAST 100 YEARS IN THE TOKACHI PLAIN, NORTHERN JAPAN

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Hokkaido, the northernmost island of Japan is well known as the region where deforestation and agricultural land use had drastically progressed only since last ca. 100 years. Therefore this change must have influence fluvial processes. On the basis of the sediments facies, chronostratigraphy using Cs137, marker tephra, tree ring and buried can with age, monitoring of present flooding as well as some documents such as settlement (deforestation) history, change of cultivation method, topographic maps of different ages, weather data etc. we have so far following remarks. 1. Topographic maps 1: 50,000 issued in 1920, 1950, 1975 and 1995 are the good documents showing the change of land use and the timing from the natural forest to agricultural land. 2. Fluvial sediments associated with the forest clearance and cultivation are significantly coarser, predominantly sand size, than those of pre-settlement. 3. The timing of grain size change of sediments has clearly coincided with the deforestation in each drainage basin. This fact implies that the fluvial processes respond rapidly to the human environmental disturbance, particularly to the deforestation. 4. The 137Cs analysis clearly shows the horizon of sedimentation in 1963. 5. A buried can found in sediments means that the sedimentation rate has been accelerated particularly during the last several years following 1963. 6. The main factors contributing to this acceleration should be the widespread use of tractors beginning in 1960s and the construction works of river channel since 1970s. 7. Monitoring of river water level and rainfall from 2000 to 2002 recorded the over bank flooding 4 times, when the total amount of rainfall attained to ca. 100 mm or more. 8. Suspension load during the over bank flooding contains the characteristic coarse particles, which is also composed of over bank sediments since the beginning of forest clearance and agricultural land use. 9. We will refer to these coarse sediments as the PWA (Post Wajin (Japanese) Alluvium).

20-18 BTH 91 Klimek, Kazimierz

SEDIMENTARY RECORD OF PREHISTORIC AND HISTORIC HUMAN IMPACT, SUB-SEDIMENTIC LOESS PLATEAU, POLAND

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Located within the temperate climatic zone of Central Europe, the northern foreland of the Sudetes is covered by Quaternary deposits related to the Scandinavian glaciations which are in turn covered by loess several meters thick deposited during the last (Wurm/Vistulian) Pleistocene cool period. Rivers flowing northward from the Sudetes often cause large floods, the loess plateau receive up to 700 mm annual precipitation, and the local stream pattern is dense. The first farmers, migrating northward from the Danube Basin, crossed the line of Sudetes-Carpathians about 7000 years ago and settled on the loess Glubczyce Plateau. The farming and breeding tribes of the Early Bronze Age created the compact settlement structure of the Lusitan culture in this area about 1600-1300 years BC, leading to extensive deforestation of the populated areas. The first forest clearance began at this time. Following depopulation of the settled area in the Migration period, a new stage of agricultural colonization started in the region between the 8th and 10th centuries AD. Colluvial deposits found in the small dry valleys and alluvial fan deposits at the mouth of these valleys are sediments dating back to the periods in question. Fine grained overbank deposits infilling palaeomeanders in the vicinity of present-day channels indicate that the fossilization of organic material that filled these palaeochannels started in Early Medieval times, due to more frequent flood waves and an increased rate of overbank sedimentation. Analysis of heavy metal concentration indicates that these alluvia derived by transfer of sediments from the deforested loess Plateau.

20-19 BTH 92 Lajczak, Adam

MAN'S IMPACTED CHANGES OF THE SEDIMENTATION COURSE OF THE SUSPENDED MATERIAL TRANSPORTED IN THE VISTULA RIVER BASIN, POLAND, IN THE 20TH CENTURY

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Abrupt changes in intensity of erosion, transport and sedimentation of deposits are one of the effects of increasing human impact on river basins. The model of such changes described by numerous authors usually consists of two phases: abrupt increase of intensity of those processes and further decrease of the their tempo, often reaching the minimum value. Various regulation works and their geomorphological and hydrological effects have been described on the basis of the Vistula, the largest river in Poland. On that background, quantitative changes in amounts of transported suspended material in the river and its main tributaries in consecutive years after 1945 have been described. The "input-output" method has been used to estimate the amount of accumulation of the material within the inter-embankment zone of the river in the consecutive years since 1945. The results have been compared with the tempo of sediment thickness increasing outside the river course in the 20th century, which estimation has been based on repeated leveling taken by the State Hydrological Survey in successive gauging stations on the river across the inter-embankment zone, and the tempo of decrease of the volume of dam reservoirs. Calculated equations of regression describe the tempo of accumulation of sediments between the embankments of the Vistula River and in large dam reservoirs. In the inter-embankment zone of the Vistula River the rate of suspended material sedimentation has been decreasing since about 1930. While, in dam reservoirs, depending of their depth, the amount and the course of accumulation of suspended material have varied. The deep reservoirs have played the role of accumulators of sediments, while the shallow ones have temporarily played the role of exporters of sediments. Increasing role of deep reservoirs in permanent accumulation of the suspended material in the Vistula River basin has been proved, however, the main accumulator is still the area between the embankments, especially in the upper, piedmont course of the river.

20-20 BTH 93 Parker, Adrian G.

DEVELOPMENT OF THE MIDDLE THAMES LANDSCAPE AT DORNEY, BUCKS, UK DURING THE LATE HOLOCENE: HUMAN - ENVIRONMENT INTERACTIONS

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Large scale excavations at Dorney, Bucks, UK, has provided the opportunity to investigate a block of floodplain of the middle Thames valley approximately 0.75 km wide running for about 2.0 km alongside the present channel of the Thames. It comprised an area of Shepperton (floodplain) gravel dissected by palaeochannels filled with fine alluvial sediments and low-lying areas of alluvial clay.

High-resolution (decadal) palaeobotanical and sedimentological analyses from a late Holocene palaeochannel has enabled detailed reconstruction of the landscape spanning from ca. 2850 C14 yr. BP (Late Bronze Age), through the Iron Age, Roman, Saxon Periods and into the Medieval period (ca. 450 C14 yr BP). The application of mineral magnetic analyses coupled with the use of simultaneous R and Q mode factor analysis help to underpin phases of active channel flow, phases of channel 'ponding', and alluviation. These phases developed in response to human activity and land use within the region resulting from deforestation, changes from pastoral to arable practice, burning and the associated destabilisation and inwash of soils into the channel.

As series of wooden bridges and timber structures were constructed across this channel between the middle Bronze Age and Late Iron Age which influenced local sedimentation patterns, fluvial energy and competency within the channel. A number of erosive events coupled with in washing due to clearance of the last vestiges of woodland for agriculture into an active channel were identified. Evidence for erosive inputs of soil are provided by peaks in C:N ratio, increased grain size, and the high concentration of ferrimagnetic material (magnetite, associated with burning).

During the Roman period, flow along the Thames channel ceased forming a pond-like feature in which peaty silts rapidly accumulated. The phase of ponding was punctuated by renewed channel activity in which inorganic carbonate sediments rich in ferrimagnetic minerals was deposited. This coincides with a major peak in cereal production and related catchment disturbance of soils due to ploughing with associated run off and in wash of soils associated with probable flooding. This view is supported by the macrofossil remains of spelt wheat and the presence of corn cockle a weed of cereal fields introduced during Roman times.

20-21 BTH 94 Schuett, Brigitta

MODERN WATER LEVEL CHANGES OF LAKE ABAYA, SOUTHERN ETHIOPIA

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Lake Abaya is a graben fill in the southern section of the Main Ethiopian Rift Valley. To the south a sill covered by swampy forestland of approx. 1 km width separates Lake Abaya from neighbouring Lake Chamo. Altogether, drainage of Lake Abaya - Lake Chamo system covers a watershed of approx. 18,600 km² while lake areas total c. 1,550 km². Lake level of Lake Abaya is measured since 1970. During that period lake level was subject to repeated changes. But at least, water levels of Lake Abaya since the middle of 1980ties continuously increased. Climatic conditions during that time also repeatedly changed, but, resuming results of climate data time series analysis, climatic conditions as the only factor influencing lake level changes have to be excluded - although they are significant. Additionally, analysing Lake Abaya's lake level changes it has to be considered that latest since the 1970ties dramatic population growth, changes in land-ownership, clearing of forests and bush-land as well as changes in cultivation manners caused dramatically increasing sediment yield of the Lake Abaya tributaries, thus, influencing basin bathymetry and volume. Consequently, lake level changes of Lake Abaya are controlled reciprocally by : climatic oscillations influencing regional water balance and human impact causing increase of soil erosion rates and, coinciding, increase of the tributary's sediment yield and, thus, causing changes in basin volume. Because of its shallow depth (max. depth of 26 m) lake level of Lake Abaya reacts quite sensitive to changes of water and sediment input and, thus, is an ideal subject-matter to analyse complex pattern of climatic and human impacts on lake level changes. Nevertheless, as Lake Abaya is located in the Main Ethiopian Rift Valley also neo-tectonics at the southern sill influencing outflow to Lake Chamo have to be kept in mind. Investigating relief of sub-aqueous areas of accumulation and character of lacustrine and fluvio-lacustrine sediments, the inter-fingering of climatic and man's impact is pointed out. In the study presented results are shown exemplarily for the northern lake area where sediments originating from the Bilate River have the predominating influence on composition of lacustrine sediments.

20-22 BTH 95 Klawon, Jeanne E.

GEOMORPHIC RESPONSE OF THE UPPER GILA RIVER, ARIZONA AND NEW MEXICO TO LEVEES, DIVERSION DAMS, AND FLOODS

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Over the past century, the majority of alluvial reaches along the upper Gila River in Arizona and New Mexico have been leveed in an attempt to protect adjacent property from flood damage. In addition, the demand for irrigation has prompted the construction of diversion dams in these alluvial reaches to divert water for agriculture. Detailed investigation of historical channel change along the upper Gila River reveals that many of these channel modifications are catalysts for major channel change and can result in catastrophic property loss rather than safeguarding valuable farmland. In fact, there is a clear relationship along the upper Gila River between the scale of channel modification and property loss.

To quantify channel changes, channel widths were measured every kilometer for approximately 160 km from Safford Valley, Arizona through Cliff-Gila Valley, New Mexico for eight decades. An overall pattern of channel narrowing and widening coincides with periods of few large floods and periods of multiple large floods, respectively. In addition, reaches along the upper Gila River with greater channel modifications have experienced more variation in channel width than reaches with fewer modifications. Many channel changes in recent decades are unprecedented in previous historical aerial photography. These changes are consistently associated with artificial channel constrict-

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tions, such as levees, bank protection, and bridges, that have been built and rebuilt following large floods and that have accelerated natural channel narrowing during periods of few large floods.

Examples of geomorphic responses due to channel modifications along the upper Gila River include lateral erosion upstream of levees and diversion dams, redirection of flow over diversion dams into opposite banks, breaching of levees during floods and resultant erosion behind levees, channel widening downstream of levees, aggradation in leveed reaches, and lateral migration associated with straightened tributary channels.

20-23 BTH 96 Wenclawiak, Bernd W

DETERMINATION OF HEAVY METALS AND PERSISTENT ORGANIC POLLUTANTS IN SEDIMENT CORES FROM SOUTH ETHIOPIA

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The determination of heavy metals and persistent organic pollutants present in lacustrine sediments is of interdisciplinary interest, supplementing the information on environmental history of a lake's drainage basin derived from mineralogical, geochemical and paleontological proxy-data. The distribution of the elements in lacustrine sediments can be used for the determination of the relative atomic variation to determine areas of higher contamination and give information on industrial and civilizational influences on the environment. Sources of environmental contamination can still be identified after a long period of time. Additionally to these purposes, the distribution of contaminants in lacustrine sediments can be used to determine the age of the respective sediment layer. A special aim of the case study shown the use of persistent organic pollutants e.g. DDT and its derivatives for age determination of most recent sediment layers (less than 50 years). The analysis of lacustrine sediments is also a challenge for scientists in chemical respect, because analytical methods well suited for the analysis of lacustrine sediments derived from sediment cores have to be designed. Thus, advanced sample preparation methods for the analysis of very different chemical pollutants, like lead, zinc, DDT, Lindane, etc. have to deal with low amounts of sample, highly contaminated sample matrices and a very high number of samples. They have to be sensitive, reliable and fast. Automation of measurements should be used when possible. In the case study shown methods well suited for all these needs were developed and applied to lacustrine sediments derived from plumb line cores from Lake Abaya (South Ethiopia). Using these high-resolution data on organic and inorganic pollutants it is possible to identify trends in the depth distribution of chemical pollutants in the lacustrine sediments extracted across the lake area (80*20 km). Consequently, pollutants allow a kind of chemical fingerprinting that allows chronological classification of lacustrine deposits and, thus, to correlate sediment sequences also beyond large distances. Next to this, from the analysis especially of organic pollutants and their derivatives data on the age of the deposits can be derived, focusing the period of the past 50 years, which, in general, comprises many uncertainties in dating.

SESSION NO. 21, 1:30 PM

Friday, July 25, 2003

S28. Late Quaternary Ecosystem Dynamics and Carbon Cycling in the Tropics (Posters)

Reno Hilton Resort and Conference Center, Pavilion

21-1 BTH 97 Ettwein, Virginia J.

VEGETATION DYNAMICS, ARIDITY, AND FIRE HISTORY WITHIN THE AMAZON BASIN SINCE THE LAST GLACIAL MAXIMUM

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The Pleistocene tropical rainforest refuge hypothesis, which attempts to explain the immense diversity and species endemism of Amazonia, is intimately connected to the concept of glacial aridity within the Amazon Basin. However both of these are topics of much debate, mainly due to the paucity of reliable, uninterrupted, regionally-representative proxy records back through the last glacial maximum (LGM). Reconstructions are often highly-localised and based on qualitative indicators of change. However material collected from the Amazon Fan allows us to examine an average signal of the whole of the Amazon Basin within a single sedimentary sequence.

Here, we present data collected from ODP Site 942 and reveal that the Amazon Basin was forested yet relatively dry during the last glacial stage. Analysis of carbon isotopes on terrestrial biomarkers reveal that there has been relatively little shift in the C3:C4 ratio of the vegetation over the last 40 ka. Quantitative reconstructions of effective moisture based upon oxygen isotope analysis of planktonic foraminifera, suggest a significant reduction in the Amazon River outflow during both the LGM and last glacial-interglacial transition. We provide further evidence for glacial aridity through a quantified reconstruction of the fire history of the Amazon Basin, where fire-specific biomarkers are of coincident increased abundance throughout the more arid periods.

We thereby refute the suggestion of encroaching savannah vegetation during glacial times, yet support the concept of a drier, cooler glacial Amazon Basin.

21-2 BTH 98 Mayle, Francis Edward

A RE-ASSESSMENT OF THE 'PLEISTOCENE DRY FOREST ARC' HYPOTHESIS: PRELIMINARY EVIDENCE FROM THE BOLIVIAN CHIQUITANO DRY FOREST

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The Chiquitano Dry Forest in eastern Bolivia constitutes the largest remaining intact block of seasonal dry forest in the world, but is critically endangered, experiencing among the highest rates of deforestation on Earth. Understanding the origin and development of these forests over sufficient-

ly long, millennial-scale time series is an important pre-requisite to predicting likely responses to future climate change and habitat degradation.

The aim of our research is to test the hypothesis that the Chiquitano Dry Forest constitutes an ancient disjunct relic or refugium of a formerly far more extensive forest formation at the last glacial maximum (LGM), termed the 'Pleistocene Dry Forest Arc' (Prado & Gibbs, 1993). Our approach is to produce palaeovegetation reconstructions from lake sediment cores constraining the current ecotonal boundaries of this ecosystem.

Our preliminary 60,000 yr palaeovegetation record from Laguna La Gaiba (17°47'S, 57°43'W) suggests that seasonally dry forests may have existed in easternmost Chiquitania since the LGM (consistent with the hypothesis). By contrast, the more detailed 50,000 yr pollen record from Laguna Chaplin (14°28'S, 61°04'W), located just beyond the northern ecotone, suggests that these forests were no more widespread at the LGM than today, raising the possibility that the 'Pleistocene Dry Forest Arc' hypothesis is false. Pollen data from both sites show that the key dry forest indicator taxon (*Anadenanthera colubrina*), which is today common throughout Chiquitania, is a relatively recent arrival, first appearing only 8,000 yr BP (in contrast to inferences based on biogeographic studies by Prado & Gibbs, 1993). Even if dry forests have existed in parts of eastern Bolivia since the LGM, they should not be considered as ancient ice-age relics or refugia, since they appear to be highly dynamic ecosystems which have undergone considerable species turnover and re-assortment over this period.

References: Prado, D.E., & Gibbs, P.E. 1993. Patterns of species distributions in the dry seasonal forests of South America. *Annals of the Missouri Botanical Garden* 80, 902-927.

21-3 BTH 99 Puyasena, Surangi W.

HOLOCENE CLIMATE AND VEGETATION RESPONSE: INSIGHTS INTO NEOTROPICAL FOREST AUTECOLOGIES

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Understanding the response of Neotropical vegetation to environmental variability is integral to understanding how tropical biomes will react to ongoing climate changes. The last 50,000 years provide a natural ecophysiological experiment for studying plant population responses, with global and regional fluctuations in temperature, precipitation, and carbon dioxide. The response patterns of tropical vegetation reflect the adaptive potential of these taxa in the face of climate change, past and present. This is a preliminary investigation of Neotropical Holocene vegetation response to climatic variability using a multivariate analytical approach. This statistical look at vegetation dynamics uses over 80 published South American pollen records and correlates patterns of taxonomic association with trends in available independent climate proxy data. The results potentially highlight the degree of susceptibility of a number of tropical genera and families to water, temperature, and carbon dioxide stress. A parallel analysis of 154 South and Meso-American forest transects provides generalized insights on the modern distribution of Neotropical families and genera and the environmental conditions that may govern these distributions.

21-4 BTH 100 Mora, German

ISOTOPIC EVIDENCE FOR THE EXPANSION OF C4 PLANTS IN THE TROPICAL ANDES DURING GLACIAL INTERVALS

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Pollen records indicate the episodic expansion of grasslands in alpine tropical regions of Hawaii, Africa, and Central and South America throughout the Quaternary. Although C4 plants make up less than 5% of the biomass of modern alpine tropical grasslands, stable-carbon isotope data suggest that C4 plants were an important component of past grasslands. The isotope data reveal, in particular, the widespread presence of abundant C4 grasses in tropical ecosystems during the last glacial period. The increased abundance of C4 plants during the last glaciation relative to the present time points to a common mechanism responsible for a global expansion of C4 grasses. In this study, carbon isotope data of soil profiles and lake sediments from the Colombian Andes are employed to evaluate the possible mechanisms responsible for the glacial expansion of C4 plants in the tropical Andes.

Isotopic analysis of lacustrine organic matter reveals the abundant presence of C4 grasses in the Bogota Basin of the Colombian Andes during the last glaciation. Confirming this conclusion, soil horizons developed in the vicinity of the lake during the same time interval exhibit organic matter with high stable-carbon isotope values indicative of a C4-dominated ecosystem. In contrast, isotope data of soil horizons developed during the same time interval, but located above 3,000 m in altitude show no evidence of C4 grasses. In agreement with this finding, outcomes from the Biome-3 model indicate that above this altitude, low temperatures (<30C) favored the development of C3-dominated grasslands over C4-dominated ecosystems during glacial intervals. Model outputs suggest that the expansion of C4 grasses in the northern Andes could result from lower concentrations of atmospheric carbon dioxide prevailing during glacial intervals. Model outputs also suggest that a 50% decrease in rainfall could also produce a C4-dominated grassland ecosystem in the tropical Andes.

Our combined isotopic and modeling results indicate the sensitivity of alpine tropical regions to climate change. In particular, these results suggest that lower concentrations of carbon dioxide and/or lower precipitation rates can promote the expansion of C4 plants in tropical regions even under cooler conditions characteristic of glacial intervals.

21-5 BTH 101 Wang, Xianfeng

MILLENNIAL-SCALE CHANGES IN PALEOPLUVIAL PHASES INFERRED FROM SPELEOTHEM DEPOSITS IN NORTHEASTERN BRAZIL

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Records of millennial-scale climate oscillations from the southern tropics exist but are still sparse. More data are needed to establish a satisfactory mechanism for these variations. Speleothems of arid and semiarid regions may cease to grow during dry intervals and therefore record only periods of relatively wet climate. Constraints on these past pluvial periods are possible provided the ages of correlated speleothem growth can be accurately determined using U-series dating techniques. We have analyzed stalagmite subsamples from caves in semiarid northern Bahia state, northeastern Brazil. In this location, speleothem deposition does not presently occur, which delineates any dated subsample as a time when climate was wetter than today. Determined with mass spectrometric techniques, our preliminary analysis of sample ages shows that all speleothems grew during glacial periods. The pattern of speleothem growth indicates that pluvial phases in semiarid northeastern Brazil are coincident with higher insolation at 100S during the austral summer. In addition, short speleothem growth intervals show millennial-scale changes, which can be

correlated to periods of cold and dry stadials in Greenland ice core records, such as Heinrich events 1, 4 and 6. This correlation may indicate a climatic teleconnection between the tropics and northern high latitudes. Abruptly enhanced precipitation in this region is generally in accordance with dramatically weakened North Brazil Current observed in the continental margin sediment cores. This may be due to the southward shift of tropical Atlantic warm water associated with thermohaline circulation shutdown. In combination with increased insolation, this shift may cause positive anomalies on sea surface temperatures in the southwestern tropical Atlantic, change easterly trade wind strength and enhance zonal moisture transport to the continental areas. Synchronicity between these Brazilian pluvial phases and times of relatively weak East Asian summer monsoon (recorded in Chinese speleothems) further illustrates the significant contribution the tropics give to these abrupt climate variations, acting either as one of control sources or as an amplifier.

P.S. Financial support from the INQUA Executive Committee

21-6 BTH 102 Parker, Adrian G.

HOLOCENE GRASSLAND DYNAMICS IN NORTHERN ARABIA: POLLEN, CARBON ISOTOPE AND PHYTOLITH ANALYSES

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The Arabian Peninsula is a key area for understanding late Quaternary climate behaviour and ecosystem responses in the low latitude regions and is central to our understanding of rapid, high-amplitude shifts in climate driven by variations in the forcing of SW monsoonal rainfall. However, no high-resolution terrestrial records exist from the entire Arabian sub-continent, unlike for North Africa and Asia.

The northeastern end of the Rub' al Khali sand sea contains a number of interdune dry lake basins of Holocene age. At Awafi, Ras al-Khaimah, United Arab Emirates, multi-proxy analyses provide a detailed terrestrial record from the Arabian sub-continent which couples pollen and phytolith analyses with physical and chemical methods. This has permitted the study of ecosystem responses to rapid and gradual climatic changes forced by the fluctuations in the SW monsoon from the north-eastern Rub' al Khali over the late Quaternary period.

Phytoliths in particular are well preserved in dryland regions and unlike pollen studies permit the reconstruction of grassland dynamics by distinguishing the dominant grass sub-family. Phytolith indexes are used to distinguish between C3 Pooidae (cool temperate), C3-C4 Panicoideae (warm humid) and short C4 Chloridoideae (warm dry) grass types. In addition phytolith studies can permit tree cover density to be estimated.

The early Holocene record shows the development of savannah grassland with some woodland elements comprising *Acacia* and *Prosopis*. The grassland is characterised by unusually high levels of C3-Pooidae (cool temperate) types. This becomes replaced by C4 - Panicoideae grasses adapted to warm humid conditions along with scattered woody elements. An abrupt arid phase in the later Holocene sees the development of scattered short grassland elements of warm dry C4-Chloridoideae types. Comparisons between modern pollen and phytolith samples and those from the Holocene are also made. These data outline the ecosystem dynamics and carbon cycling in response to palaeomonsoon variability during the Holocene.

21-7 BTH 103 Page, Susan

A RECORD OF LATE PLEISTOCENE AND HOLOCENE CARBON ACCUMULATION AND CLIMATE CHANGE FROM AN EQUATORIAL PEAT BOG

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A 9.5 m peat core from a peat deposit in the central lowlands of Kalimantan (Indonesian Borneo) reveals that organic matter accumulation in the Sunda Shelf area started over 22,000 ¹⁴C yrs ago during the Last Glacial Maximum (LGM), representing the first evidence of ombrotrophic peat accumulation in the lowlands of Southeast Asia since the late Pleistocene. Most other lowland peat deposits in this region document the onset of carbon accumulation during the early or middle Holocene. The core shows that organic matter accumulation and thus carbon storage was not uniform and some intervals just shortly after the LGM may represent climatic changes that favoured degradation and thus carbon release to the atmosphere. Carbon storage was slow or negative during most of the late Pleistocene, but was rapid during the early Holocene. More than 3.5 m of peat accumulated between 11,000 and 7,500 ¹⁴C yrs BP, indicating that Southeast Asia possibly acted as a large sink of atmospheric CO₂ during that time. This may, in part, have contributed to the decrease in atmospheric CO₂ in the early Holocene to a minimal 260 parts per million by volume (p.p.m.v.) around 8,000 yr BP. The 20 p.p.m.v. rise over the last 8,000 yrs observed in the Taylor Dome ice core has been attributed to a decrease in terrestrial biomass and also coincides with a reduced organic carbon accumulation rate in the Kalimantan peat core as well as at other sites around Southeast Asia.

21-8 BTH 104 Robertson, I.

CARBON CYCLING REFLECTED IN RAINFOREST CARBON ISOTOPE VALUES

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The influence of the tropics in determining global climate has recently received renewed interest. In years of the El Niño-Southern Oscillation (ENSO), high pressure over the Indonesian region causes severe droughts on Sabah, Malaysia. Unfortunately climatic measurements are limited and therefore, proxy measures are required to reconstruct past drought events.

A radial segment was obtained from a recently fallen tree (*Shorea superba* Sym.) growing near to Lahad Datu, Sabah. Asymmetrical growth and indistinct rings resulting from an aseasonal climate prevented absolute dating. A time frame was established successfully by wiggle-matching high-precision radiocarbon dates to reject ambiguous values. Carbon isotope values were determined on the resulting 250-year time-series.

Carbon cycling is evident in the "juvenile effect" resulting from the assimilation of respired carbon dioxide and lower light levels below the canopy and, the "anthropogenic effect" caused by

increased industrial activity in the late-nineteenth century. This research represents one of the first attempts to date the primary rainforest and reconstruct past environmental conditions on Sabah.

SESSION NO. 22, 1:30 PM

Friday, July 25, 2003

T7. Determining the Extent of Glaciation in Areas of Limited Evidence (Posters) (Commission on Glaciation)

Reno Hilton Resort and Conference Center, Pavilion

22-1 BTH 106 Iturrizaga, Lasafam

THE TRANSGLACIAL DEBRIS LANDSCAPE IN HIGH ASIA: ARE TALUS CONES A KEY FORM OF THE PERIGLACIAL LANDSCAPE ASSEMBLAGE?

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In the classical view of geomorphology, talus cones are considered to be part of the periglacial landscape assemblage. Frost weathering processes were identified as one of the main processes of rock desintegration in high mountain areas. However, new research investigations in High Asia proved, that the genesis of a major part of debris accumulations is glacial-induced (ITURRIZAGA 1999, 2002). The extent of glaciation during the Last Glacial Maximum and the Late Glacial, with its glacial valley shaping and legacy of glacial sediments, may be considered the most important supraglacial geoparameter in the distribution of debris accumulations. The debris supply areas consist of high-lying, late glacial moraine deposits, which cover the valley flanks over 1000 m above the valley floor. They are transformed by post-sedimentary processes into transglacial debris accumulations. These transglacial landforms show often convergent forms to pure slope accumulations and can be easily mistaken for weathering landforms. Erratic and rounded boulders, the high clay content and their position-specific topographical relationship to the corresponding stages of glaciation indicate among other factors their glacial origin. The widespread distribution of talus cones and talus slopes ranging over a vertical distance of up to 4000 m already implies that these landscape forms do not represent climatic-controlled geomorphological features. Moreover, the transition from an "oversteepened ice-age debris accumulation landscape" to a Postglacial "adjustment debris accumulation landscape" results in various polygenetic collapse debris accumulations. The presentation will focus on representative case examples of semi-arid high mountain areas in the Hindukush and Karakorum, including especially the Shimshal, Hispar, Chogolungma, Braldu, Karambar, Chapursan and Mastuj valleys.

Iturrizaga, L. (1999): Typical debris accumulation forms and formations in High Asia. A glacial-history-based concept of the origin of Postglacial debris accumulation landscapes in subtropical high mountains with selected examples from the Hindu Kush, the Karakoram and the Himalayas. In: *GeoJournal* (M. Kuhle, ed.), Tibet and High Asia V, vol. 47, nos 1-2, 277-339.

Iturrizaga, L. (2002): Transglacial landforms in the Karakoram (Pakistan). In: *Karakoram in Transition: The Hunza Valley* (in press).

22-2 BTH 107 Meiners, Sigrd

CHANGES OF LANDSCAPE AFTER DEGLACIATION IN THE BATURA- AND THE HARAMOSH MUZTAGH, N.W. KARAKORAM

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The glaciation history of the Haramosh Valley and Bar Valley gives basic information about the landscape after deglaciation. The former glacial extend can be found using the system of glaciogeomorphic indicators and the snowline calculation. During postglacial period the tributary glaciers Kukuar-Baltar and Daintar in the Batura Muztagh and the Mani-Baska and Phuparash branches in the Rakaposhi/ Haramosh reached few kilometers downvalley and left the Great Lateral Moraine (GLM) type. The ice thickness of the postglacial tongue was even 300 m or more. Today the glacier surfaces have been sunk in deeply without retreating their ends of the subrecent stage. This is typical for glaciers in the subtropics with high average catchment areas of c. 6500 m² and a dense surface moraine cover. During the Late Glacial c. 700 – 800 m thick glaciers reached downvalley into the main the Indus and the Hunza river. After the Late Glacial and Postglacial period loose morainic sediments are widespread along the oversteep and polished trough profiles.

As a new aspect, investigation has been done to find out the rate of postglacial erosion of the solid rock and loose morainic material after deglaciation. In a first step recent erosional processes and forms have to be selected from the movements originated exclusively through destabilization of the slopes after the ice retreat. In a second step the volume of break offs in the solid rock and morainic material should be deduced. For this quantitative analysis we use a photogrammetric method which allows to extend a digital field model without having a fixed position of the camera used in the field. Because the postglacial stage is clearly separated from the Late Glacial extend chosen valleys are qualified for this subject. The space for geomorphological processes after deglaciation in between these periods has a vertical distance of 1200 m and a horizontal distance of 18 – 26 km.

22-3 BTH 108 Zhou, Shangzhe

THE TIMING OF THE OLDEST GLACIATIONS IN THE MOUNTAINS OF THE QINGHAI-TIBETAN PLATEAU

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The Qinghai-Tibetan Plateau consists of broad planation surfaces, basins, and mountain ranges. Research in the past several decades has argued that Quaternary glaciations developed only around the high mountains on the Plateau. In recent years we and other researchers have dated the oldest moraines in several mountain ranges using ESR. The relative age of these moraines was first confirmed based on their geomorphologic position and degree of weathering. The results show that the oldest glaciation, the Zhonglianggan Glaciation, in the Qilian Mountains, occurred at about 462.9ka BP (Zhou Shangzhe et al. 2002), and the high Wangfeng glaciation, the oldest one in the Tianshan Mountains, was dated at 477.1 and 459.7 ka BP (Zhou Shangzhe 2002). These ages imply that the earliest glaciation in Qilian and Tianshan Mountains probably occurred during MIS-12. The oldest glaciation in the Hengduan mountains, the Daocheng Glaciation, which is characterized by moraines with deeply weathered red soils having a SiO₂/Al₂O₃ ratio of about 2.42 and a SiO₂/R₂O₃ ratio of about 2.35, was dated 571.2ka BP. This was also reconfirmed by the ages 592.6ka BP (Zheng Benxing, 2000) and 500-600ka BP (Yao Xiaofeng, 2000) on the oldest

moraine at Yulong Shan in the southern Hengduan Mountains. The Wangkun glaciation, the oldest in the Kunlun Mountains, was dated 710ka BP by Cui Zhijiu (1995) using ESR. This was similar to the C136 age of bottom ice layer of a 309m ice core of Guliyu Ice Cap (Shi Yafeng, 1998).

These dates of the oldest moraines in several mountain ranges suggest that the glaciers began to develop during MIS-12 in Qilian and Tienshan Mountains, MIS -14 in Hengduan Mountains and perhaps MIS-16 in Kunlun Mountains. Cui Zhijiu and Li Jijun suggest that wide spread, rapid uplift of Qinghai-Tibetan Plateau (Kunlun-Huanghe Tectonic Movement) occurred between 1.1-0.6Ma BP. We suggest that uplift of mountain ranges on the Plateau during this time initiated widespread mountain glaciation, but not widespread ice sheets.

22-4 BTH 109 Spötl, Christoph

SPATIAL AND TEMPORAL CONSTRAINTS ON THE EXTENT OF GLACIATION IN THE EUROPEAN ALPS DURING ISOTOPE STAGE 3 TO 6 BY ²³⁰TH-DATED SPELEOTHEMS

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It well established since the pioneering work of Penck and Brückner (1901/09) that the European Alps have been repeatedly buried beneath an extensive ice sheet during the Pleistocene. Recent studies have shown convincingly that the maximum ice extent during the last glacial cycle (Würm), with valley glaciers advancing well beyond the geographical borders of the Alps, was only reached for a short period of time between c. 25 ka and 20 ka. While this glacial maximum is fairly well constrained by radiocarbon dates, little is known about older ice advances up to and possibly beyond the borders of the Alps, the main reasons being the scarcity of intramontane records and the difficulty of dating them. Carbonate deposits in subsurface cavities and fractures (speleothems) can provide critically needed anchor points for reconstructing past ice sheets, because they (i) require ice-free conditions at the surface and (ii) can be precisely dated using U-series techniques. Ongoing work in the Eastern Alps revealed a number of important observations from cave deposits which are clearly inconsistent with the widely held view of speleothem deposition during interglacial times only. A high-alpine cave site in the Central Alps of Austria (Spannagel Cave) was ice-free subsequent to 135 ± 1.5 ka, providing the first isotopically dated time constraints on the duration of the penultimate glaciation (Riss?) in this part of the Alps. Calcite speleothems present as fracture-lining flowstones show that the central Inn Valley near Innsbruck, which hosted one of the largest valley glaciers in the Eastern Alps during the Pleistocene, was ice-free at 73 ± 1 ka, i.e. during the final stage 5a. A similar age was obtained from a flowstone overlying fossiliferous clastic deposits in cave in the central part of the Northern Calcareous Alps and, more importantly, also in Spannagel Cave (72-78 ka). A fairly large number of dates clustering around 47-59 ka provide evidence of a generally mild climate and limited ice extent during the peak of stage 3 in the Alps, corroborating previously presented evidence of abundant cave bear populations in some of these caves presently situated above the timberline.

22-5 BTH 110 Winguth, Cornelia

EXTENT OF THE SCANDINAVIAN ICE SHEET DURING THE LAST GLACIAL-INTERGLACIAL CYCLE

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Several aspects of the Scandinavian Ice Sheet's extent during the last glacial-interglacial cycle are still unknown or controversial. The ice sheet's maximum lateral extent was probably time-transgressive and was reached earlier on the western margin (ca. 28-23 cal ka BP) than on the eastern side (after 17 cal ka BP). For the time of 21 ka BP, a key time in paleoclimate modeling, the position of the eastern ice margin is not known. The ice sheet's vertical extent in the mountainous areas of western Norway at the last glacial maximum has long been disputed due to divergent geologic evidence.

We use a two-dimensional, time-dependent, thermomechanically coupled ice flow model along two E-W transects running at ca. 62°N and at ca. 67-59°N, respectively, in order to address these questions. The model is mainly driven by temperature and precipitation. Estimates of LGM and later climate conditions in the area are taken from various GCM and regional climate model studies as well as paleoclimate reconstructions from proxy data. The GISP $\delta^{18}O$ record has been adapted to the local data in order to provide us with a continuous temperature record used as input for time-transient model runs. Known ice extents through time, especially on the western margin, are used for model validation. In addition, consolidation samples have been sampled along the northern flowline and these will provide minimum thickness estimates.

Our model results seem to support the "nunatak theory" for western Norway, suggesting that the ice sheet did not completely cover all mountain peaks. This is in good agreement with ice thickness values derived from cosmogenic dating in an area close to the southern transect and with a trimline that has been interpreted as the vertical Younger Dryas ice extent. According to first model results for the northern transect, the eastern margin was probably located ca. 300 km west from its maximum extent at 21 cal ka BP.

22-6 BTH 111 Bavec, Milos

NEW SIMPLE MATHEMATICAL MODEL TO HELP EVALUATING THE EXTENT OF THE LATE-QUATERNARY VALLEY GLACIER IN THE UPPER SOËA REGION (JULIAN ALPS, NW SLOVENIA, SE EUROPE)

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Late Quaternary valley glacier thickness was calculated along the axes of major valleys in the Upper Soča Valley by assuming a spatially-uniform basal shear stress falling within the range of 10 kPa \pm 50 kPa. Using this assumption, ice thickness $h(x)$ at a certain point along the glacier centerline (x) away from a glacier terminus (where $z=0$) can be calculated by integrating the basic equation for basal shear stress, (δb) Equation with assumed $z(x)$ and δb permits us to model an approximate ice surface geometry ($z(x) + h(x)$) for any arbitrarily selected position of glacier terminus along the valleys. A consecutive sequence of hypothetical glacier termini was then generated by going upstream from the furthest possible terminus in steps of 5 km all the way to the most remote cirques in the hinterland. Having constructed the hypothetical glacier surface profiles, we can then estimate the position of equilibrium line altitude (ELA) that would be needed to provide sufficient accumulation area for the modelled glaciers. ELAs for all modelled glaciers were calculated using two common criteria: the toe-to-head altitude ratio (THAR) and the Accumulation-Area Ratio (AAR). We used THARs of 0.4, 0.5 and 0.66 and AAR of 0.66 \pm 0.05 in our calculations. Once the ELAs for the hypothetical glaciers have been estimated, we can test the feasibility of the considered glacier termini positions by comparing the hypothetical ELAs to the likely lowest regional ELA reached during the glacial maximum. By comparing the THAR- and AAR-based calculations of ELA for the modelled glaciers to the selected minimum glacial ELA, we estimate the likely maximum extent of glaciers. Our modeling suggests that only relatively small glacier(s)

could have existed in the research area, corroborating our previous interpretation that investigated sediments were not deposited in an ice-marginal, but in a paraglacial environment.

22-7 BTH 112 Lewis, Claudia

MAXIMUM EXTENT OF GLACIERS AND CHRONOLOGY OF GLACIAL OUTWASH EVENTS IN THE SPANISH PYRENEES FROM REGIONALLY CORRELATED FLUVIAL TERRACES

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Records of glacial activity in the Pyrenees are preserved in the adjacent Ebro basin (Spain) as fluvial outwash terraces along the Cinca and Gallego Rivers. Ages for terraces derived from OSL dates on sand lenses overlying terrace straths agree with dates related to the maximum extent of late Pleistocene moraines. This correlation suggests terrace aggradation is related to deglaciation, supporting a link to glacial activity. Time-related trends in soil development confirm radiometric ages of alluvial terraces and glacial deposits obtained by radiocarbon, luminescence, and magnetostratigraphic methods. Terrace soils show strong trends related to pedogenic accumulation of calcium carbonate and Fe oxides, carbonate morphology, and total profile thickness.

We report the first chronology of a sequence of glacial outwash events in the central Pyrenees and adjacent Ebro Basin. We document glacial retreat at ~10 ka [5-16 ka (Younger Dryas)], ~36 ka [34-46 ka; marine isotope stage 3 (MIS 3)], ~53 ka [45-58 ka (MIS 3)], ~60 ka [53-84 ka (MIS 4)], and ~85 ka [75-113 ka (MIS 5b)] with the maximum extent of glaciers in the Pyrenees occurring at ~60 ka in the Cinca River valley and 85 ka in the Gallego River valley. Our terrace chronology is consistent with millennial-scale vegetation changes in the Mediterranean region, although uncertainties on our luminescence dates prevent exact matching of climatic events. The absence of fluvial terraces of ~14 kyr age, and the previously documented absence of large volumes of ice in the Pyrenees during the Last Glacial Maximum (LGM; 18-20 ka) suggest low precipitation in the Pyrenees at that time. Glacial advances and retreats in the Pyrenees Range appear linked to the position of the polar front in the North Atlantic Ocean. The position of the polar front during the YD and MIS 3, 4, and 5b was near its mean position, allowing warm subtropical water to circulate to the northwest of Iberia, resulting in transfer of heat and moisture to the atmosphere in the path of the prevailing westerlies that bring storm tracks across Iberia. The zonal position of the polar front at ~43°N during the LGM resulted in an extreme southerly position for the jet stream such that polar conditions prevailed in Iberia while Tropical Depressions delivered enough precipitation to the Sahara to allow expansion of lacustrine deposition.

22-8 BTH 113 Engels, Jennifer L.

NEW SIDESCAN SONAR EVIDENCE FOR THE WESTWARD FLOW OF ICE ACROSS THE ALASKA MARGIN, ARCTIC OCEAN

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Recent post-processing of 12kHz sidescan sonar data collected during the 1999 Science Ice Exercises (SCICEX) cruise shows strong evidence for the westward flow of ice across the Alaska Margin in the Arctic Ocean. Linear alignments of submarine glacial flutes measuring up to 10s of meters deep, >10km in length and arrayed in fields several kilometers across are prominent on the seafloor south of the continental shelf/slope break. The orientation of these flutes trends parallel to the Alaska Margin at 72°N between -158° and -142°. In some locations, it is possible to distinguish flutes with slightly differing orientations in the same geographic area, though no obvious overprinting relationships are visible. There are also several regions that have been deeply scoured by randomly oriented furrows typical of iceberg keel tracks. These iceberg-impacted areas tend to cluster in the shallowest water depths at the southern margin of the study area.

Though it is not possible to determine from the bi-directional linear flute features observed in the sidescan data the true paleo-flow direction of the ice that formed them, there are two previous studies that predict westward flow of ice in this area. Work by Polyak et al., [2001] on the proximal Chukchi Plateau and Northwind Ridge indicates ice flow directions trending northwest, while sites due landward of the Chukchi Plateau show ice scours with a northeast orientation. Polyak et al., [2001] hypothesize that ice streams flowed west from the Canadian Arctic Archipelago (CAA) across the Alaska Margin and then were deflected to the north by a northeast trending Chukchi Ice Sheet or a steep continental shelf. Grosswald and Hughes [1999] predict that ice streams from the CAA would be deflected west across the Alaska Margin by a central pan-Arctic ice mass. Our data from the Alaska Margin are consistent with both of these predictions and also match the inferred paleo-flow direction of the Beaufort Gyre. Additional data will be necessary to determine the true cause of westward ice flow in the region.

22-9 BTH 114 Barendregt, Rene W.

TIMING AND EXTENT OF PLIO-PLEISTOCENE GLACIATIONS IN NORTHWESTERN CANADA AND EAST-CENTRAL ALASKA

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Northwestern Canada and eastern Alaska are recognized as having one of the oldest known continental glacial records (late Pliocene) preserved in stratigraphic sections. These include the individual and complex records of Cordilleran, montane and continental glaciations. Regional scale glaciations (Cordilleran and continental) started in northwestern Canada and east-central Alaska between 2.9 and 2.6 million years ago. Overall, two Cordilleran glaciations and two plateau ice caps (Horton Ice Cap) developed in late Pliocene (Gauss and Matuyama Chron). During the early Pleistocene, three Cordilleran glaciations occurred, while one to five continental glaciations (Keewatin Ice Sheet and Horton Ice Cap) are inferred from the Banks Island stratigraphic record (late Matuyama Chron). Three mid-Pleistocene glaciations are recorded for the Cordilleran (including the Reid Glaciation) as well as three continental (Keewatin Ice Sheet and Horton Ice Cap) events (early Brunhes Chron). During the late Pleistocene (late Brunhes) a well defined, extensive continental ice sheet (Keewatin) covered western and northwestern Canada, while in the Yukon Cordillera and Yukon-Tanana Uplands, two glaciations (early-late Pleistocene Eagle Glaciation, and late Pleistocene McConnell Glaciation) are recognized. Successive Cordilleran glaciations diminished in size, while continental glaciations increased. The moisture source for the Cordilleran ice was largely the Pacific Ocean, however, for the Horton Ice Cap, an open Arctic Ocean may have been a significant moisture source. The role of tectonics in the development of the two major physiographic barriers (Wrangell/St Elias Mountains and the Continental Divide (Mackenzie/Selwyn Mountains) appears to have been an important controlling variable in mois-

ture distribution in northwest Canada and east-central Alaska. The timing and interplay of tectonic uplift versus erosion of these barriers has very much controlled the growth, thickness and decay of ice masses in the interior of Yukon and valleys east of the continental divide.

22-10 BTH 115 James, L. Allan

GLACIALLY ERODED LANDFORMS IN THE NORTHWESTERN SIERRA NEVADA, CALIFORNIA
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Geomorphic features can be reliable indicators of the extent, relative age, and processes of late Quaternary alpine glacial advances, particularly where no glacial maps are available. Unfortunately, glacial reconnaissance mapping based on erosive forms has fallen from favor, although in many alpine areas erosional landforms are the dominant expression of glaciation. This poster presents evidence of glacial erosion in the northwestern Sierra and interpretations of glacial processes inferred from them. Landforms identified in this region for the first time include large roches moutonnées, a 220-meter-high crag-and-tail, and bedrock benches interpreted as former ice-marginal channels. Along the northern divide to the Royal Gorge of the North Fork American River, erosional forms indicate substantial upland erosion. This is in contrast to more common evidence of severe erosion confined to valley bottoms which implies progressive Quaternary canyon deepening.

Geomorphic inquiry historically went through a transition from studies of form to studies of process and stratigraphy. In the late 19th and early 20th centuries, topographic form in the Sierra Nevada was often linked to glacial process by geomorphologists such as LeConte, Gilbert, and Matthes. This practice waned, however, as stratigraphic studies began to focus on questions of Quaternary climate change. Yet, in many alpine regions, stratigraphic evidence is sparse, incomplete, or absent, so maps are not available and interpretations of Quaternary glaciation must be extrapolated over large distances. Extrapolations are dangerous in alpine areas where glacial advances can vary greatly between valleys, no radiometric dates exist, and sedimentary deposits are rare, coarse-grained, and barren of carbon for dating. Cosmogenic radionuclide surface-exposure dating may provide stratigraphic controls in these environments but provide limited information about contemporary processes. Modern glacial-process studies have progressed considerably over the past 50 years and now often allow unambiguous inferences to be made from form. Glacially eroded landforms can provide important information in alpine regions that allows mapping and interpretations of glacial processes.

SESSION NO. 23, 1:30 PM

Friday, July 25, 2003

T9. Geologic Emissions of Methane from Lands and Seafloor: Mud Volcanoes and Observing System (Posters) (Commission on Carbon)

Reno Hilton Resort and Conference Center, Pavilion

23-1 BTH 129 Etiope, Giuseppe

A NEW ESTIMATE OF GLOBAL METHANE FLUX TO THE ATMOSPHERE FROM ONSHORE AND SHALLOW SUBMARINE MUD VOLCANOES

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Geological emission of radiocarbon-free methane has been recently recognised as an important component of global natural methane source, being on the same level as biological fluxes from the ocean and termites. Accordingly geological flux may be considered as a "missing source" of the atmospheric methane budget. However, the estimates of the strength of various geological sources need to be refined. Mud volcanoes (MV) on land and the seafloor, and submarine gas seepage are the largest geological methane source. Although flux data from direct measurements are still scarce, four preliminary independent estimates of global methane emission into the atmosphere from MVs have been recently published by Dimitrov (2002), Kopf (2002), Etiope and Klusman (2002) and Milkov et al. (2003). Only Etiope's and Milkov's estimates were based on actual direct flux measurements and/or detailed statistical elaboration. In this presentation we refine those estimates on the basis of 1) new experimental flux data (including diffuse microseepage around craters and vents), and 2) a classification of MV sizes (in terms of area, km²). The studied dataset includes ~120 mud volcanoes. The emission results to be conservatively between 5 and 9 Mt/y, that is 3-6 % of the natural methane sources officially considered in the atmospheric methane budget. The total geologic source, including MVs (this work), seepage from seafloor (Kvenvolden et al., 2001), microseepage in hydrocarbon-prone areas and geothermal sources (Etiope and Klusman, 2002), would amount to 35-45 Mt/y. We believe it is time to add this parameter in the IPCC official tables of atmospheric methane budget.

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23-2 BTH 130 Garcia, Maria Luisa

ENVIRONMENTAL AND GEOLOGIC APPLICATION OF SOLID STATE METHANE GAS SENSORS

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The atmospheric concentrations of one of the key greenhouse-gases, methane (CH₄), have been increasing at a variable rate for every year, with potential influence on global climate changes.

Although the amount of methane released into the atmosphere is relatively small compared to other trace gases like carbon dioxide, methane is more effective at trapping heat on Earth. Recently, geologic emissions of methane have been recognized as an important component of the global sources. The characterization of the spatial and temporal variability of these emissions is an important target for future environmental research; in this respect a series of technical specifications are demanded by the scientific community, including sensor portability, low detection limit, the need of analyzing small volumes of gas. Solid State Gas Sensors is one of the monitoring technique used increasingly for environmental measurements. Metal Oxide semiconductor (SnO₂, ZnO₂, etc...) is used to fabricate chemical sensors for several gases, in particular methane. The potential of this technique is based on the low conductivity of the material in clean air, which increases with the methane gas concentration in the air. The interaction mechanisms of CH₄ with the semiconductor are discussed for environmental applications using portable gas detectors. An important factor for high sensitivity and selectivity to methane is its manufacturing and structure and the most used growth technique is discussed in this work for future applications. Applicability for on-shore and off-shore geologic measurements is examined with the principal objective for assessment of induced changes in the atmosphere due to methane emission.

23-3 BTH 131 Yang, Tsanyao F.

GAS EXHALATION FROM MUD VOLCANOES IN SW TAIWAN

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Many mud volcanoes are distributed along the tectonic sutures in SW Taiwan. Most mud volcanoes are exhaling CH₄-dominated gases with low helium isotopic ratios (3He/4He < 0.2Ra, where Ra is the air ratio), which indicates a crustal source in origin. Nevertheless, bubbling gases from a mud-pool (ca. 100 m²) in Chung-lun (CL), which is situated in the Chu-ko (CK) active fault zone with a potential for re-activation in the future, show much higher helium isotopic ratios (3He/4He=5.2-6.6Ra), with CO₂-dominated compositions. This implies that there are multiple sources for gas exhalation in SW Taiwan.

A monitoring station was set up at the CL mud-pool and gases collected through the water replacement method using an up-side-down funnel. Gases collected were continuously transferred into the analyzing system. This setup enabled measurement of gas compositions and gas flow of bubbling gases from the mud-pool at intervals of less than two minutes. The major compositions of gases exhalation from this site were 80-85% of CO₂ and 8-12% of CH₄, respectively. Meanwhile, the gas flow ranges from 0.1 to 15 litre/min. The funnel covering about 1/4 bubbling gases of the mud-pool, hence, the amount of gases exhalation from the mud-pool can be estimated to be about 1.5 ton/year for CH₄ and 34 ton/year for CO₂, respectively. The exhalation flux of CH₄ will be 15000 t km⁻² y⁻¹, which is much higher than those from other mud volcanoes in the world.

23-4 BTH 132 Yang, T.F.

GEOCHEMICAL EVIDENCE FOR OFFSHORE GAS HYDRATES GENETICALLY RELATED TO ON-LAND MUD VOLCANOES IN SW TAIWAN

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Taiwan is located at the plate boundary between Eurasian plate and West Philippine plate. Mud volcanoes, which are believed to be the products of accretionary prism due to collision, are commonly found in on-land of SW Taiwan. According to available seismic data, many active mud volcanoes were also observed in offshore SW Taiwan. Meanwhile, many bottom simulating reflectors (BSR) can also be identified, which indicates potential submarine gas hydrate deposits may exist in this area. Since the diapiric structures can be continuously extended from offshore towards on-land in SW Taiwan, local geologists suggested that on-land mud volcanoes may be genetically related to offshore mud volcanoes and gas hydrate deposits.

For better understanding their relationship, fluid samples of representative mud volcanoes in SW Taiwan were collected for geochemical analyses. According to the data of chlorine concentrations and oxygen isotopes, some of on-land mud volcanoes exhibit compositions which fall in the mixing trend between published compositions of gas-hydrate waters and seawater. This indicates that on-land mud volcanoes are genetically related to offshore gas hydrate deposits. Furthermore, some of them exhibit higher δ¹⁸O value than the mixing line. It implies that these fluids may be derived from the deeper sources which have been experienced serious water-rock interaction during diagenesis processes.

23-5 BTH 133 Marinaro, Giuditta

GMM - A GAS MONITORING MODULE FOR SEABED METHANE LEAKAGE

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Methane monitoring in marine environments is an urgent task demanded by the scientific community in the framework of geohazard, biological and global change studies. In this respect a new seafloor lander module (GMM - Gas Monitoring Module) has been developed by the European Commission ASSEM project (Array of Sensors for long term Seabed Monitoring of Geohazards) for continuous and long-term measurements of methane concentration in seawater at the benthic boundary layer. The module is designed to host a series of sensors controlled and managed by a data acquisition and control system capable of performing first-level data quality checks. The prototype includes semi-conductor methane sensors and a CTD for temperature, salinity, pressure recording, as well as interfaces available for further sensors. The electronics can perform a series of tasks including: data acquisition from all scientific packages and status sensors, preparation and continuous update of a periodic (e.g. hourly) data message, ready to be transmitted via serial link on request, management of the sensors (switch on/off of individual sensors according to command from operator; event detection), reception and management of commands from external units (data request, system reconfiguration, restart, etc.), monitor internal status parameters and external power supply, back-up of data in internal memory. The methane sensor (METS by Capsum) is an improved version of a commercial product used for short-term deployment such as profiling. It uses a semi-conductor as sensing element, integrated in a small gas volume in the sensor-head. Protection against the outside water and pressure is given by a special membrane. The improved version for GMM addresses long-term operativity, increased operation depth and increased sensitivity. A series of tests showed the improved METS performance. GMM can be linked to submarine cables for real-time data transmission to onshore operators. The system is

suitable to monitor, for long periods, natural gas emission from seafloor or leakages from pipelines and boreholes.

23-6 BTH 134 Leifer, Ira

INTEGRATING BUBBLE FLUX SPECTRA AND DIRECT FLUX MEASUREMENTS OF MARINE HYDROCARBON SEEPAGE

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Marine hydrocarbon seep gas often escapes the seabed as bubbles that rise towards the sea surface. The fate of this gas (transport to the atmosphere or dissolution followed by bacterial oxidation or exchange across the air-sea interface) depends upon several factors, most significantly, seep depth. Numerical simulations show that for a given seep depth there is a strong sensitivity to bubble size. As a result, size-dependent bubble flux spectra are critical to predicting the fate of escaping gas. Currently, this data can be provided solely by bubble measurement systems (BMS); however, due to video's large data storage requirements, it is not amenable to long term deployment. Direct flux measurements by capture devices or turbine seep tents provide time data at reasonable data storage size.

To study the fate of marine seep gas, a BMS was developed and deployed to measure the size dependent bubble flux spectra from the Coal Oil Point (COP) Seep Field, in the Santa Barbara Channel, California. A detailed survey of seep bubbles at the seabed and sea surface was conducted at an active seep area, Shane Seep, in the seep field. For direct measurements, three turbine seep tents were deployed that measured gas flux by relating the turbine rotation rate to the flux. The rising bubbles and advected water drive the turbine. Also deployed was a direct capture flux buoy that allowed determination of spatial variability and flux rate estimation.

Besides bubble size, simulations show ambient conditions such as the upwelling flow and dissolved gas concentrations are important to seep gas's fate. The local upwelling flow was measured by the BMS while dye studies measured water column values. Dissolved concentrations were obtained from water samples. SCUBA divers collected seabed and sea surface samples. Bubble gas samples were collected and analyzed for subsequent model validation.

Data from the approaches was synthesized and used to predict the fates of the seep gas (transport to the atmosphere versus dissolution in the water). Data was used to initialize and validate a numerical bubble model that predicted the gases' fates. Then, sensitivity studies were used to illustrate the importance of both flux spectra and long-term flux measurements to understanding marine seepage.

23-7 BTH 135 Huseynov, Dadash

PLIOCENE-QUATERNARY METHANE EMISSION FROM SOUTH CASPIAN MUD VOLCANOES

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South Caspian sedimentary basin is a unique area with thick Mesozoic-Cenozoic sediments (up to 30-32 km) characterized by an extremely high fluidgeneration potential. A great amount of active mud volcanoes and volume of their gas emissions prove the vast scale of fluidgeneration. From 187 onshore and 170 offshore mud volcanoes estimations annually erupt more than 109 cubic meters of gases consisting of CH₄ (79-98%), and small admixture of C₂H₆, C₃H₈, C₄H₁₀, C₅H₁₂, CO₂, N, H₂S, Ar, He. The large accumulations of gas hydrates confined to bottom sediments of the Caspian Sea mud volcanoes craters fields (interval 0-0.4m, sea depth 480m) and to volcanoes body at the depth 480-800 from the sea bottom. Here gas hydrates consist of CH₄ (58.7-87%), C₂H₆ (10.4-19.4%), C₃H₈ (1.8-15.8%), iC₄H₁₀ (0.1-2.5%), C₄H₁₀ (0.4-2.0%), C₅H₁₂ (0.00-0.68%). Resources of HC gases in hydrates saturated sediments up to depth 100 m are estimated in 0.2x10¹⁵m³-8x10¹⁵ cubic meters. According to the average rate of sedimentation in these parts of the Caspian Sea (2mm/year) the age of submarine (prebottom) gas hydrates is not older than 200 years. Amount of HC gases concentrated in them is 1011-1012 cubic meters. Caspian Sea, being inland closed basin is very sensitive to climatic and tectonic events expressed in sea level fluctuations. In regressive stages as a result of sea level fall and reducing of hydrostatic pressure the decomposition of gas hydrates and releasing of great volume of HC gases consist mainly of methane are observed. From the data of deep drilling, seismoacoustics, deep seismic mud volcanic activity in South Caspian basin started since Lower Miocene. The most intensity it reached at the border of Miocene and Pliocene and was associated with dramatic Caspian Sea level fall in Lower Pliocene up to 600 m, which led to isolation of Paleocaspian from Eastern Paratethis. Catastrophic reducing of Paleocaspian size with increasing scale of mud volcanic activity caused the oversaturation and intoxication of water by methane led to mass extinction mollusks, fishes and other group of sea inhabitants. In Upper Pliocene and Quaternary mud volcanism occurred under the conditions of semi-closed sea periodically connected with Pontian and Mediterranean basins. Those stages of Caspian Sea history are characterized by the revival of Caspian organic world.

SESSION NO. 24, 1:30 PM

Friday, July 25, 2003

T10. Glaciogeological and Geomorphological Evidence of Ancient Ice Streams and Outlet Glaciers (Posters) (*Commission on Glaciation*)

Reno Hilton Resort and Conference Center, Pavilion

24-1 BTH 116 Lian, Olav B.

SUBGLACIAL DYNAMICS OF THE LAST CORDILLERAN ICE SHEET NEAR ITS TRANSITION FROM THE COAST MOUNTAINS TO ADJACENT LOWLANDS, SOUTH-WESTERN BRITISH COLUMBIA

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During the Pleistocene the Canadian Cordillera were repeatedly covered by large ice sheets that had a profound effect on global sea level and climate. Although there has been considerable sedimentologic and stratigraphic work undertaken to understand the extent of the last Cordilleran Ice Sheet, and the timing of its advance and retreat, comparatively little work has been done to reconstruct subglacial conditions that can be used to understand the nature of glacier flow. Knowledge of this parameter is crucial to developing three-dimensional models of ice sheet geometry and behaviour.

One of the most informative regions of the last Cordilleran Ice Sheet was near its south-west margin, where ice from accumulation areas in the Coast Mountains drained into adjacent lowlands. Existing sedimentologic and glacial geologic evidence from the Fraser and Puget lowlands suggest that ice flow in these regions was enhanced by a soft (commonly wet and muddy) bed of un lithified sediment that provided little resistance to flow. This in turn suggests that ice in the lowlands was undergoing extending (rapid) flow, which would have resulted in relatively low ice surface profiles. In contrast, very little is known about the nature of ancient ice flow in the mountain valleys that open onto the lowlands. In this paper we present glacial geologic evidence from subglacial till in valleys in the Pacific Range of the Coast Mountains (immediately north of Vancouver) which suggests that ice flowing in the valleys was moving over a substrate (till) that was deforming mainly by brittle deformation (simple shear) and indicates effective transfer of shear stress from the ice to the substrate. This in turn suggests less extending flow, and that the mountain valleys acted as "bottlenecks" for ice draining accumulation areas in the back-ranges.

24-2 BTH 117 Lesemann, Jerome-Etienne

ASSESSING SUBSTRATE GENESIS AND MECHANISMS OF FAST ICE FLOW ALONG THE SOUTHERN MARGIN OF THE CORDILLERAN ICE SHEET, BRITISH COLUMBIA, CANADA
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Zones of fast ice flow in past ice sheets are often inferred from broad tracts of streamlined landforms (e.g. drumlins, mega-lineations). Such inferences assume that i) pervasive deformation of bed sediment (till) is mainly responsible for fast ice flow and, ii) bed deformation creates streamlined forms. Inferences of fast ice flow seldom include field evidence supporting these assumptions.

We evaluate the field evidence for fast ice flow around the Okanagan Valley, British Columbia, Canada. The Okanagan Valley is a 250 km-long, linear, North-South trending valley bounded by plateaus to the East and West. Along-valley ice streams have been proposed where plateau ice may have converged toward the valley. Field evidence in the valley fails to support this proposition as i) streamlined bedforms are few and tend to occur in bedrock and, ii) till is rare in the stratigraphic record. However, streamlined bedforms and till are abundant on the plateaus; hypothetically, these may record fast ice flow.

The plateau landsystem contains drumlins eroded in bedrock, diamicton, and diamicton interbedded with sand and gravel. Diamictons are poorly consolidated and contain mainly sand and gravel. Silt and clay are rare and are concentrated in laminations within the diamicton. Clast fabric and shape data suggest these are not primary deposits. The material is interpreted as a 'hybrid till' resulting from lodgement followed by melt-out and squeeze-flow into water-filled subglacial cavities and localized deformation and poreflow at sticky spots.

Drumlins exhibit crescentic scours, an echelon arrangement, and enhanced development over positive bedrock steps. Sediment and bedrock drumlins develop in association with tunnel channels crossing topographic highs. Sediment characteristics, drumlin morphology and form continuity in the landscape are consistent with meltwater erosion in a broad underburst.

The plateau landsystem highlights the importance of subglacial water storage and release in till genesis and the formation of streamlined bedforms. This landsystem may record a type of fast ice flow controlled by changes in basal water pressure rather than by pervasive deformation of ice sheet substrate.

24-3 BTH 118 Stokes, Chris R.

ICE STREAM INITIATION AND SHUT-DOWN: EVIDENCE FROM THE DUBAWNT LAKE PALAEO-ICE STREAM, NW CANADIAN SHIELD

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Ascertaining the triggers for ice streaming and the controls on their location is essential in order to understand the behaviour of former ice sheets and their interactions with the ocean-climate system. The prevailing paradigm for the Laurentide Ice Sheet is that ice streams predominantly occurred in topographic troughs that caused localised flow acceleration, or over areas of soft fine-grained sediment that facilitated rapid ice flow through subglacial till deformation or basal sliding. The location of the Dubawnt Lake ice stream in Keewatin on the low relief, relatively hard bedrock of the north-western Canadian Shield conflicts with this paradigm and raises a number of questions regarding its activity: why did the ice stream initiate in this location, and what caused it to switch on (and off)? We use a combination of digital satellite imagery (Landsat ETM+ and ASTER) and Digital Elevation Models (DEMs) to explore the idea that the development of a glacial lake was an important trigger for this ice stream. Using reconstructed ice flow patterns and DEMs the location and depth of ice-dammed lakes are predicted at a range of margin positions.

Calving into a deep (>100 m) lake in the Thelon Basin is likely to have been influential in triggering the ice stream by inducing high calving rates, drawing down ice and propagating fast ice flow. After ice stream initiation the margin is inferred to have advanced into the lake and through the lake basin. Identification of lake shorelines superimposed on the ice stream flow pattern is clear evidence that a lake formed in a similar location post-ice stream activity. Transverse ridges (ribbed moraines) are also superimposed on the ice stream bedforms (drumlins and mega scale glacial lineations) predominantly in the upstream (onset) zone. We argue that their occurrence is a manifestation of ice stream shut-down and speculate that sticking and slipping as basal coupling increased and/or localised basal freeze-on, may have formed them. It is concluded that glacial lakes are likely to have been an important control on ice sheet dynamics and the deglaciation of the Laurentide Ice Sheet. This work also highlights the potential of detailed examination of palaeo-ice stream beds to test theories of ice stream shut-down (freeze-on, water piracy, etc.).

24-4 BTH 119 Stokes, Chris R.

ICE STREAM INTERACTIONS AT THE NORTH-WESTERN MARGIN OF THE LAURENTIDE ICE SHEET, VICTORIA ISLAND AND PRINCE OF WALES ISLAND, ARCTIC CANADA
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Several palaeo-ice streams have been hypothesised on Victoria Island and Prince of Wales Island in the Canadian Arctic at the north-western margin of the Laurentide Ice Sheet. However, complex cross-cutting flow patterns have so far prevented an overall synthesis of the interactions between individual ice streams and a plausible reconstruction of the glacial history of the region. It is important to resolve the location and activity of these ice streams, firstly to reconcile them with (often conflicting) ice sheet models and secondly, to examine their possible role in known iceberg and meltwater events in the Arctic Ocean. In this paper we present an overview of results from mapping a variety of glacial landforms (e.g. drumlins, mega-scale glacial lineations, ribbed moraine, eskers, and marginal moraines) on Victoria Island and Prince of Wales Island using digital satellite imagery and aerial photographs in combination with Digital Elevation Models. Ice stream tracks are identified on the basis of their unique characteristics: convergent flow patterns with extremely abrupt lateral margins (< 500 m) and comprising subglacial bedforms (drumlins and mega-scale glacial lineations) with high elongation ratios. It is demonstrated that ice streams preferentially developed in subglacial troughs often bordered by higher elevations which appear generally devoid of ice flow indicators, although this is not always the case. It is apparent that ice stream activity did not conform to a simple pattern of flow orthogonal to the ice sheet margin and retreating time transgressively. Individual ice streams appear to intersect (capture?) each other at oblique angles. This attests to rapid changes in ice sheet configuration and suggests that ice stream activity switched on and off during deglaciation. It appears that warm-based ice streams may have drawn down ice, isolating cold-based patches at higher elevations. In other locations, the presence (and orientation) of eskers suggests that warm-based deglaciation took place at oblique angles to the ice stream flow patterns. The emerging picture is that of rapidly-flowing ice streams facilitating deglaciation and forcing abrupt changes in ice sheet configuration and basal thermal regime.

24-5 BTH 120 Evans, David J.A.

PALAEO-ICE STREAMS OF THE SOUTHWEST LAURENTIDE ICE SHEET
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Former ice streams of the SW Laurentide Ice Sheet have been identified using regional glacial geomorphology and sedimentology. During ice sheet recession from western Canada some ice streams appear to have terminated in surge lobes, as documented by the recognition of a surging glacier landsystem. During the LGM, the most prominent ice streams produced a 1,000km long swath of subglacial lineations from the Athabasca basin in the north to the Milk River Ridge in the south. Landforms within the ice stream trunk display high levels of spatial coherency suggesting that they represent the bed at an instant in time ('rubber stamped'), whereas at the margin, ice stream recession is recorded by large transverse ridge complexes (end moraines) in the Red Deer and Bow river drainage basins. The moraines comprise multiple ridge crests, often comparable in form to glaciectonic thrust ridges. A glaciectonic origin is supported by exposures through thrust and deformed stacks of Quaternary sediments and bedrock. Additionally, spectacular subglacial meltwater channels may have contributed large volumes of water for localized ice stream decoupling.

The lack of thick sediment sequences on the Milk River Ridge also appears to have dictated the nature of ice stream marginal deposition. Here, minor flutings fan out to numerous small push moraines, similar to the landform assemblages produced by contemporary actively receding temperate glacier snouts. Overridden thrust moraines are evident in the Pakowki basin in SE Alberta, confirming a spatial relationship between large scale thrusting and thick, pre-existing sediment sequences. Additionally, thick sequences of tills, glaciectonites and associated bedrock mega rafts crop-out on the down-ice sides of buried valley systems. Ice stream beds can contain palimpsests of their initial advance phase, and late stage streaming moulds and redistributes pre-existing depo-centres/moraines so that the occurrence and pattern of bed deformation and sliding is dictated by the localized "continuity" of subglacial materials.

24-6 BTH 121 Miller, Gifford

PALEO-ICE STREAMS REVEALED BY COSMOGENIC EXPOSURE DATING OF DIFFERENTIALLY-WEATHERED LANDSCAPES

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Recent results from the northeastern margin of the Laurentide Ice Sheet (LIS) suggest that fiords along northeastern Baffin Island contained ice streams during the Last Glacial Maximum (LGM). Differentially-weathered fiord landscapes across the Arctic have been interpreted differently in terms of glacial history. Highly-weathered inter-fiord uplands have been interpreted by some to indicate that they escaped LGM glaciation, and by others as having been covered during the LGM, but by non-erosive, cold-based ice. Erratics perched on highly-weathered uplands indicate that they have been covered by ice in the past.

We applied cosmogenic exposure dating to differentially-weathered landscapes in the Clyde Region, northeastern Baffin Island. Paired cosmogenic nuclide data (²⁶Al and ¹⁰Be) indicate that tors among weathered upland surfaces surrounding Clyde Inlet are at least 160 to 480 ka (n=5), whereas erratics perched on the tors range from 10 to 40 ka (n=23). The majority of the erratics fall between 10 and 20 ka (n=16), indicating that the uplands were covered by cold-based, non-erosive ice during the LGM. Cold-based ice on the uplands surrounding Clyde Inlet was almost certainly contemporaneous with warm-based glaciation of the fiord, suggesting that an ice stream

occupied the fiord during the LGM. Extrapolated to similar settings, these findings imply that the northeastern margin of the LIS, and possibly other Pleistocene ice-sheet margins, may have been dominated by ice streams.

24-8 BTH 123 Roberts, David H

BEDROCK SIGNATURES OF THE JAKOBHAVNS ISBRAE ICE STREAM, WEST GREENLAND: IMPLICATIONS FOR ICE STREAM AND ICE SHEET DYNAMICS

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Geomorphological evidence for palaeo-ice streams includes streamlined bedforms, lateral shear moraines, dispersal trains, drift lineations, pervasively deformed till or general landform assemblages. However, such drift features are absent in formerly glaciated areas where bedrock landforms and landscapes of areal scour dominate. In these areas other control mechanisms, particularly topography, influence ice stream initiation, location, and bedform signature. However, the identification and understanding of 'rigid bed' ice stream bedforms remains a poorly investigated area of glacial geomorphology.

One of the main reasons bedrock bedforms have not been used to map the flow-paths of palaeo-ice streams is because they can represent ice flow dynamics through a number of glacial cycles. In addition, local bedrock geology can exert strong controls over bedrock form, with joint plane orientation, joint frequency and joint dip all affecting the resultant landform. However, the presence of cross-cutting striations on a bedform, or the identification of double-plucked bedforms, can be used as evidence for changing flow direction. In addition, differences in bedform morphology (roche moutonnée or whaleback) can provide evidence of bed separation, which can be used to infer slow versus fast ice flow. Furthermore, bedform configuration (elongation, bed form density) can also be used to reconstruct ice flow velocity.

This study investigates the bedform ice stream signal of Jakobshavn Isbrae, the fastest flowing ice stream in West Greenland. Based on a combination of air photo interpretation and detailed field mapping, we i) characterise the bedform signal of the current ice stream margin, ii) compare and contrast the ice stream signature with bedforms formed beneath adjacent ice sheet areas and hence, iii) reconstruct the interplay between ice stream and ice sheet dynamics. Evidence of overtopping events and significant switches in ice flow direction and bed morphology in areas adjacent to the current ice stream are evident. These show that Jakobshavn Isbrae may have become partially unconfined during maximum growth phases, causing significant regional changes in ice sheet dynamics and ice discharge along the west coast of Greenland.

24-9 BTH 124 Boulton, Geoffrey

STREAMING FLOW IN THE LAST EUROPEAN ICE SHEET

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The locations of fast ice streams have been inferred within the area of the last European ice sheet from extensive and well-integrated sets of glacial lineations (often drumlins and mega-flutes) and protrusions of the contemporary ice margin marked by moraines or fanning of the flow lineations. Zones of streaming flow have been identified for the whole period of retreat of the ice sheet, a period of about 8-10,000 years. Some appear to have been sustained for the whole period of retreat, others appear to have been ephemeral, reflecting an imbalance between the accumulation flux and flow. In some cases, the length of time for which ephemeral fast streams were sustained can be estimated.

A high resolution, numerical ice sheet model has been used to simulate streaming flow in the European ice sheet. It permits model results to be compared with glacial geological and geophysical observations on the scale at which they are made, and yields velocity and shear stress estimates for the streams. In some cases there is a very close correspondence between model output and reconstructions based on geological data. The overall pattern of fast streaming permits aspects of glacial geology that had hitherto been highly problematic to be explained. However, it is clear in detail that the basal boundary that has been selected does not permit some aspects of geological and geophysical evidence to be explained, and requires coupling between basal melting/drainage and basal decollement. The extent to which sediment deformation has facilitated this decollement and streaming flow is discussed.

24-10 BTH 125 Heroy, David Carlson

GEOMORPHIC FEATURES ASSOCIATED WITH PALEO-ICE STREAMS ON THE WEST ANTARCTIC CONTINENTAL SHELF

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Detailed marine geophysical (seismic and multibeam) surveys were conducted on the West Antarctic continental shelf, from the Ross Sea to the Antarctic Peninsula, focusing on large glacial troughs where ice streams are believed to have been located during the last glacial maximum. Most of these troughs cut into crystalline bedrock on the inner shelf and overlying sedimentary strata on the outer shelf. Thus, the influence of bedrock geology on ice stream behavior is assessed. An offshore transition in geomorphic features from grooves and striations (crystalline bedrock) to highly attenuated drumlins (thin sediment cover) to mega-scale glacial lineations (thick sedimentary strata) typifies the troughs. These features indicate accelerating ice flow across the deformable sedimentary bed. Mega-scale glacial lineations are believed to indicate ice flowing over a deforming bed and are the most common bedform associated with a sedimentary bed. Recently acquired data from the Antarctic Peninsula provide superb examples of the subglacial meltwater plumbing system that supplied the water to these deforming beds.

24-11 BTH 126 Marks, Leszek

MAP OF WEICHSELIAN DIRECTIONAL ICE-FLOW FEATURES OF CENTRAL AND EASTERN EUROPE

MARKS, Leszek¹, GUOBYTE, Rimante², KALM, Volli³, PAVLOVSKAYA, Irina E. ⁴, RATTAS, Maris³, STEPHAN, Hans-Jürgen⁵, ZELÉS, Vitáljij⁶, GOGOREK, Waldemar¹, BIELECKI, Tomasz¹, and KOCZYŃA, Jacek¹, (1) Polish Geol Institute, Rakowiecka 4, Warsaw, 00-975, Poland, imar@pgi.waw.pl, (2) Geol Survey of Lithuania, Konarskio 35, Vilnius, 2600, Lithuania, (3) Institute of Geology, Univ of Tartu, Vanemuise 46, Tartu, 51014, Estonia, (4) Institute of Geological Sciences, National Academy of Sciences of Belarus, Kuprevich 7, Minsk, 220 141, Belarus, (5) Landesamt für Natur und Umwelt Schleswig-Holstein, Hamburger Chaussee 25, Flintbek, 24220, Germany, (6) Department of Geography, Univ of Latvia, 19 Rainis Blvd, Riga, LV-1586, Latvia

In the area to the south of the Baltic Basin numerous glacial features have been studied for years and many directional data have been collected. The project ICE-FLOW directions in the peribaltic

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area during the Weichselian Glaciation combined the previously published and unpublished data. It was supported by INQUA and national funds of participating countries.

Ice-flow directions were detected from linear glacial landforms and sediment fabric. They are direct (striations, till fabric, local glaciotectionic deformations, streamlined landforms) and indirect (glacial tunnel valleys, eskers, kame chains, end moraines) ice-flow features. Their spatial distribution indicates radial structure of the ice sheet terminal zone and location of interlobate zones.

A final result is a data base and collection of national maps (scale 1 : 500,000) of the area in Belarus, Estonia, Germany, Lithuania, Latvia and Poland, constructed in 2000-2003 with a use of the ArcInfo system. The maps are to be put together into a complex map (scale 1 : 1,000,000), to present unified image of ice-flow directions during the Late Weichselian. It will create background for further palaeoglaciological 3-D modelling of the palaeo-ice streams in the Central European area.

24-12 BTH 127 Zelès, Vitālijs

MAP OF LATE WEICHSELIAN DIRECTIONAL ICE-FLOW FEATURES OF LATVIA

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The map of Late Weichselian directional ice-flow features of Latvia is an integral part of the INQUA project Ice flow directions in the Peribaltic area during the Weichselian Glaciation. Directional ice-flow features in the Latvian database and on the map were classified according to the legend worked out for the map of the entire Central and Eastern European area. The Latvian map and database were constructed using the ArcInfo system during the period of 1999-2003. The map is supported by a supplementary map showing the lobate structure of the peripheral cover of the Scandinavian ice sheet with major interlobate zones in Latvia and patterns of drift lineations in glaciated lowlands. Directional ice features were digitized from 1:50,000 (or 1:75,000) topographic maps, derived from the interpretation of satellite images and digital maps and from papers, unpublished reports and personal communications. The geographic base was compiled from the satellite map of Latvia on scale 1:50,000 and consists of multiple coverages that include basic geography. The main directional ice-flow features were formed during the Late Weichselian. Streamlined landforms are strongest and constant directional indicators of ice flow. Only when the till fabric, striations and deformational features were formed under the extensional flow regime of rapidly advancing glacial tongues they indicate the final local direction of glacial movement. In other cases they reflect directions of local stress or older ice movements. Superimposed sets of radial and transverse glacial topographic lineations formed beneath the margin of the retreating ice lobes and indirect features complicate the ice-flow mosaic. However, near parallel mega-scale lineations with latest cross-cutting features are common in macro-depressions with longitudinal extensional or compressional ice flow. The diverging pattern of ice-flow appears in glacial lowlands widening downglacier, while converging lineations occur in lowlands narrowing downglacier or along the sides of the largest interlobate uplands. Furthermore, in upland areas also transverse and isometric topographic features dominate, and the reconstruction of ice flow direction should be based mainly upon indirect features and fabric lineations.

24-13 BTH 128 Brunotte, Ernst

PALEOZOIC GLACIAL VALLEY-SYSTEMS IN NAMIBIA? NEW ASPECTS: MORPHOGENETIC CONTRADICTIONS AND MORPHOTECTONIC RELATIONS

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Geomorphological investigations on palaeosurfaces and their tectonic deformations lead to a critical review of palaeo-landforms hitherto interpreted as glacially shaped Palaeozoic valleys. Such an age has proven as inconsistent with the known surface development considering the effects of valley superimposition and of post-Karoo tectonics. Tillites in situ as convincing Palaeozoic sediments are widely missing. Glacial striae of differing directions plead for overriding ice sheets but not for valley glaciers. Some of the features in question must be interpreted as products of gravity flow processes. Several valley sections are structurally controlled and have been formed as rupture valleys. Only a minimum of valley remnants can be attributed to Palaeozoic times.

SESSION NO. 25, 1:30 PM

Friday, July 25, 2003

T20. Fossil Organic Carbon in Modern Environments (Posters) (Commission on Carbon)

Reno Hilton Resort and Conference Center, Pavilion

25-1 BTH 136 Di-Giovanni, Christian

ORGANIC CARBON RELEASED FROM CARBONATES AND SHALES BY CHEMICAL WEATHERING: IMPLICATIONS FOR THE GLOBAL ORGANIC CARBON CYCLE UNDERSTANDING

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We propose in this study an initial estimation of the annual organic matter yield induced by chemical weathering of carbonates and shales considering their global surface at outcrop and their organic matter content. The calculation also uses data on river fluxes resulting from carbonate rocks and shales weathering in major world watersheds, published by numerous authors [1]. The results obtained from the studied watersheds have been extrapolated to a global scale. Despite rather large uncertainty inherent to such an approach, the calculated value [2] of ca. 0.1 Gt implies that the annual organic carbon yield related to carbonates and shales chemical weathering might be a non-negligible component of the global carbon cycle. The calculated yield does not constitute a direct supply to soils and the rivers because a part of the produced organic matter can be mineralised, thus escaping recycling. Depending on the real fate of the organic carbon released from weathered ancient formations, i.e. mineralisation or recycling, this process might affect the efficiency of chemical weathering as a carbon sink, the global soil organic carbon amount estimation, or the evaluation of the total amount of the organic matter occurring in rivers. Whatever the hypothesis considered, this study suggests that the inherited organic yield is a key-component of the global organic carbon cycle understanding that has been to much omitted up to now. Because it exists and in addition because it might represent a non negligible carbon pool, fossil organic

carbon deserves to be taken into account for a better evaluation of the organic stocks in soils and rivers presently only based on climatic data and current vegetal production.

[1] Amiotte-Suchet 1994. Mémoire Sciences Géologiques, 97, 100p. [2] Di-Giovanni Ch., Disnar J. R., Maccare J. J. 2002. Global and Planetary Change, 32, 195-210.

25-2 BTH 137 Di-Giovanni, Christian

MINERALIZATION OF REFRACTORY CARBONS IN SOILS AND SEDIMENTS: INFERENCE ON THE CARBON BIOGEOCHEMICAL CYCLE

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Black Carbons (BC=soots and charred particles) and Geologic Carbon (GC) form a cluster which can be defined as Refractory Carbon (RC), by considering their inertia to the degradation. Despite their occurring in the different surface carbon reservoirs, their contribution to the carbon biogeochemical cycle is still poorly known. Admitting their inertia, RC could be considered as a carbon sink. But they are also subject to mineralization processes in soils, outcropping sediments and waters, and can be assimilated to a source of atmospheric CO₂. A review is here presented in order to appreciate their weathering ability and subsequently their role of sink and/or source of carbon. Oxidative alteration of RC leads successively to the formation of highly aromatic humic compounds and to the release of CO₂ [1,2]. However, mineralization rate depends on the nature of RC and on some various factors (chemical structural, temperature, duration of exposition). So, the schematic classification "soots-charcoals-GC", can be established and reflects a progressive increase in the weathering potential. Up to now, few studies mention the mineralization degree of BC (one mentions 60% in a turbidite [3]). On the other hand, numerous studies of weathering profiles of GC exist and can be interpreted in terms of loss of organic carbon (mineralization). For example, a degree of mineralization of 20 / 25% for bituminous coals, and even 60 / 100% for black shales have been calculated [4, 5]. Recently, we have examined two weathering profiles of semi-anthracite and estimated that 30 / 45% of GC have been mineralised during this process enduring since 10ky [6]. This overview involves that the mineralization degree of RC is not really known and that further studies are required in order to get a better knowledge of their contribution to the carbon cycle as sink or source of atmospheric CO₂.

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25-3 BTH 138 Di-Giovanni, Christian

FOSSIL ORGANIC MATTER IN MODERN SOILS: OPTICAL EVIDENCES

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Soil organic matter is one of the key components in the global carbon cycle understanding. Its description and quantification has then been subject to many investigations. The present work is driven by the following question: does soil organic matter (OM) only depends on the vegetal net primary production or also on the incorporation of organic matter coming from underlying geological formations?

Brief replies were provided by the comparative study of particulate OM present in the rocks (marl and limestone) and the soils of the catchment area of Annecy Lake (French Alps). About twenty samples of soils and underlying rocks were studied by optical study that consists of counting of organic particles isolated from the mineral matrix after acid treatment. Observations were performed in natural light in both transmitted (palynofacies) and reflected modes (vitritine reflectance).

Observation in transmitted light shown that the geological formations OM is almost made of opaque particles (OP). In soils, OM consists of both well preserved translucent particles resulting from the overlying primary production and variable amounts of OP (1- 11% of total OM). In the rocks, the OP size distribution presents mean values around 20 micrometre. This size fraction is also found in all the studied soils. These observations clearly indicate that ~20 micrometre OP particles observed in the soils are derive from underlying sedimentary rocks.

However, for 50% of the soils considered, some OP particles with mean size values around 60 micrometre are also found. This fraction is never observed in the rocks of the underlying rocks, indicating that these particles cannot derive from the geological substrate. Moreover, the observations in reflected light show that the ~ 60 micrometre particles from the soils exhibit common features of wood fire debris (pyrofusinite). Consequently, in some cases, in addition to primary production derived particles, the soils may also contain opaque OM coming from both sedimentary rocks and from forest fires.

These results show : - that altered OM of the geological formations can be found in modern soils and then must be taken into account in the understanding of the carbon cycle models ; - the possibility to distinguish fossil OM (geological OM) from present OM (particles from present biomass and fire forest).

25-4 BTH 139 Longworth, Brett E.

ANCIENT SEDIMENTARY ORGANIC MATTER IN A MODERN RIVER CARBON CYCLE: THE HUDSON-MOHAWK RIVER SYSTEM, NEW YORK, USA

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The connection between erosion of rocks on the continents and deposition of marine sediments is riverine transport. Current understanding of the geochemical carbon cycle holds that rivers carry relatively modern dissolved and particulate organic matter derived from autochthonous sources, watershed vegetation and soils, and that OM from shale-rich lithologies exposed in the watershed is fully oxidized upon soil formation. In some systems, this is not the case. Ancient rock-derived organic matter may play an important role in the modern carbon cycle through erosion, delivery, utilization and transformations between particulate and dissolved carbon pools. Our work seeks to quantify ancient OM contributions to the Hudson-Mohawk watershed of upstate New York, USA. Large portions of this watershed are underlain by organic matter-rich Palaeozoic sedimentary rocks. This river system provides an ideal natural laboratory for distinguishing rock, soil, terrestrial vegetation and autochthonous sources of dissolved and particulate organic matter to natural waters.

Prior research has indicated a significant flux of radiocarbon-depleted organic matter to the Lower Hudson River (Raymond and Bauer, 2001). Our preliminary results suggest substantial

SESSION NO. 26, 1:30 PM

Friday, July 25, 2003

T23. Arroyo Processes and Histories (Posters)

Reno Hilton Resort and Conference Center, Pavilion

fluxes of organic carbon out of small catchments draining lithologies rich in organic carbon. These fluxes may also relate to land-use patterns (forested, pasture, tilled agricultural and urbanized). Through a combination of elemental analysis, stable carbon and nitrogen isotopic analysis, pyrolysis-gas chromatography, and radiocarbon analysis, we are examining dissolved and particulate river organic matter, soils and sediments to trace the delivery of ancient organic matter from weathered sedimentary rocks to modern river systems.

Weathering of ancient, organic matter-rich sedimentary rocks may prove to be an important source of organic matter to some river systems. As such, these systems would represent "short-circuits" in the geochemical carbon cycle and may impact the composition and apparent age of coastal waters and sediments.

25-5 BTH 140 Raymond, Peter

VARIABILITY IN THE AGE OF RIVERINE ORGANIC MATTER FROM RIVERS OF THE EAST COAST OF THE UNITED STATES

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The age of riverine organic matter provides critical information on the residence time of terrestrial organic matter and is also used to evaluate the contributions of terrestrial organic matter in ocean basins. Here we present ¹⁴C data on particulate organic, dissolved organic and dissolved inorganic carbon from a number of United States east coast rivers. Although these rivers occupy a small geographic range, they display a large variation in ¹⁴C values. Many systems have significantly depleted ¹⁴C values indicating the potential for contributions from relic pools. The high within and across system variation, however, makes it difficult to either evaluate landscape controls on the export of relic carbon from terrestrial catchments or estimate the amount of terrestrial carbon in the associated ocean margin.

25-6 BTH 141 Drenzek, Nicholas J

DELIVERY OF ANCIENT ORGANIC CARBON TO THE BEAUFORT SEA

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The Mackenzie River system represents the primary source of sediment to the Arctic Ocean and provides an excellent opportunity to study the delivery of fossil organic carbon (OC) to contemporary marine sediments. Bulk radiocarbon dating of fluvial suspended matter and surficial sediments in a transect from the river delta to the Beaufort Basin reveals the presence of a high content of older carbon, with conventional ¹⁴C ages ranging from 7690 to 10700 yr BP. Bulk ^δ¹³C measurements on the same samples indicate a significant terrigenous OC component, with values ranging from -26.0 to -23.8 ‰ and increasing with distance offshore. These old ¹⁴C ages may reflect OC of vascular plant decent that is pre-aged (possibly through sequestration in permafrost soils), fossil OC derived by erosion of the extensive outcrops of organic rich sedimentary rocks in the drainage basin, or both. In order to resolve the contributions from kerogen weathering versus sequestration of higher plant debris, molecular level ¹⁴C and ¹³C measurements were performed on free and macromolecularly bound *n*-alkanes as well as vascular plant derived *n*-alkanoic (fatty) acids. Compound-specific ^δ¹³C values of pyrolysis-liberated alkanes from demineralized sediment are homogeneous from C₁₅ to C₃₅ at ca. -30 ‰, suggesting a predominantly fossil origin. This is supported by the significantly depressed radiocarbon ages of the same compounds. Free fatty acids, meanwhile, exhibit a trend of modern shorter chain length (C₁₄-C₁₈) to much older higher chain length (C₂₄-C₂₈) homologues, which along with the companion ^δ¹³C values reflect their autochthonous and allochthonous origins, respectively. Moreover, the ages of individual alkananoic acids appear to increase with distance offshore, possibly reflecting association with fine grain minerals. However, the fractional abundance of even the oldest homologue at the most distal site cannot account for the depressed bulk OC ages, further demonstrating the presence of ancient carbon. In order to estimate the magnitude of this component, model results exploiting these paired molecular level isotopic measurements will be presented. These results will be coupled with elemental abundance data from each site to yield a more complete picture of OM provenance and cycling in this important arctic margin system.

25-7 BTH 142 Yamskikh, Anton A.

ANTHROPOGENIC CARBON DIOXIDE EMISSION DURING OIL FIELD EXPLORATION IN EASTERN SIBERIA

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The gas emission during oil field exploration occurs during engine work and oil and gas tests. Up to 600 wells is designed to be drilled during exploration. This amount of the well will produce significant amount of the gas which will enough for the regional changes in regional CO₂ concentrations. The amount of the carbon dioxide emission will be determined using standard calculations. These calculations will be used for simulations of the carbon dioxide concentration within the ground surface. Distribution will be simulated using "Prizma" model - standard model for environmental calculations in the Russian Federation. Simulations will be based both on the engine and oil and gas tests CO₂ emissions and regional natural features (relief, temperature, wind strength and direction) These simulations will be resulted in the map of the carbon dioxide concentrations resulted from the oil and gas field exploration in Eastern Siberia.

26-1 BTH 143 Fanning, Patricia C.

VALLEY FLOOR GULLIES IN WESTERN NSW, AUSTRALIA: PROCESSES AND HISTORIES
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Considerable landscape change followed settlement of European pastoralists in semi-arid and arid rangelands of NSW, Australia in the mid to late 19th century, and particularly extensive incision of valley floors. The cause was the change from indigenous hunter-gathering to sheep and cattle grazing. Here, we review evidence from sites widely distributed across the western NSW region, and monitored over varied time-scales, which confirms a post-European settlement time frame for these changes. Age control is provided by radiocarbon dating of charcoal from Aboriginal heat retainer hearths, OSL dating of sediments, burial of fences and other European artefacts, and direct measurement of geomorphic processes over days, years and decades.

Stratigraphic analysis of upland valley fills exposed in the walls of entrenched channels shows that sediments derived from erosion of topsoils on the slopes were initially deposited across valley floors forming a distinctive unit termed post-European material (PEM). This was followed by a shift from relatively shallow, single or multi-thread channels to the wide, flat-bottomed valley floor gullies, equivalent to North American arroyos, characteristic of the region today. Downstream, the systems are characterised by rapid sedimentation, channel avulsion and floodout formation.

Monitoring over the last 20 y indicates that erosion rates outside stream channels may exceed 200 t ha⁻¹ y⁻¹, and that channel enlargement and knickpoint retreat through the upland stream systems are continuing to destabilise valley floors. Mean overall rates are approximately 0.01 m y⁻¹, but more likely much higher following intense rainfall. Downstream, buried fences and abandoned dams indicate that the channels of ephemeral creeks have migrated laterally at rates of 1-2 m y⁻¹ since 1883, and are associated with channel down-cutting of 0.06 m y⁻¹ over the same period.

The range of rates presents challenges to integrating localised data into a more coherent regional picture. Mean long-term rates conflate brief periods of intense activity with far longer periods of little change. However, the overall end result is a redistribution of soil from the more susceptible parts of the landscape to sediment sinks.

26-2 BTH 144 Pavich, M.J.

RATES AND SCALES OF SEDIMENT PRODUCTION IN THE RIO PUERCO BASIN, NEW MEXICO

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The rates at which sediment is generated on hillslopes by weathering (sediment production) is highly variable, poorly known, and difficult to predict. We show, using in-situ-produced ¹⁰Be measured in alluvial sediment, that rates of sediment yield and sediment production vary over significantly different temporal and spatial scale in the Rio Puerco Basin of northern New Mexico. Suspended sediment concentrations in the Rio Puerco, the largest tributary of the Rio Grande, are among the highest in the world, up to 600g/l. The alluvial drainage network is deeply incised, the result of an arroyo-cutting episode that began in the late 1800s. Large volumes of unconsolidated sediment are delivered directly to the channel during downcutting and subsequent channel widening. As headcuts develop, soil piping progresses headward and arroyo walls collapse. Radiocarbon dating and the lack of identifiable paleosols, demonstrate that the cutting and filling of Rio Puerco arroyos have occurred repeatedly during the Holocene. Thus, it appears that average sediment storage times in the valley bottom are short, on the order of no more than a few thousand years. To determine the rate at which sediment is generated by rock weathering and to test the relationship between ¹⁰Be activity and drainage basin area we collected sand-sized alluvial sediment from 37 sites in the channel and on aggraded alluvium within the boundaries of the 20th century arroyos. Drainage basin areas above the sample sites ranged from 170 km² to 16,000 km². We separated quartz from the samples and isolated ¹⁰Be using standard techniques. We use an interpretive model that relates nuclide activity in fluvial sediment to the rate at which drainage basins are eroding and producing sediment. Individual basin-scale rates for sediment generation range from 2.1*10⁴ kg km² y⁻¹ to 1.0*10⁶ kg km² y⁻¹, the equivalent of rock erosion at 8 to 400 m My⁻¹ (=2600 kg m³). Basin to basin variance is high for smaller basins (<2000 km²) but dampens with increasing basin area, demonstrating the importance and efficiency of sediment mixing during fluvial transport.

26-3 BTH 145 Gellis, Allen C.

RECENT GEOMORPHIC CHANGE IN THE RIO PUERCO ARROYO OF NORTHERN NEW MEXICO, U.S.A

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Stream incision into valley alluvium during the late 19th- and early 20th-centuries formed deep, continuous arroyos in the southwestern United States. Since the initial incision of the Rio Puerco, the arroyo has widened and in some reaches may be aggrading. Bryan and Post's 1927 observations and 1935 aerial photographs indicate that most of the 200-km-long Rio Puerco arroyo had enlarged by lateral erosion. By the 1950s and 1970s, the stream channel in the lower Rio Puerco was becoming narrower, and an inner flood plain within the arroyo was becoming stabilized by vegetation; however, these changes were not apparent in the upper reaches. Cross sections surveyed at 25 sites in 1977 were resurveyed in the mid 1990s. The channel at 12 sites in the upper Rio Puerco was characterized by a large width-to-depth ratio, a small amount of silt- and clay-size material in the channel perimeter, unstable and poorly defined channel banks, low vegetation density on the inner flood plain, a laterally unstable channel, and vertical arroyo scarps. The channel at 13 sites in the lower Rio Puerco were characterized by a small width-to-depth ratio, a large amount of silt- and clay-size material in the channel perimeter, steep and resistant channel banks, dense riparian-zone vegetation on the inner flood plain, a relatively stable channel position, and less common erosion of arroyo scarps. Most upstream sites continued to be unstable in the 1990s with lateral erosion of the arroyo scarps progressing since the 1970s; some upstream sites

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have aggraded and others have degraded. Downstream sites were relatively stable, but all had decreases in bankfull width and in width-to-depth ratio; 10 had decreases in cross-sectional area due to sediment deposition on the bed and banks. The channel at seven downstream sites had an increase in mean bed elevation of at least 0.3 m, and eight had a bankfull elevation increase of at least 0.3 m. Aggradation in upper arroyo reaches may occur where the relatively large channel width-to-depth ratio results in insufficient depth and shear stress to transport sand-size material. Channel aggradation in both reaches and width and area decreases in the downstream reaches also may be a result of transience loss from infiltration leading to streamflow attenuation and sediment deposition. Nearly 80% of runoff is lost to attenuation.

26-4 BTH 146 Gellis, Allen

SEDIMENT BUDGETS FOR TWO SEMI-ARID WATERSHEDS, RIO PUERCO BASIN, NEW MEXICO

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Three major channels have cut and filled the Rio Puerco valley in the past 3,000 years. Recent surveys indicate that the Rio Puerco channel is now in a cycle of aggradation, which is independent of a change in the base level of the Rio Grande. This raises questions about the source(s) of sediment and processes that govern aggradation.

To determine possible sediment sources in the Rio Puerco basin, a sediment budget was constructed for two subbasins of the Rio Puerco, Volcano Hill Wash (9.30 km²) and Arroyo Chavez (2.28 km²), from 1995-98. Sediment yields and sediment concentrations were measured with sediment traps and at a streamflow-gaging station located at the outlet of each subbasin.

The average annual sediment yield measured at the streamflow-gaging station at Arroyo Chavez (981 tonnes/km²/yr) is more than twice the sediment yield of Volcano Hill Wash (405 tonnes/km²/yr). Similarly, the discharge-weighted sediment concentration measured at the streamflow-gaging station at Arroyo Chavez (92,500 mg/L) is more than twice the concentration at Volcano Hill Wash (34,000 mg/L). Averaging sediment yields from all sediment traps indicates the sediment yield for Arroyo Chavez (0.683 kg/m²/year) is more than twice the average sediment yield for all traps at Volcano Hill Wash (0.274 kg/m²/year). Accounting of sources in each basin shows that 57% of the sediment transported out of Arroyo Chavez is from channel erosion (bed and bank) and 43% is from upland sheetwash erosion. In Volcano Hill Wash, 32% is from the channel and 68% is from sheetwash erosion.

Differences in land-use factors could contribute to the higher erosion and sediment yields in Arroyo Chavez compared to Volcano Hill Wash. Although both subbasins predominately are used for grazing, Arroyo Chavez is considered in poor range condition and Volcano Hill Wash is in good condition. Arroyo Chavez also contains gas pipeline activity, dirt roads, and a higher livestock density. Visually, the basin is gullied with many areas of bare ground. The larger contributions from channel erosion in Arroyo Chavez may reflect human disturbances.

26-5 BTH 147 Friedman, Jonathan M.

USING TREE-RING ANATOMY TO DATE FLOODPLAIN DEPOSITION

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Determination of sediment deposition rates from recent stratigraphy is typically limited by a scarcity of chronological information. We present a method for precise dating of sedimentary beds based on the change in anatomy of tree rings upon burial. When stems of tamarisk (*Tamarix ramosissima*) and sandbar willow (*Salix exigua*) are buried, subsequent annual rings in the buried portions become narrower, xylem vessel diameter increases and ray width increases. Observation of these changes can be combined with tree-ring counts to determine the year of deposition of sedimentary beds that are at least 20 cm thick. Using a backhoe we dug trenches across the flood plain at three locations along the arroyo of the Rio Puerco, New Mexico, USA. At each cross section we prepared a detailed stratigraphic description and excavated several tamarisks to depths as great as 5 meters. From each excavated tree we cut and sanded 15-50 slabs for tree-ring analysis. We cross-dated slabs within and between plants and used the burial signature in the tree rings to date all sedimentary beds in the vertical sequence near each plant. We tied vertical sequences into cross sections using trench stratigraphy, and extended results between cross sections using topographic surveys, GIS analysis of historic aerial photos, and repeat surveys of historic cross sections. Using this method we quantified sediment transport by 9 floods between 1936 and 1999. Along the Rio Puerco, arroyo cutting, widening, and filling have all migrated upstream over time. Introduction of tamarisk in 1926 occurred just prior to the beginning of channel narrowing and arroyo filling. Thus the tamarisks record a process of channel change to which they may have contributed.

26-6 BTH 148 Ellis, Lucy A

THE MORPHOLOGICAL REPRESENTATION OF CHANNEL-FORMING FLOW IN ARROYOS

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Three large arroyos, the Santa Cruz River, the San Simon River and the Rio Puerco, were studied to determine whether a channel-forming flow, or range of flows, exists in arroyos. These three arroyos were chosen for this study due to the availability of long-term discharge records and measured suspended-sediment discharge data. The hydrologic regime of each channel was examined by observing the seasonality of flow and sediment discharge variability, flashiness and attenuation rates using daily average discharge data. Discharge records collected every 15 minutes were also available for the Rio Puerco and Santa Cruz River, enabling a comparison of results. Magnitude-frequency analysis of both detailed and averaged discharge records were combined with a sediment rating curve to produce the effective discharge for each arroyo.

Significant arroyo morphologies were quantified by carrying out repeat cross-sections. These surveys highlighted the fact that arroyo systems are complex, with different channels within the main arroyo trench occupied by different magnitude flows. The surveyed morphologies were compared with the calculated effective discharge to enable process-form relationships to be established. The three arroyos evolved differently under different scenarios and yet all have similar morphological characteristics and behaviour patterns. The majority of arroyos in the southwestern USA have been aggrading for the past thirty or more years, forming a distinct low-flow (active) channel. Preliminary results from the arroyos studied indicate that this active channel is adjusted to a dominant flow, the exact value of which has yet to be determined.

26-7 BTH 149 Klinger, Ralph E.

LATE HOLOCENE ALLUVIAL STRATIGRAPHY AND GEOMORPHOLOGY OF THE LITTLE COLORADO RIVER BETWEEN HOLBROOK AND WINSLOW, ARIZONA

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Four major terraces mapped along the Little Colorado River between Holbrook and Winslow, Arizona document episodes of aggradation and degradation during the past 3,000 years. The alluvium forming these four terraces are denoted as the Desert Broom, the Tamarisk, the Cottonwood, and the Moenkopi alluvium in order of increasing age. The terraces and their associated deposits were mapped on the basis of their elevation and relative position to the active channel and adjacent units, their surface morphology, and the dominant type of vegetation and relative coverage of that vegetation on the terrace surface. The extent of soil formation, stratigraphic relationships, and other sedimentological properties also helped distinguish the various units from each other.

The chronology for these alluvial units was based on the extent of soil development, 14 radiocarbon ages, and ring counts from 42 tree cores or slabs. The Desert Broom alluvium exhibits no soil development and is covered by sparse or no vegetation. This alluvium appears to have been deposited during the last decade based on the maximum age of vegetation. The Tamarisk alluvium also shows very little or no soil development. Stratigraphic and dendrochronologic data indicate that this is a complex unit deposited between the 1940's and 1970's. The Cottonwood alluvium exhibits a weak to moderately developed soil and, based on numerous tree cores and several radiocarbon ages, was deposited between several hundred years to perhaps 1000 years ago. The Moenkopi alluvium is a complex cut-and-fill sequence that apparently represents time-transgressive deposits. Based on the extent of soil formation, the Moenkopi terrace has been stable for at least 1000 years, but radiocarbon ages indicate that the older parts of the deposit may be more than 3000 years old.

The timing of aggradation and degradation in this reach of the Little Colorado River is similar to the alluvial history reported in nearby areas on the Colorado Plateau. The favored theory is that these episodes are climate-driven with periods of alluviation occurring during dry cycles and periods of degradation occurring during wet cycles. Based on present channel conditions and presence of bedrock in the channel, the river between Holbrook and Winslow currently appears to be in a stable or slightly degrading state.

26-8 BTH 150 Bullard, Thomas F.

LIMITED RESPONSE OF EPHEMERAL STREAM DYNAMICS TO EXTREME VEGETATION CHANGE- LATE HOLOCENE ALLUVIAL HISTORY OF EPHEMERAL STREAMS, CATALINA ISLAND, CALIFORNIA

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The role of climatic transition and related changes in vegetation in arroyo development remains a controversial topic. Most studies in the semiarid southwest US suggest that either latest Holocene climate change or overgrazing triggered widespread historic aggradation and incision in ephemeral stream systems, yet a clear consensus has not been reached. The arroyo incision question is important when trying to anticipate geomorphic changes in the landscape in response to global climate change. A well-documented history of extensive vegetation disturbance due to 150 years of intense grazing on Catalina Island and a record of late Quaternary fluvial erosion and deposition provides an opportunity to address how ephemeral fluvial systems responded to extreme vegetation change. Alluvial and colluvial deposits and soils were characterized in the Middle, Cape, Skull, and Bulrush canyons of Catalina Island. These drainages contain ephemeral streams in narrow alluvial valleys that are incised locally more than 3 m and preserve up to 6 discontinuous terraces. Fluvial deposits contain multiple buried Holocene soils that contain strong A horizons and weak to moderate Bw horizons. These soils record cycles of deposition, stability, and erosion. Most hillslopes contain soils indicative of relative stability over the past several centuries to several thousand years, although, scattered but localized areas of historic erosion are observed. Whereas the Holocene depositional and erosional record is well represented in the valley bottoms, there is little stratigraphic evidence for widespread historic hillslope erosion and fluvial deposition in tributaries or trunk streams. The relation implies that considerable and extensive decrease in vegetation by itself appears to be insufficient for triggering a cycle of historic hillslope erosion and valley aggradation. This means that historic incision and sedimentation is considerably less extensive than what previously occurred in the Holocene. Limited geomorphic response to grazing suggests that other response processes such as complex geomorphic response, extensive fires, or an increase in extreme storms may be required to mobilize sediment and trigger extensive arroyo filling and incision.

SESSION NO. 27, 1:30 PM

Friday, July 25, 2003

T31. Late Quaternary Climate Change in Tropical America (Posters)

Reno Hilton Resort and Conference Center, Pavilion

27-1 BTH 151 Beatriz, Ortega

LATE HOLOCENE CYCLES OF SEDIMENTATION AND ENVIRONMENTAL CHANGE IN WESTERN MEXICO: THE RECORD FROM SANTA MARIA DEL ORO, NAYARIT, PRELIMINARY RESULTS

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Preliminary results of a multiproxy paleoenvironmental research project in late Holocene lake sediments are presented. Santa María del Oro is a crater lake 60 m deep, in Western tropical Mexico (21.3° N, 104.5° W, 760 m asl). Four parallel cores, between 4 and 9 m long, were recovered from a shallower area (< 12 m in depth). Sediments are characterized by alternated laminations (few millimeters to 2 cm) of brown silt, sand, peat, reddish silt, or ochre, carbonate-rich silt. The sediment 14-C dated at 8 m depth, yielded an age of ca. 2,500 yrs. B.P. Given this date, it is possible that each set of laminations represent annual sedimentation cycles. The record is a potential

high-resolution archive of environmental and climatic variability for western Mexico for late Holocene. To investigate the controlling factors in the sedimentation of the sequence, several analyses are currently under progress: computerized axial tomography (CAT), total organic/inorganic carbon (TOC/TIC), x-ray diffraction, diatom, pollen, ostracodes, and mineral magnetic properties analyses. It is considered that this multiproxy approach will allow to characterize the laminae and to identify the authigenic and allogenic processes controlling sedimentation in this specific area of the lake. One of our aims is to assess the existence of sedimentation cycles using magnetic properties in finding the frequency and the probable origin of the changes sedimentation mechanisms. High-resolution CAT images, scanned and converted to a 255 gray-scale, help in characterizing the sediments and in finding periodicities in the sedimentary processes. Preliminary results show that the main differences among each type of layer are in TIC and TOC content, in variations in the concentration of magnetic minerals and their paramagnetic contribution, and in the particle-size distribution. Initial magnetic measurements of susceptibility vs. high temperature show that partially oxidized magnetite and Ti-magnetites are the main magnetic phases identified in most layers. Pollen is scarce in most of the sequence, while diatoms and ostracodes show nearly monospecific "blooms".

27-2 BTH 152 Israde, Isabel

QUATERNARY PALAEOENVIRONMENTS AND LAKE LEVEL RECORDS FROM CUITZEO LAKE, WEST CENTRAL MEXICO

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Cuitzeo lake located at the high plateau (1820 m.o.s.l.) in North Michoacán is a large vulcanotectonic lake. Twenty seven meters coring in the Cuitzeo lake spanning the last ca. 127,000 y. B. P. shows a high resolution lacustrine record involving diatoms, pollen, mineralogy, TOC and TIC analysis. Sediments of this closed basin are mainly composed of clayed silts, silts and diatomite. Tephra deposition observed in three periods (ca.80 ky, ca.50 ky and ca.35 to 25 ky) modifies palaeogeography and palaeoenvironments. The record from Cuitzeo lake can be divided fairly in two episodes: the first one from Late Pleistocene and the second one in Early Holocene. Evidence indicates that in Late Pleistocene dry conditions dominate, *Staurorsira* construens and herbaceous vegetation (Poaceae, Chenopodiaceae, Ambrrosia) and subaquatic communities (Cyperaceae) dominates the pollen diagram. Mineralogically constant low TOC values and the presence of gypsum are a characteristic of low water levels. This trend was punctuated by small humid phases of relatively short duration at ca. 17 ky, 44 ky and 42 ky. The most evident short humid phase is observed in the last glacial maximum (ca.17 ky B. P.) in which increases up to 80% the percents of *Stephanodiscus niagarae* and also shows an expansion of open pine-oak forest. However warm weather and arid summer are recorded by *Quercus*, *Ambrosia* and *Coelastrum* and benthonic diatoms indicating also low lacustrine levels. An important aridity interval was recorded from ca. 23 ky to 18 ky and the lake went dry or dropped significantly below modern level. A hiatus from 8 ky B. P. to 17 ky B. P. product of erosion cut the biological and sedimentary record but the trend is toward arid conditions. The second episode from Early to Middle Holocene suggest an improvement in the temperature conditions with an increase in rain precipitation and subhumid temperate forest. For the Middle Holocene the lake changes from freshwater (*Staurorsira construens*) to a shallow saline water lake. Finally a sharp increase of altononous material and successive eutrophication are suggested for the *Botryococcus* disappearance and the *Cyclotella meneghiniana* increase evidence the establishment of the modern conditions. Clearly more coring sites with higher resolution are needed to understand the palaeoenvironmental evolution in a big lake with a tectonic and volcanic configuration as this one.

27-3 BTH 153 Davies, Sarah J

LONG AND SHORT TERM CHANGE SINCE THE LAST GLACIAL MAXIMUM IN THE PÁZCUARO BASIN, MICHOACÁN, MEXICO

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Much palaeoenvironmental work in Mexico has focused on the Pátzcuaro Basin. Presented here are results from a series of new cores collected from the northern and south western parts of the basin, covering the last 19,000 years. The cores were collected using both Livingstone and min-Kullenberg cores. The chronology is provided by ¹⁴C dating and tephrochronology. Mini-Kullenberg cores contain the Paricutin tephra (AD 1943) at the surface, although show signs of mixing. The cores have been analysed for diatoms, mineral magnetic properties, sediment geochemistry, LOI and stable isotopes. The chemical composition of tephra layers has been identified using an electron microprobe. As well as reconstructing long term patterns of change, we have also examined the response of the lake system to inputs of tephra.

The pattern of change since the last glacial maximum is generally consistent with that published by Watts and Bradbury (1982) and Bradbury (2000). The lake was relatively deep and clear in the last glacial, but became increasingly turbid and generally shallower through the Holocene. Long term catchment disturbance is indicated by a range of mineral magnetic parameters. The use of an unmixing model allows identification of the contribution of different sediment sources, indicating that inputs of topsoil have been important during the last 3,000 years. Increasing inputs of terrestrial organic matter are also evident from higher C/N ratios. It appears that P is unlikely to have been a limiting nutrient, but available P has increased sharply in recent decades. This is consistent with available limnological data. Over the last 4,000 years, periodic dry phases are indicated by accumulations of ostracods and $\delta^{18}\text{O}$ values in authigenic carbonate, but the exact timing needs to be established. At least 16 tephra layers have fallen over the basin in the last 19,000 years, but their impact on the long term evolution of the basin appears minimal.

Sediments from the Pátzcuaro Basin record a complex interaction of climate change, human and volcanic impacts. Increasing the range of proxies has enabled us to begin to extract a climate signal for the highly disturbed Late Holocene portion of the record.

27-4 BTH 154 Vazquez-Selem, Lorenzo

LATE PLEISTOCENE AND HOLOCENE GLACIAL CHRONOLOGY AND EQUILIBRIUM LINE ALTITUDES OF IZTACCIHUATL VOLCANO, CENTRAL MEXICO

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There is evidence of late Quaternary glaciation on thirteen mountains of central Mexico (~19°N) peaking above 3850 m. Iztaccihuatl volcano (5286 m) probably has the most complete record in the region. This work presents the late Pleistocene and Holocene glacial chronology of Iztaccihuatl, the reconstructed equilibrium line altitude (ELA) of glaciers for different advances, and some paleoclimatic implications. The chronology is based on morphostratigraphy, ⁸¹Ca surface exposure ages, and 3 radiocarbon-dated tephras from Popocatepétl volcano. The ELAs for the past 20,000 years were reconstructed using the terminus-to-headwall altitude ratio (THAR=0.4). The most extensive recorded advance reached ~3000 m and falls within MIS 6 (~190 ³⁶Cl ka) (*Nexcoalango* moraines of White, 1962, *GSA Bulletin*, 73:935-958). There is no clear evidence of Wisconsin glaciation prior to the LGM. The main advance of the late Pleistocene occurred between 20 and 17.5 ³⁶Cl ka, with a mean ELA of 3940 m (*Hueyatlaco-1* moraines of White). An ELA depression (compared to A.D. 1960) of ~1000 m is consistent with similar estimates from North America and northern South America for the LGM. After a short recession, massive moraines formed between 17 and 14 ³⁶Cl ka, with a mean ELA of 4040 m (*Hueyatlaco-2* moraines). This substantial late glacial ELA depression (~900 m) might be related to the cooling effect of Laurentide meltwater flow to the Gulf of Mexico. Glacier retreat occurred slowly from 14 to 13 ³⁶Cl ka, then faster between 13 and 12 ³⁶Cl ka. Glaciers expanded (mean ELA: 4240 m) and receded from ~12 to ~10 ³⁶Cl ka (*Milpulco-1* moraines). There is clear evidence of an advance peaking shortly before 8.0 ³⁶Cl ka, with recession in progress by 7.5 ³⁶Cl ka (*Milpulco-2* moraines). This could represent the 8200 cal yr BP cooling event of the North Atlantic. The mean ELA of 4420 m implies a depression of ~50% with respect to the maximum ELA lowering of the late Pleistocene. The younger next advance is dated in <1 ka (based on tephrochronology) and likely corresponds to the Little Ice Age (*Ayoloco* moraines). The mean ELA (4720 m) was depressed ~250 m, equivalent to 24% of the late Pleistocene maximum. As everywhere in the tropics, the glaciers of Iztaccihuatl have undergone accelerated retreat since the beginning of the 20th century. The current ELA lies around 5000 m.

27-5 BTH 155 Davies, Sarah J

STABLE ISOTOPE RECORDS OF LATE HOLOCENE CLIMATE VARIABILITY IN MICHOACÁN, CENTRAL MEXICO

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Previous studies indicate that climate has varied in the central Mexican highlands during the last c. 3,000 years. Evidence remains ambiguous, since the climate signal from biological proxies (pollen, diatoms) is partially masked by long-term human impact, which began around 3,500 years ago. Here, we present the results of stable isotope analysis on lake sediment cores from two lakes in Michoacán: Pátzcuaro and Zacapu, which provide more information on Late Holocene climate variability in the region.

Lago de Pátzcuaro has been the focus of much palaeoenvironmental research, including analysis of $\delta^{18}\text{O}$ values in ostracods (Bridgwater et al., 1999). The modern lake water is enriched in $\delta^{18}\text{O}$ relative to the GMWL, so it should provide a record of changes in precipitation – evaporation ratios. Results from $\delta^{18}\text{O}$ analysis of authigenic carbonate in two new sediment cores, one spanning the last 1,000 years, the other covering the last 3,500 years, are presented. Two distinct dry phases are evident in the record. The first occurred between 2,500 and 3,000 years ago, whilst the second occurred several hundred years ago. It has not been possible so far to obtain a precise date for this most recent drought, but it may be related to sustained droughts identified in historical documents from the Colonial Period.

Laguna Zacapu is a spring-fed lake. The stable isotope composition of its modern lake water shows that it lies on the GMWL. As this lake is not evaporated, changes in $\delta^{18}\text{O}$ values should reflect the influence of temperature, rather than precipitation. No carbonates are present in sediments from Laguna Zacapu, they consist mainly of diatom valves. It was therefore possible to obtain an oxygen isotope record from the biogenic silica. The record itself is, however, rather complacent, with only minor fluctuations, suggesting that temperatures have not varied significantly over the last 3,000 years. This technique has great potential for further applications in Central Mexico, where lake sediments are often rich in diatoms, but poor in carbonates.

Our results show that by applying a combination of stable isotope techniques with other proxy data, such as diatoms, pollen, magnetic susceptibility and sediment geochemistry, we can begin to disentangle the climatic and anthropogenic signals in lake sediment records.

27-6 BTH 156 Lozano-García, Socorro

LATE QUATERNARY VEGETATION HISTORY OF THE UPPER LERMA BASIN, CENTRAL MEXICO

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Recent palaeoenvironmental research in continuous and semicontinuous lacustrine sequences of central Mexico provides a picture of the climate change during the last 25,000 yr. Most of the sites has good resolution for the full/interglacial cycle, but only a few display enough resolution in the Holocene. In the Upper Lerma Basin (ULB), the record for the last 10,000 yr is less disturbed and has better resolution. The (ULB) is the highest intermontane basin in Central Mexico (2570 m) and it is the origin of the longest river in the country. There are three water bodies connected by the Lerma river. Most of the paleoecological research in the area is related to the limnological evolution of the lakes and pollen data are scarce. A core of 9.54 m was drilled in lake Chignahuapan near the archaeological site of Santa Cruz Atizapan. Evidence of history of plant communities in the surrounding area during the last 22,000 yr is presented. The chronology is based on six AMS radiocarbon dates and two tephra layers. Pollen data indicate that during the late Pleistocene, from ca. 22,000 yr BP to 11,600 yr BP, open forests of pine, oak and alder with abundant herbaceous vegetation were growing in the area. Glacial advances correlate with increases in grass pollen at ca. 16,000 yr BP and ca. 14,000 yr BP. Magnetic data indicate high sediment input to the lake, in agreement with the pollen stratigraphy indicating open communities and a lower tree-line. During the Holocene, plant communities changed notoriously with the expansion of pine and oak forests, the reduction of the grass assemblage and higher pollen concentration values. After the fall of the TCT tephra, with an age of 8500 yr BP, the fir forest, indica-

tive of mesic conditions in the highlands, is documented. The late Holocene record shows the presence of *Teosinte* and *Zea* mays pollen, associated with high levels of charcoal particles related with agricultural activities.

27-7 BTH 157 Sosa-Nájera, Susana

THE HOLOCENE RECORDS OF THE BASIN OF MEXICO: A HISTORY OF ABRUPT CHANGES
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Results of pollen analyses from two sites in the south of the Basin of Mexico in combination with glacial chronology, tephrochronology and magnetic properties provide information of Holocene abrupt climatic changes. The high altitude site, Valle El Marrano at 3850 m is located in the NW side of Iztaccihuatl volcano. Glacial advances occurred between 12 to 10 ka (Mipulco-1) and from 8.4 to 7.4 ka (Mipulco-2) according to the ^{36}Cl chronology. A Mipulco-1 moraine depression was formed and swampy conditions established where sediments began to accumulate. In this moraine depression a 450-cm core was drilled. The sequence elapses the last 9000 years according to the ^{14}C dates and the presence of distinctive pumice with an age of 5000 yr. BP. The pollen record of the Valle El Marrano shows after the retirement of the moraine a gradual colonization by the elements of the alpine grasslands during the early Holocene. After the Mipulco-2 glacial advance a sudden change in vegetal communities is documented; the site is invaded by pine forest at ca. 6000 yr. BP and after this event the alpine grasslands return. For the last 4000 years the expansion of the *Pinus hartwegii* forests is recorded. In the low altitude site, Chalco lake at 2250 m several cores were taken. The Holocene sequences show important arboreal cover in the area during the early Holocene mainly pine and oak forests. A fir forest expansion occurred between 9000 and 7000 yr. BP. At ca. 6000 yr. BP the pollen assemblages changes and only herbaceous taxa are recorded. Low lake levels and important fires in Chalco area are shown in the sequences. Humid conditions are established during the late Holocene with increase in the forests and higher lake levels. In the Basin of Mexico, a region that can be considered as the northern limit of the tropics in America, proxy records document changing Holocene environments with a period of warming conditions at around 6000 yr. BP.

27-8 BTH 158 Islebe, Gerald A

MID AND LATE HOLOCENE VEGETATION CHANGE IN QUINTANA ROO, MEXICO
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Different pollen records of Mid to Late Holocene sediment cores from the Mexican Caribbean coast (Quintana Roo) show the development and changes of mangrove and tropical forest ecosystems. In southern Quintana Roo moist conditions prevailed and high forest was present around 5000 ^{14}C yr BP. Around 4200 ^{14}C yr BP the high forest was replaced by mangrove vegetation, probably due to permanent flooding of the Rio Hondo river. In northern Quintana Roo a palynological analysis revealed humid climatic conditions for the period approximately 2500-1500 ^{14}C yr BP, and mangrove *Rhizophora* mangle dominated with a good representation of elements from the nearby semi-evergreen tropical forest. During the period approximately 1500-1200 ^{14}C yr BP the mangrove *Conocarpus erecta* dominated. *R. mangle* almost disappeared and other taxa appeared, suggesting drier climatic conditions and generally more open vegetation. This dry period coincided with the period of the Maya cultural decline. The following period (approximately 1200-1000 ^{14}C yr BP) was characterized by the recovery of *R. mangle*, indicating more humid conditions than in the preceding pollen zone. Approximately 1000 ^{14}C yr BP till present drier periods occur with *C. erecta*; this marks the transition to present day conditions.

27-9 BTH 159 McAndrews, John H.

HOLOCENE POLLEN DIAGRAM FROM LAKE ANTOINE, GRENADA
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Upland vegetation history of the Lesser Antilles Islands is poorly known because there are few lakes - Grenada with late-Pleistocene volcanism is an exception. Lake Antoine (17 ha, 6 m asl) occupies a circular volcanic explosion crater, which is 500 m from the sea; it may have formed when rising seawater encountered hot magma about 14,000 years ago. There is no inlet or outlet. Around the lake margin is marsh of *Montrichardia arborescens*, *Cladium jamaicense*, *Acrostichum danaeifolium*, *Eleocharis flavescens* and *Nymphaea ampla*. On the adjacent slope is pasture, sugar cane fields and plantations of coconut, cocoa and banana; the upper slopes support secondary dry forest including *Bursera simaruba*, *Spondias mombin* and *Pisonia* fragrans. Organic sediment fills the lake to 5-7 m depth. An 850-cm long core of detritus gyttja bottomed on sand. Five calibrated radiocarbon dates and two historic levels permit modeling of sedimentation rate and chronology. Palynological analysis of 66 levels shows four zones. Zone 1 in basal sand is dominated by the brackish water marsh fern *Acrostichum*. Zone 2 is dominated by pollen of the palm *Roystonea oleracea* with shrub *Triumfetta* and the alga *Pediastrum argentinense*. Zone 3 begins at 4,300 years B.P with a peak of the disturbance-indicating *Cecropia*; it generally lacks palm pollen. The enigmatic monolete fern spore, cf. *Nephrolepis rivularis* is abundant; *Bursera*, *Spondias*, *Pisonia* and cf. *Pouteria* indicate upland dry forest; relatively abundant *Cladium* and *Nymphaea* indicate freshwater marsh. Beginning 300 years ago historic Zone 4 (0-190 cm) features *Poaceae* and especially *Zea* and *Cocos*.

27-10 BTH 160 Iriondo, Martin

THE PLEISTOCENE OF THE URUGUAY RIVER BASIN, SOUTH AMERICA
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The Uruguay river basin (365,000 km²) comprises tropical and subtropical latitudes in eastern South America. The basin was shaped late in the Tertiary. The oldest Quaternary unit is the San Salvador Formation (Lower Pleistocene), which was generated by the union of the Uruguay and the Paraná rivers; the formation is composed of a very large meandering channel and associated flood-plain deposits. Subtropical humid conditions are inferred for that period. Around 1 Ma B.P., a dry and

cold climate occurred in the continent (the Great South American Glaciation). The Uruguay river accumulated a large playa (Hernandarias Fm) composed of montmorillonite with segregations of gypsum; the river discharge at that time is calculated in only 13% of the present. Synchronously, the south of the basin underwent a Pampa-type loess accumulation (Punta Gorda Group).

The whole Middle Pleistocene is represented in the basin by a large hiatus. The Upper Pleistocene, on the contrary, is registered by a variety of sedimentary sequences. The OIS 5 is represented in the middle basin by El Palmar Formation, a fluvial unit (channel and associated flood-plain facies) sedimented under a tropical climate. A 10 m high marine terrace was generated at the Uruguay river mouth.

The OIS 3 is represented by a fluvial terrace in the tributaries of the basin (Arroyo Feliciano and Sopas Fm). Loess deposition occurred in the southwestern of the basin during OIS 2 (Tezanos Pinto Fm) under a dry and fresh climate. At that time the wind dynamic dominated also in the tropical upper basin, generating a red tropical loess (Oberá Fm). A generalized process of flash floods and mudflows under a dry climate affected the Oberá Formation, accumulating a diamict facies in the Uruguay valley (Yapeyú Fm). The Late Pleistocene is represented by a major channel shifting of the Paraná river, which invaded the present Uruguay basin and accumulated the Tapebicú Formation in a wetland environment.

The Holocene events registered in the basin are similar with those published elsewhere for the North Pampa.

27-11 BTH 161 Cordeiro, R.C.

PALEOENVIRONMENTAL CHANGES AND MERCURY DEPOSITION IN A REMOTE AREA OF AMAZONIA

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Geochemical analysis of four cores collected in Lagoa da Pata (Morro dos Seis Lagos, Sao Gabriel da Cachoeira, Amazonas State) showed important changes in the environmental history of this area during the last 45,000 years. Three distinct sections were clearly identified in the cores. They consist of upper and lower organic-rich layers, separated by an inorganic layer which represents a short period of rapid accumulation around 18000 ^{14}C yr BP. The first phase between, at least 45500 and 26000 B.P., it was observed a decrease in lacustrine productivity until the last glacial maximum, probably associated to a decrease in water level. In the LPT V core values of $\delta^{13}\text{C}$ (around -32‰) are associated to high C/N ratio related to woody material contribution. The second phase at around 18000 ^{14}C yr BP appears to have been a sudden input of clastic material. This was represented by a sandy facies, which exhibits lower carbon and water contents and high bulk density. This event may have been due to the occurrence of sudden and torrential rains, typical of dry climate, at about 18 ka BP. At the third phase, between at least 18000 ^{14}C yr B.P. until the present occurred an increase in lacustrine productivity attested by an increment in the chlrophyll derivatives and the carbon flux mainly after 4000 ^{14}C yr BP attested in the LPT III core which have the highest resolution in this phase in comparison with the other studied cores. It probably corresponds to a lake level rise increasing the production of the system. The C/N values dropped indicating an increase in algae organic matter contribution. The $\delta^{15}\text{N}$ decrease in this phase. The mercury accumulation rate after the last glacial maximum is found to be larger than the period between 45500 to 25000 ^{14}C yr BP with higher fluxes between 9000 and 4000 ^{14}C yr BP in LPT III, IV and LPTVI core. In the four cores analysed the mercury flux is greater after the last glacial maximum and mainly in the Holocene. These large accumulations rate of mercury is probably associated with an increase in oceanic degassing or a high frequency of forest fires during the Holocene.

27-12 BTH 162 Neary, Nicholas

SOUTH AMERICA DURING THE LGM: A REGIONAL MODELING STUDY
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Despite considerable reconstruction efforts, the LGM climate of the Amazon basin is not well understood. There is some general agreement that the region was some 3-6°C cooler, but conflicting evidence and interpretation about the precipitation. Rainfall reconstructions from adjacent regions such as Lake Titicaca are helpful, but the relationship to the Amazon is not clear. An improved understanding of the physical mechanisms that relate precipitation in the Amazon and the high Andes would help resolve this issue. Such a problem is well-suited for a modeling investigation. Global models of climate (general circulation models, or GCMs) have been used extensively to simulate the climate of the LGM. However, they are of limited use for South America because of their relatively coarse resolution and related difficulties in resolving the sharp Andean topography. In this study, a higher-resolution regional climate model (RCM) is used to contrast the rainfall regimes over South America for the present day and LGM. Extensive testing and evaluation are used to optimize the RCM for simulations of the South America climate through choice of physical parameterizations and boundary conditions (surface and lateral). The RCM provides an improved simulation of South American precipitation regimes compared with a GCM, and resolves some of the smaller-scale features of the circulation that are important in connections between the Amazon basin and high Andes. Multiple seasonal climate-mode simulations are conducted to understand the physical processes of moisture transport and wind convergence in and between the Amazon and high Andes regions, and to evaluate the roles of the various LGM forcing factors (e.g., orbital parameters, CO₂, sea surface temperatures, vegetation changes) individually.

27-13 BTH 163 Marchant, Robert

POLLEN-BASED BIOME RECONSTRUCTIONS FOR LATIN AMERICA: APPLICATIONS AT A RANGE OF SPATIAL AND TEMPORAL SCALES

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The biomisation method is used to reconstruct vegetation from fossil pollen data across Latin America at 6000 and 18000 radiocarbon years before present (yr BP), we then focus in on Colombia at a higher temporal resolution. Tests using modern pollen from core top, surface sam-

ples, pollen traps and moss polsters were able to broadly reproduce vegetation distribution as reflected in a map of potential natural vegetation. The calibration between the pollen-based reconstruction and the potential vegetation makes it possible to reconstruct vegetation at past periods, and determine patterns of change relative to the present. Mismatches between the pollen-based vegetation reconstruction and the potential vegetation results from forcing factors such as human impact, methodological artefacts and mechanisms of pollen transport and representivity of the parent vegetation. At a Latin American scale, the main differences between the modern and the 6000 yr BP reconstruction is a transition to biomes characteristic of a slightly drier climate. At 18,000 yr BP the pattern of vegetation change is more pronounced and is characterised by a range of biomes where tropical dry forest, tropical seasonal forest and cool grass / shrub are common, these describing a generally cool and dry environment.

By focusing our analysis on Colombia, which is prominent in Latin America due to the high quality and quantity of pollen-based environmental records stemming from some 50 years of palaeoecological study, it is possible to increase the temporal and spatial resolution, while retaining more information from the analysis that has to be discarded at the broader scale. Results are presented from the Holocene where the increasing importance attributed to human activity is documented initially in the lowlands and then at higher altitudes. This spatial and temporal zoom allows a discussion about differential response of the vegetation to Late Quaternary environmental change and a greater understanding on the forcing factors behind changing vegetation patterns than attainable at a continental scale.

This abstract is coauthored with Latin American Pollen Database members, Latin American Pollen Database, <http://www.ngdc.noaa.gov/paleo/lapd.html>.

27-14 BTH 164 Almeida-Leñero, Lucia

PALYNOLOGY OF CHIGNAHUAPAN LAKE, CENTRAL MEXICO

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A palynological análisis of sediments from Lake Chignahuapan, allowed the reconstruction of vegetation and climate. Six sediment cores were obtained. The samples were treated with acids, acetolised. The data were analysed with TILIA and CONISS.

Early Holocene, Zone I, 9800-8500 BP

Conspicuous oscillations are registered of the Pine forest and the moist forest, with *Alnus* as an important element. The oak forest remains constant. These changes correspond changes from a humid temperate climate to a temperate subhumid climate, supported by the presence of *Abies*.

Lower mid Holocene, zone II 8500-5200 BP

Pine forest is dominating, the moist forest disappears but increments at the end of the pollen zone, the oak forest seems to disappear. This period could be by erosion as it is indicated by the presence of sands. This zone corresponds to a temperate climate, without fluctuations.

Upper mid Holocene, zone III, 5200-3,500 BP

This zone is characterized by an increase of the oak forest with a maximum representation. The moist forest shows fluctuations. The pine forest shows low values with oscillations, decline of the oak and moist forest is registered.

Late Holocene, Zone IV, 3500-1300 BP

This zone is characterized by a slight increase of the pine forest, and a decrease of the moist and oak forest. It corresponds to a temperate climate, slightly colder than the preceding zone. Presence of man is indicated by the increase of *Cheno-Ams*, *Asteraceae*, *Poaceae* and the appearance of *Cucurbitaceae* and *Zea mays*.

Recent, 1300 till present

This zone is characterized by a continuous increase of grassland, and the pine forest, while the oak forest decreases. Climatic conditions are very similar to actual ones.

Conclusions

Five zones were recognized which show climatic and vegetational fluctuations of the last 10 000 years. Fluctuations are mainly changes in available humidity. Presence of *Zea mays*, *Cucurbitaceae* and *Cheno. Ams* during the last 3000 years is related with agricultural practices. The result confirm other data for the Central Mexican region.

SESSION NO. 28, 8:00 AM

Saturday, July 26, 2003

S5. Ice Sheets as Active Agents of Sediment Redistribution in the Earth System (Commission on Glaciation)

Reno Hilton Resort and Conference Center, Tahoe

28-1 8:10 AM Kleman, Johan

SPATIO-TEMPORAL PATTERNS OF FENNOSCANDIAN ICE SHEET EROSION

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Direct geological evidence for erosion beneath the Fennoscandian Ice Sheet (FIS) yields a variability between zero and >30 m per glacial cycle. Morphological evidence and cosmogenic dating confirmation indicate that large regions experienced insignificant glacial erosion despite sustained ice cover. One key factor controlling the pattern of subglacial preservation is topographically induced basal thermal zonation. This spatial variability indicates that the concept of average glacial erosion, though of interest in long-term landscape evolution models, should be applied with caution as it will involve the calculation of average erosion from physical systems (frozen-based versus wet-based) with entirely different modes of functioning. A better understanding of the glaciological mechanisms that control the geological patterns requires that the more specific where and when's of glacial erosion are addressed.

We here attempt to decipher the first-order and second-order erosion patterns of the FIS, using mapped distributions of bare bedrock (erosional regime) and thick drift covers (depositional regime), in conjunction with time-stratified ice sheet flow patterns, as the primary input data to our qualitative analysis.

Our analysis suggests that the pattern of erosion and deposition can be largely explained by considering the effects of a binary glaciation model. This model entails the existence of a Mountain Ice Sheet (MIS) configuration and a Full Fennoscandian Ice Sheet (FFIS) configuration.

MIS configurations were dominant between 2.5 and 0.9 Myr and during initial stages of subsequent glacial cycles. FFIS configurations were dominant only during the last 0.9 Myr. In the west, the erosional and depositional zones of the two configurations roughly coincide. On the other hand, these zones are spatially distanced in the central, southern and eastern parts of the area. Thick till covers occur at the formerly eastern margins of successive MIS, and we note that subsequent FFIS have been unable to completely remobilize this material, presumably because of low ice flow velocities and largely frozen-based conditions in its central parts.

28-2 8:30 AM Hindmarsh, Richard C.A.

MODELLING THE GEOMORPHOLOGICAL EFFECTS OF TILL REDISTRIBUTION: ASSESSING A DYNAMIC THEORY FOR ROGEN MORAINÉ FORMATION AND DRUMLIN FORMATION

HINDMARSH, Richard C.A.¹, DUNLOP, Paul², and CLARK, Christopher D², (1) Physical Science Division, British Antarctic Survey, High Cross, Madingley Road, Cambridge, CB1 3BZ, England, rcah@bas.ac.uk, (2) Department of Geography, Univ of Sheffield, Sheffield, England

A theory of sub-glacial till deformation which predicts the correct wavelength for Rogen moraine formation has emerged over the past few years. It relies on plausible values for ice velocity, shear stress and the water pressure beneath the ice, none of which are well constrained. These values are sufficient to define a till viscosity. The wavelength of Rogen moraine formation is particularly dependent on the ice viscosity chosen, which is a much better constrained parameter. The theory is compared with an extensive suite of Rogen moraine wavelength measurements taken from imagery of Europe and Canada.

The theory shows qualitative promise in explaining some aspects of drumlinisation of pre-existing relief, and can explain the curious phenomenon of drumlins having blunt ends at either or both ends.

The theory has yet to explain drumlin formation as a 3d instability phenomenon, and may have some difficulties in explaining the relative thicknesses of till carapaces and stratified cores, if these phenomena are associated with instabilities rather than drumlinisation of pre-existing features.

In this paper, a recent version of the theory is presented and its successes and difficulties are discussed.

28-3 8:50 AM Shaw, John

SEDIMENT EROSION, TRANSPORT AND DEPOSITION BY OUTBURST FLOODS

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Ice sheets give rise to enormous volumes of meltwater. The effects of returning meltwater to the oceans on sea level and climate are crucial aspects of earth system change. Erosion, sediment transport and deposition by ice sheets themselves are responsible for spectacular landscapes and thick sedimentary sequences. But the contribution of meltwater to these processes may be underestimated because the possibility of enormous outbursts from past ice sheets is not widely acknowledged. This situation may change in light of recent observations on modern glaciers that lend credibility to the notion that such floods took place.

I consider the evidence for such floods beneath the Pleistocene ice sheets by looking in detail at the form and sedimentology of landforms attributed to catastrophic floods. The characteristics of bedrock erosional forms (s-forms), some drumlins, fluting, hummocky terrain and transverse ridges including, Rogen moraine, are analogous with erosional forms in nature and experimental forms. Hillshade models covering hundreds of thousands of square kilometers illustrate the arrangement of these forms in vast tracts (flood paths) scaling with the ice sheets.

Two approaches are used to estimate the amount of sediment eroded from flood tracts. First, total flow volume is estimated and a range of plausible suspended sediment concentrations is applied to give a range of total sediment load. The load is converted to volume of sediment removed to obtain the depth of erosion over meltwater flow tracts. A second method obtains the average depth and volume of erosion by subtracting the present drumlinized surface from an approximation of the original land surface. The former land surface is modeled by fitting a surface to a DEM of drumlin crests. The two methods of calculation give remarkably similar estimates for the depth of erosion.

There must be a sedimentary record of these floods had they existed. Although some deposits on land and the continental shelves are candidates for deposition by outburst floods, the most promising deposits are found on the abyssal plains of the Labrador Sea and the Pacific Ocean. In the Labrador Sea, these are thick beds of detrital carbonate. Their sedimentology is as intriguing as their timing is perplexing.

28-4 9:10 AM Evans, David J.A.

GLACIAL LANDSYSTEMS: THE VALUE OF MODERN ANALOGUES IN QUATERNARY PALAEOGLACIOLOGY

EVANS, David J.A., Department of Geography & Topographic Science, Univ of Glasgow, Glasgow G12 8QQ United Kingdom, devans@geog.gla.ac.uk.

Since the introduction of the primary glacial landsystems, intensive research around modern glacier margins has led to an expansion of the landsystem concept. This has led to an appreciation of the influence of glacier morphology and dynamics in the construction of landform-sediment assemblages. Additionally, variability in landform-sediment assemblages is dictated not only by the location of deposition but also by the 'style' of glaciation. Glaciation 'styles' are a function of climate, basement and surficial geology and topography and consequently a wide range of glacial landsystems have been compiled for different ice masses and dynamics. Research on modern glacier margins defines evolving glacial landsystems according to the range of processes active at particular sites over time. This has led to the identification of landform-sediment suites indicative of specific styles of glaciation or the impacts of certain ice dynamics. Once a landform-sediment suite pertaining to a single period of glacier occupancy or activity can be identified, it often becomes possible to differentiate overprinted signatures. This is invaluable to reconstructions of Quaternary palaeoglaciology. The expanding data base on process-form relationships is applied in holistic assessments of glacial environments to provide landsystems models. Examples are provided of the following glacial landsystems: a) lowland active, temperate glacier lobes, based on Breidamerkurjökull, Iceland; b) surging glacier lobes, based on Bruarjökull and Eyjabakkajökull, Iceland; c) plateau icefields, based on examples in Arctic Norway and Iceland; and d) sub-polar glaciers, based on the Canadian high arctic. These models are then applied to case studies of palaeoglaciological reconstruction.

28-5 9:30 AM Piotrowski, Jan A.**LAND-BASED ICE STREAMS OF THE SOUTHERN SCANDINAVIAN ICE SHEET: MOVEMENT MECHANISMS AND ICE/BED INTERACTIONS**

PIOTROWSKI, Jan A.¹, JØRGENSEN, Flemming², KRISTIANSEN, Sonny¹, LARSEN, Nicolaj K.¹, RATTAS, Maris³, WINDELBERG, Sophia⁴, and WYSOTA, Wojciech⁵,
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The Peribaltic area between Denmark and Estonia experienced repeated and non-synchronous ice streaming during the last glaciation. These ice streams are believed to have been major dynamic elements of the southern periphery of the Scandinavian Ice Sheet (SIS), controlling regional-scale mass balance and sediment redistribution patterns. The most prominent of them was the Baltic Ice Stream that has operated for hundreds of kilometres along the Baltic Sea basin and fed numerous second-rank ice streams along the ice sheet margin. All ice streams in the area were soft-bedded and land-based, and their terminal areas are accessible to direct geological studies.

Geomorphological data (attenuated drumlins, subglacial meltwater channels and eskers), together with geological (striated bedrock pavements and soft-sediment deformations) and hydrogeological data (substratum hydraulic conductivity) indicate that ice streams' fast flow was facilitated by temporarily and spatially transient mosaic of enhanced basal sliding and bed deformation. Subglacial water pressures were in the vicinity of glacier flotation point and small variations of water pressures, possibly caused by local parameters such as the drainage capacity of the substratum, controlled the ice movement mechanism.

The outermost parts of the ice streams were highly dynamic in the sense of local flow directions and contrasting flow velocities. In some areas along past ice margins thick accumulations of boulder gravel deposited from high-energy subglacial meltwater conduits occur. Close to the ice limits, meltwater channels containing eskers are found side-by-side with drumlins. It is suggested that only models involving complex interactions between subglacial hydraulics and soft sediment rheology can constrain flow dynamics of ice streams along the southern margin of the SIS.

28-6 10:10 AM Tulaczyk, Slawek**PRODUCTION- AND TRANSPORT-LIMITED EROSION BENEATH ICE SHEETS: A COUPLED MODEL OF SUBGLACIAL EROSION AND SEDIMENT TRANSPORT**

TULACZYK, Slawek¹, VOGEL, Stefan¹, BOUGAMONT, Marion¹, JOUGHIN, Ian², and HOWAT, Ian M.¹, (1) Earth Sciences, UCSC, Santa Cruz, CA 95064, tulaczyk@es.ucsc.edu, (2) Jet Propulsion Lab, MS 300-235, 4800 Oak Grove Drive, Pasadena, CA 91109

Many of the highly populated regions of the Northern Hemisphere were shaped by sub-ice sheet erosion and sedimentation. In addition, glacial landforms and sediments give insights into past physical conditions beneath ice sheets. Yet, subglacial geomorphic and sedimentary systems are much less understood than their fluvial and eolian counterparts. Most existing models of subglacial erosion are based on observational studies performed on mountain glaciers. These models typically assume that glacial erosion rates are (nearly) linearly proportional to ice velocity or to work done by flowing ice. The 'classical' models of subglacial erosion assume that subglacial sediment production is independent of sediment transport and make no provision for negative erosion rates (i.e. deposition).

Here we present a mathematical model, which couples subglacial erosion, transport, and deposition. The model is an outgrowth of our laboratory simulations of rock erosion by shearing till. Results of these laboratory experiments indicate that glacial erosion rates should decrease by up to several orders of magnitude when subglacial till builds up beneath an ice base. The classical, production-limited model of subglacial erosion is valid when debris removal rates are greater or equal to the rate of debris production. This should be the case where ice overrides resistant bedrock and/or subglacial water drainage removes debris very efficiently. The other end-member situation is the 'transport-limited' erosion, which should predominate where ice overrides highly erodible bedrock or sediments and debris is stored in a subglacial till layer. Then, subglacial erosion rates are dictated by the horizontal divergence of till flux.

We conjecture that widespread subglacial till layers should occur in these parts of an ice sheet where 'transport-limited' erosion predominates. We use ice velocity data from West Antarctica to illustrate that there the transport-limited parametrization of subglacial erosion is more successful at explaining the regional topography than the classical, production-limited parametrization.

Our main conclusion is that realistic models of subglacial geomorphic and sedimentary processes should incorporate the close coupling between subglacial erosion and sediment transport.

28-7 10:30 AM Boulton, Geoffrey**A THEORY OF DRAINAGE BENEATH ICE SHEETS, AND THE ORIGIN OF ESKER AND TUNNEL VALLEY SYSTEMS FROM THE LAST EUROPEAN ICE SHEET**

BOULTON, Geoffrey¹, VIDSTRAND, Patrick², MAILLOT, Bertrand³, and ZATSEPIN, Sergei¹, (1) School of GeoSciences, Univ of Edinburgh, Kings Buildings, West Mains Rd, Edinburgh, EH9 3JW, g.boulton@ed.ac.uk, (2) Chalmers Univ, Se-41296, Gothenburg, (3) Department of Geology, Université de Cergy, Paris, France

The hydraulic system and the efficiency of drainage beneath an ice sheet determine the subglacial water pressure regime, and many aspects of ice sheet dynamics and stability. Esker systems and tunnel valleys are a reflection of the subglacial hydraulic state, such that a theory of their formation would be a key to understanding this vital part of the ice sheet system. A theory is developed that the ice sheet wide pattern of distribution of major esker and tunnel valley systems is a consequence of dynamic interactions between subglacial tunnel flow and groundwater flow, primarily controlled by the basal melting rate and bed transmissivity. Meltwater is drawn to tunnels by transverse-to-ice-flow groundwater flow, and efficiently discharged from the glacier by the longitudinal tunnels. Tunnel spacings relax towards the maximum spacing that is able to discharge the winter meltwater flux (basal melting), without creating dynamic instability in the ice sheet. Summer meltwater fluxes, involving a major component of surface meltwater, are the major controls on glaciofluvial erosion and sediment flux.

The theory is tested by its ability to simulate a modern glacier meltwater system and to simulate the observed systematic changes in esker and tunnel valley frequency in the area of the last European ice sheet.

The theory predicts that this system also controls the pattern of deep groundwater circulation; downward flows in inter-channel zones, and strong upwards flow beneath channels. This pattern has three important effects: on the geochemistry of subglacial groundwaters; in producing large upward potential gradients beneath channels with a tendency for quicksand conditions beneath channel floors; in generating large amounts of heat in permeable sediments beneath channels. The former process can create carbonate precipitates with distinctive geochemistries, and can be used to test the theory. It is suggested that the latter two processes are of major importance in the development of tunnel valleys.

28-8 10:50 AM Clark, Chris D.**SEDIMENT TRANSFER BY PALAEO-ICE STREAMS**

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The anatomy of the ice stream system can be idealised as a series of zones through which sediment may be transferred from source-to-sink. Material may be eroded and entrained over large areas of the catchment zone which is fed into the ice stream trunk via the onset zone (where flow acceleration occurs). Given high velocities in the onset and trunk zones this is where most erosion is expected. Ice stream termini may be marine with a rapidly-calving margin or feeding an ice shelf, or terrestrial, with a splayed lobe of low relief, or discharging into an impounded glacial lake. If the ice stream was a powerful agent of erosion and transport the terminus zone should yield a spatially-focused accumulation of sediment in contrast to the neighbouring margin. For marine-terminating ice streams, a far-travelled component may be recorded in ocean cores by ice-rafted debris (Heinrich layers).

We have compiled estimates of sediment transfer from the literature and use our own observations of palaeo-ice stream tracks to explore the question of how effective ice streams are in redistributing sediment at continental scales. One view of ice streams found in deep topographic troughs is that they eroded these and moved considerable volumes of sediment. This is supported by huge trough mouth fans which can provide valuable estimates of sediment flux, although the chicken and egg problem remains to be resolved, i.e. which came first the ice stream or the trough? Other records of ice stream activity indicate that they functioned by merely smearing existing sediments without transferring sediment in significant quantities. We illustrate a continuum of sediment redistribution by ice streams with reference to three ice streams that drained the north-western sector of the Laurentide Ice Sheet. The M'Clintock Channel Ice Stream eroded and transferred large volumes of sediment, The Dubawnt Lake Ice Stream transported very little, and the MacKenzie Corridor Ice Stream System attests to extremely variable sediment redistribution. It is concluded that sediment transfer beneath ice sheets is highly variable and patchy in time and space, with the main controls being the thermal regime (warm vs. cold based), emergence of ice streams and their longevity, and the nature of ice stream basal processes (basal sliding, sediment deformation, groove-ploughing).

28-9 11:10 AM Iverson, Neal R.**LABORATORY STUDIES OF TILL MECHANICAL BEHAVIOR AND FABRIC EVOLUTION DURING SHEAR**

IVERSON, Neal R.¹, MOORE, Peter L.¹, HOOVER, Thomas S.², THOMASON, Jason F.¹, and MCLOUGHLIN, Meaghan P.¹, (1) Dept. of Geological and Atmospheric Sciences, Iowa State Univ, 253 Science 1, Ames, IA 50011, niverson@iastate.edu, (2) Wisconsin Geological and Natural History Survey, Univ of Wisconsin, 3817 Mineral Point Road, Madison, WI 53705

Shear deformation of subglacial till has been invoked widely to explain large sediment fluxes from some Pleistocene ice masses and genesis of subglacial landforms. Empirical studies of this process have usually involved either measurements beneath modern glaciers, in which only a small fraction of the bed can be studied, or studies of the geologic record, which is more accessible but difficult to interpret. In contrast, laboratory studies of till deformation have been relatively few, reflecting the weak experimental tradition in glacial geomorphology relative to most other disciplines of Earth science. In 1995, a ring-shear device that shears a large till specimen (0.6 m O.D., 80 mm thickness, 125 mm width) at either constant shear rates or stresses was constructed to help fill this void.

Experiments reveal unexpected mechanical behavior of till. Experiments at constant shear stresses illustrate that pore-water pressure is reduced during increases in shear rate, due to the effect of shear rate on dilation rate, which can result in slow episodic shear without external changes in forcing. Thus, pore-water pressure is not necessarily independent of shear rate, as is usually assumed. Similarly, during experiments designed to study plowing of clasts through the bed surface, pore-pressure diffusion does not keep pace with the rate of till compaction in front of clasts, resulting in pore-water pressure well in excess of hydrostatic that greatly reduces plowing resistance. Since such clasts couple a glacier to its soft bed, this process will weaken the ice-bed coupling, particularly at high sliding speeds, and cause slip of ice over the bed.

Ring-shear experiments also provide new techniques for interpreting the geologic record. Experiments on tills conducted to various shear strains allow till structural characteristics to be calibrated to shear strain. Macroscopic, elongate particles in shearing till align parallel to the shearing direction to form a strong fabric at shear strains of about 2. Alignment of clay-mineral particles in till, measured using high-resolution, X-ray texture goniometry, increases progressively up to shear strains as large as 140. These experiments, by linking till attributes to shear-strain magnitude, allow determination of the extent to which basal tills of the geologic record have been sheared.

28-10 11:30 AM Clark, Peter U.**MODELING THE CONTRIBUTION OF GLACIAL EROSION TO THE CENOZOIC SR ISOTOPE EVOLUTION OF SEAWATER**

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The increase in the oceanic Sr isotopic ratio during the Cenozoic reflects some combination of increased glaciation and continental collision of India with Asia. Here, we use a Sr model built into an existing coupled climate-ice sheet-sediment model to examine the contribution of Antarctic glaciation to the flux of radiogenic Sr to the ocean. An asynchronous coupling method is used, which enables the ice model spanning the whole Antarctic continent to be integrated for several million years through the observed major transition to large ice volumes around the Eocene-Oligocene boundary. The sediment component predicts the thickness of unconsolidated sediment in response to deformation under the ice sheet, generation by quarrying of exposed bedrock, and physical erosion and fluvial transport to the ocean in ice-free areas. The fractions of the major minerals within the sediment that are relevant to Sr are added as tracers. Their fractions within the evolving sediment layer are predicted in the model, depending on (i) advection by subglacial deformation, (ii) input of quarried bedrock, and (iii) chemical weathering in a 1-m thick soil layer in ice-free areas, at a rate depending on time of exposure modified by a species-dependent factor. Separate fractions are predicted for the soil and sub-soil layers in ice-free regions, mixed together when overrun by ice. The rate of chemical weathering for each species is calculated at each timestep, then summed over the entire Antarctic continent, and used to deduce the contribution to the change of ⁸⁷Sr/⁸⁶Sr of global ocean water throughout the simulation.

Preliminary results for a 5 Myr run of the coupled model across the E-O transition predict a rate of increase of ocean ⁸⁷Sr/⁸⁶Sr of only ~.00006 per Myr, which is smaller than the observed oceanic rate for this time. Whereas this might indicate the greater contribution from ongoing Asia-India collision, the low rate from Antarctic glaciation might be due to the suddenness of the transition in the ice model, which exhibits a very rapid jump from minor ice caps to a large ice sheet. A more gradual transition over several million years, with more extensive and repeated fluctuations in ice area over more of the continent, would convert more bedrock to till and thus increase flux of radiogenic Sr to the ocean.