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LOESS

Eroded cliffs in the Chinese Loess Plateau. The natural exposures show paler and darker bands that reflect, respectively, alternations between loess deposition ("glacials") and paleosol development ("interglacials")(Photo: B. Maher, University of East Anglia, UK).

EDITORIAL

Continuing our intention to focus on specific themes within each Newsletter, the present issue includes a major section devoted to paleoenvironmental research on the Chinese loess and paleosol sequences that provide one of the world's most detailed and continuous continental records of past environmental change.

This compilation serves an additional purpose, since it allows us to honor Professor Tungsheng Liu in his 80th year. Among many other notable accomplishments, Professor Liu is the father of paleoenvironmental research on Chinese loess. His interests focused on this theme in the late 50's after earlier research in paleontology. As early as 1954, he had founded the Quaternary Laboratory in the Institute of Geology, Chinese Academy of Sciences. This was the first, and for a long time the only institution of its kind in China. By 1961 he was able to present to the INQUA Congress an account of the long term paleoclimatic record from key loess sections that reinforced the recent marine evidence for many more glacial and interglacial cycles than had previously been believed. During the 70's and 80's, intensive studies on the Luochuan type section led to fruitful international collaboration and to the founding of the Xian Laboratory of Loess and Quaternary Geology, of which Professor Liu was the first Director. His leadership within and influence on the development of Quaternary Science, Environmental Geology and Global Change Research in China, and the international respect for his work, cannot be overstated. PAGES has been fortunate to benefit from his wise input throughout its short history and it is an honor for PAGES to have an opportunity to dedicate this compilation to him.

The short reports we present confirm the unique value of the loess record. They also illustrate new approaches to refining climate proxies from key sections, as well as to improving chronological control. The stimulus provided by Professor Liu's pioneering work has evolved into a dynamic field of research with just that beguiling mixture of coherence and debate to keep us all on our toes.

Finally, I would like to acknowledge the help of Zhentang Guo in compiling the reports presented here.

Frank Oldfield

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Technical notes

For readability the figures for the 13 loess reports have been numbered in sequence.

Full references for the loess papers can be obtained from the respective authors.

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Loess Dating Progress in China

Loess is a sediment difficult to date. The loess sequences of the last climatic cycle in China are usually dated by radiocarbon and thermoluminescence (TL) measurements. Correlation with marine $\delta^{18}O$ records and orbital cycles is also frequently used for the construction of time-scales. In previous studies, soil S0 was correlated with the deep-sea oxygen isotope stage 1; loess L1 was correlated with isotope stages 2, 3 and 4, the weak soil complex within L1 with stage 3, and the S1 soil with stage 5.

Recently, the Weinan loess section was intensively dated for determining the ages of the major stratigraphic boundaries using TL and twenty-eight radiocarbon dates. The radiocarbon dating was carried out on the humin fraction of the organic matter in the samples using AMS. The results confirms the previous land-sea correlation pattern except for the lower boundary of the soil complex in the Malan loess (*Fig. 1*): most of the TL dating yielded ages centered at ~50 ka, which is significantly younger than the age of stage 3 (~59 ka) according to Martinson *et al* (1987). The TL age is, however, in good agreement with the oxygen isotope age of ~50 ka provided by the eolian dust record in the North Pacific (Hovan *et al.* 1989), which represents a direct link between the Chinese loess and marine $\delta^{18}O$ records. These dates provide an independent timescale for the loess-paleosol sequence of the last climatic cycle.

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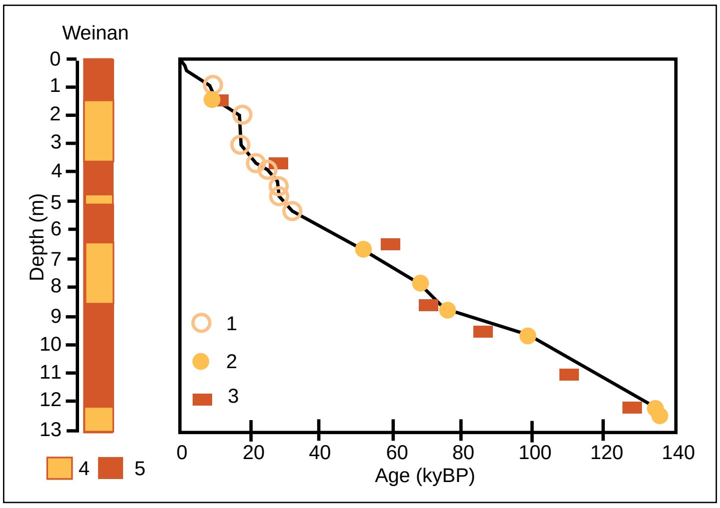

Fig. 1: Depth-Age transformation of the Weinan loess section based on absolute dating compared with that obtained by correlating with the SPECMAP time scale (figure from Liu J.Q. et al., 1994). SPECMAP data are from Imbrie et al., 1984). 1. AMS 14C age; 2. TL age; 3. stratigraphic boundary age obtained through correlation with SPECMAP $\delta^{18}O$ record; 4. Loess; 5. Paleosol

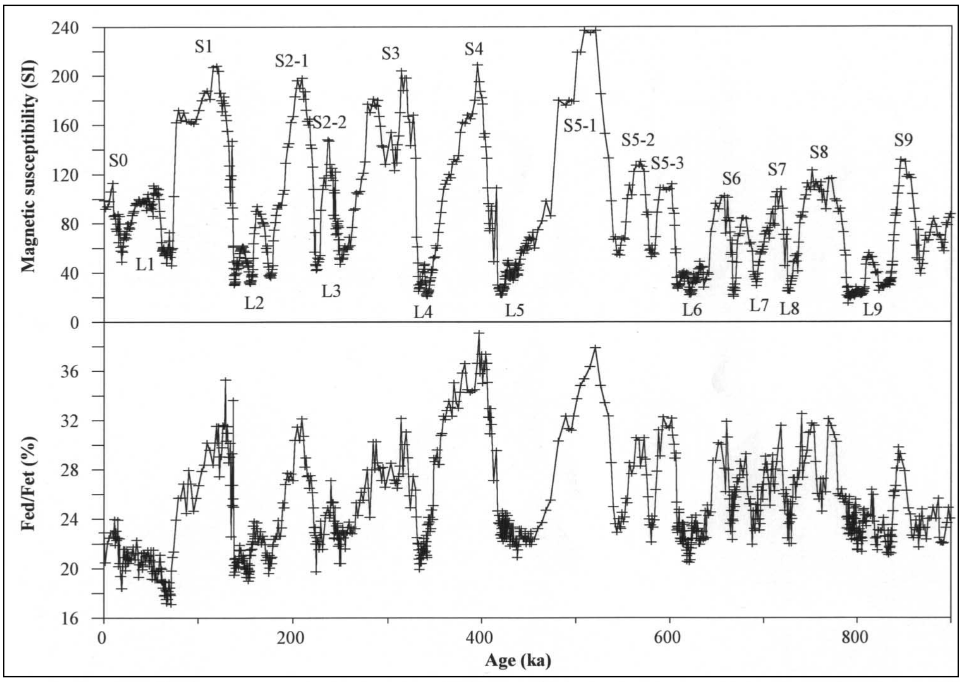

Fig. 2: Variations in the Fed/Fet ratio from the Changwu loess section compared with the magnetic susceptibility values. The timesacle is obtained by correlating the susceptibility signals with that of Xifeng (see Kukla et al., 1990, Trans. Royal Society of Edinburgh: Earth Sciences, 81:263-288)

A new Proxy of the East Asian Paleomonsoon

Magnetic susceptibility variations in Chinese loess-paleosol sequences are used by many authors as a proxy for the strength of East-Asian summer monsoon. Susceptibility values are higher in paleosols than in the overlying and underlying loess. Recently, we carried out a paleopedological study on three loess sections (Weinan, 34.33°N, 109.5°E; Changwu 35.2°N, 107.8°E and Xifeng 35.7°N, 107.6°E) for the last 900 ka using various pedological methods and found that the susceptibility value is not always consistent with the pedological indicators *(Fig. 2)*. For example: (1) The S4, S5-1 and S5-3 soils represent the most developed soils while the susceptibility values for S4 and S5-3 are not higher than for the other soil units (in the case of S5-3 they are even lower). (2) For the three sub-units of S5, the intensity of pedogenesis shows an order of S5-1 (strongest), S5-3 and S5-2 (weakest) while the susceptibility shows an order of S5-1 (highest), S5-2 and S5-3 (lowest). (3) The soils S6, S7 and S8 are similar to S2 and S3 while the susceptibility values for the major soil units older than S5-1 are much lower than for the younger interglacial soils (S0 to S5-1), even lower than for some weakly developed interstadial soils in the loess units L1, L2 and L3. These results therefore provide a complex picture for the climatic significance of the magnetic susceptibility in paleosols. Understanding the basis of this complexity will require much additional work. The Loess Plateau is located in the East-Asian monsoon zone. Since the average soil temperatures in the region are below 0°C from late autumn to early spring under modern interglacial conditions, the chemical weathering of loess mainly depends upon summer temperatures and precipitation. Consequently, a chemical weathering index would be expected to reflect the paleomonsoon intensity: high weathering intensity can be interpreted as an indication of strengthened summer monsoon and lower weathering intensity indicates the reverse. Recently, we have generated a high-resolution paleo-weathering

The PAGES report 96-4 "Continental Drilling for Paleoclimatic Records" has been reprinted by the Geoforschungszentrum Potsdam and is again available in hardcopy from the PAGES IPO in Bern.
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record (at 10 cm intervals) for the Changwu loess section using the ratio of free Fe_2O_3 (Fed) (extracted by dithionite-bicarbonate-citrate method) to total Fe_2O_3 widely used by pedologists for characterizing the soil weathering intensity. The new proxy is highly consistent with other indicators of the intensity of pedogenesis: (1) the most developed S4, S5-1 and S5-3 have the highest Fed / Fet ratio; (2) for the three sub-units of S5, the ratio is the highest for S5-1 and lowest for S5-2, thus in close agreement with the macro and micromorphological observations; (3) the ratios for the soil units S6, S7 and S8 are similar to those for S2 and S3; and (4) the susceptibility time-series shows a major shift in amplitude at ~ 600 ka BP while that for the new proxy is at ~ 800 ka, similar to that defined according to the paleosols. Therefore the Fed / Fet ratio seems to be a better indicator of the strength of the East Asian summer monsoon than do variations in magnetic susceptibility.

We believe that the strong development of the S4, S5-1 and S5-3 soils is not solely a function of a longer period of soil-formation, but of climate conditions. The data match well with the higher $\delta^{13}C$ values (marine oxygen isotope stages 11, 13 and 15) in the marine record (see Raymon *et al.*, 1990, *Earth and Planetary Science Letters*, 97:353-368; and Oppo *et al.*, 1990, *Palaeoceanography*, 5:43-54). These periods also correspond with the periods of greatest Atlantic-Pacific benthic $\delta^{13}C$ gradients, suggesting a link with the rate of the deep-water formation in the North Atlantic.

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Reconstruction of Paleoclimate in the Loess Plateau using Non-Linear Mathematical Methods

In reconstructions of Quaternary climate, most researchers have made quantitative estimates of paleoclimate from linear relations between paleoclimatic proxy records and single climatic factors (e.g. temperature or precipitation), and established non-linear equations related to two climatic parameters such as temperature and precipitation by using response surface analysis. In this study, we use a non-linear inversion method to synthesize the data of three different proxy indicators and reconstruct paleoclimate. 63 records of Magnetic susceptibility (MS), 12 of the total Fe_2O_3 (Fet) and 28 of the mollusk species (*Vallonia* cf. *pulchella*) were taken from modern surface soils of the Loess Plateau and used as proxy indicators of physical, chemical and biological records. For stratigraphical study, we chose the Luochuan loess section, a standard section for Chinese loess. This section was sampled at intervals of 10 cm from S1 to S0. A total of 120 samples for MS, Fet and mollusks have been studied. The data for annual mean temperature (AMT) and annual mean precipitation (AMP) at the modern surface soil sites were used to set up the multiple regression climatic functions. *Fig. 3* shows temperature and precipitation variation in Luochuan over the past 11,000 ka based on the non-linear inversion method. From *Fig. 3*, we can see that there are some phase differences in the variations of the three proxy records. However, the AMT and AMP satisfy the non-linear relationship between the three climatic proxies and temperature and precipitation within acceptable limits, indicating a mutually consistent solution of the three climatic proxies.

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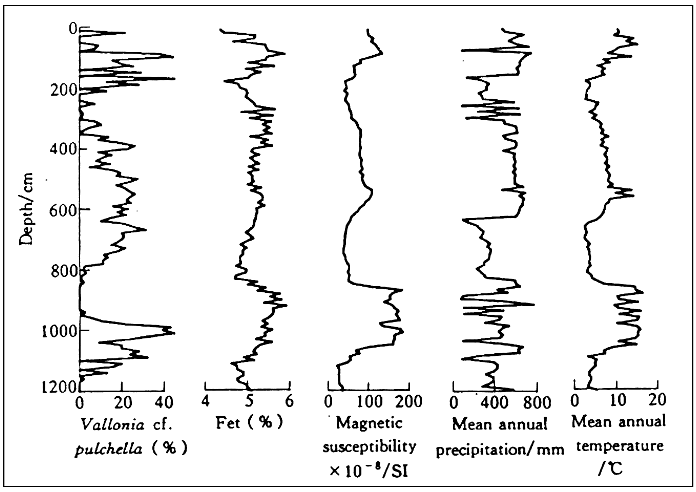

Fig. 3: Variations in the three proxy records of Vallonia *cf.* pulchella, *Fet and MS in the Luochuan loess section since the last interglacial together with variations in AMT and AMP as derived from the non-linear inversion of these three proxy indicators.*

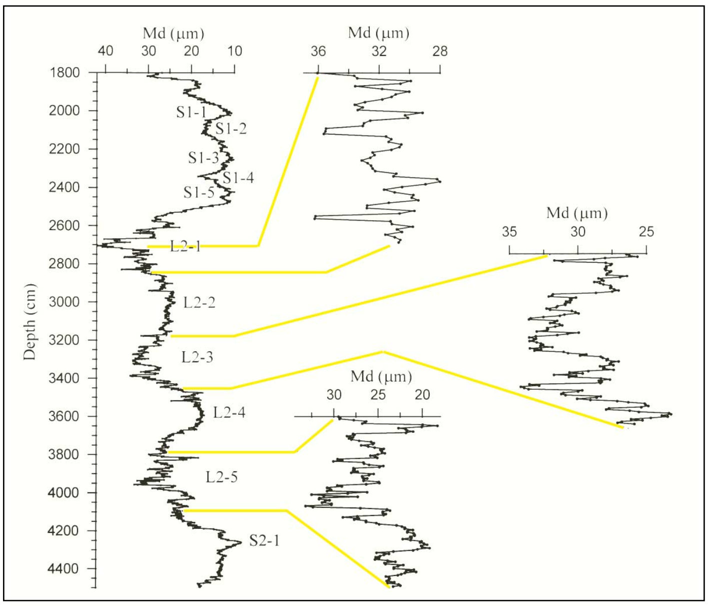

Fig. 4: Huining high resolution grain size record

Climatic Instability during the Penultimate Glaciation: Evidence from the Chinese Loess Deposits

Since the recognition of millennial-scale climatic oscillations in the Greenland ice cores, high-resolution records derived from various deposits all over the world have convincingly demonstrated that paleoclimatic variability of this kind is recorded in different parts of the global climate system, implying that climate instability during the last glacial period may be regarded as a global phenomenon. However, most of the high-resolution proxy records obtained hitherto only cover the last glaciation, and so climatic variability on sub-Milankovitch time scales in the older glacial periods is poorly known. Recently, we generated a high-resolution grain size record at Huining, the northwestern part of the Loess Plateau. The loess-soil sequence accumulated during the last two glacial-interglacial periods is about 45 m thick in the Huining section. We took samples of this part at 2 cm intervals. This sample spacing yields an average depositional time resolution of below a hundred years. Examination of the grain size record for the last

continued on page 4

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glaciation shows that the millennial-scale climatic variations in the Loess Plateau can be correlated fairly well with the Dansgaard-Oeschger cycles documented in the Greenland ice cores. *Fig. 4 (previous page)* shows the grain size curve of the S2-L2-S1 portion at Huining. The soils S2 and S1 were accumulated respectively during the penultimate and last interglacial periods; the loess bed L2 during the penultimate glaciation. Grain size changes in L2 clearly indicate two maxima and three minima, which are obviously forced by the precessional changes in the Earth's orbit. When we increase resolution for parts of the grain size minima, as shown in *Fig. 4*, it is seen that frequent, large-amplitude, millennial-scale variability also occurred during the stadials of the penultimate glaciation. This preliminary result implies that millennial-scale climate variability could be a common feature in the glacial periods of the late Pleistocene.

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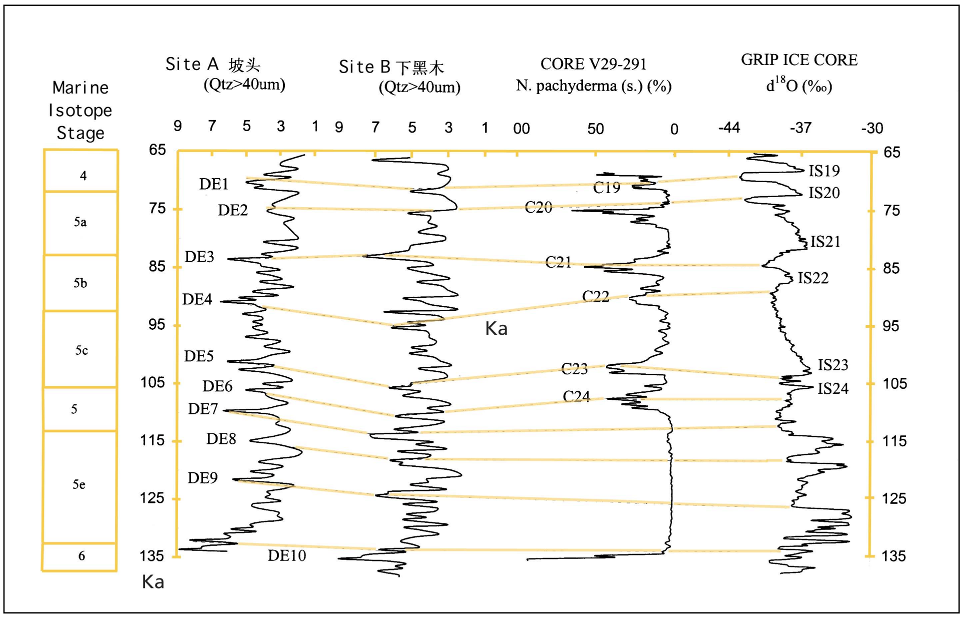

Fig. 5: Loess-Paleosol-Profiles in central China in comparison with North-Atlantic sediment cores and Greenland ice-sheet cores

Millennial-Scale Climatic Oscillations during the Last Interglaciation in Central China

Repeated southward excursions of North Atlantic polar water during the last interglacial ($\delta^{18}O$ stage 5, 130-74 ka) are recorded by planktonic foraminifera and ice-rafted detritus (IRD) in North Atlantic sediment cores, and Greenland ice-sheet cores display quasi-synchronous fluctuations. Comparable high-frequency variations in the East Asian winter monsoon climate are discernible in three loess-paleosol profiles in central China that span the last interglacial *(Fig. 5)*. Peak values of the >40 µm quartz fraction and bulk sediment samples from the S1 (last-interglacial) accretionary paleosol complex reflect major dust-flux events when winter monsoon winds strengthened. Frequent oscillations of the dust flux and nine significant dust events are recorded. Six events, falling between ca. 110 and 70 ka, are correlated with cold peaks (C19-24) identified in North Atlantic cores. Two comparable dust peaks occur within paleosol S1SS3 (=substage 5e); the older of these, dating to ca. 121 ka, may correlate with a brief cold event recently recognized in high-resolution marine and terrestrial climate-proxy records.

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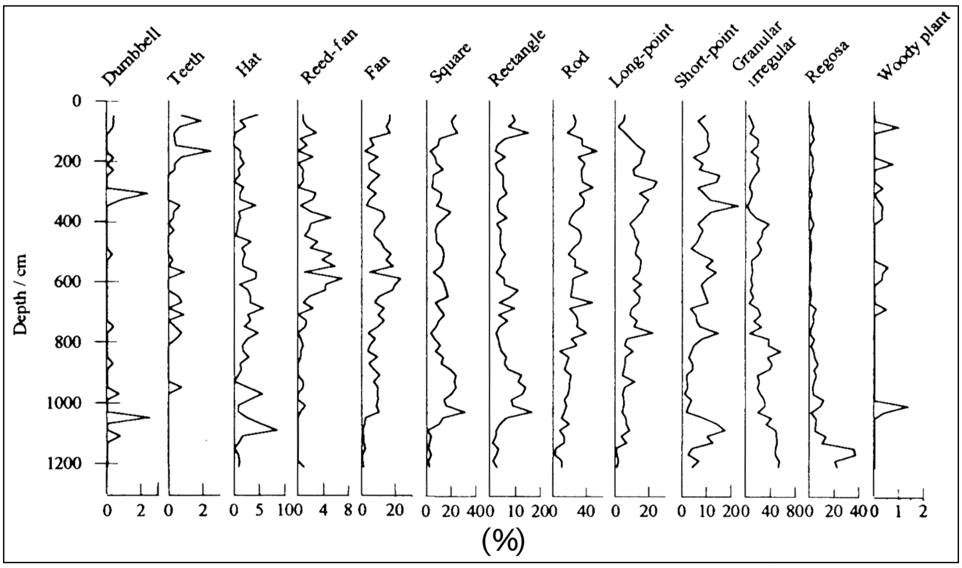

Fig. 6: Diagram of the percentage frequencies of 13 major phytolith types from the Baoji loess sequence for the last 150 ka.

Seasonal Climatic Variation recorded by Phytolith Assemblages from the Baoji Loess Sequence in Central China over the last 150 ka

153 samples from modern surface soils in China were collected and analyzed quantitatively alongside related meteorological data. 25 types of opal phytoliths, with significant climatic linkages, were selected to establish climatic transfer functions. The modern climatic parameters used in this study are based on data for annual mean temperature and annual mean precipitation over the past 40 years from the Chinese National Meteorological Bureau (1995). *Fig. 6* is a percentage diagram of 13 major phytolith types from the Baoji loess sequence in the south of the Loess

Plateau. *Fig. 7* shows the phytolith-based reconstructions of temperature and precipitation in Baoji over the last 150 ka and the 95% confidence interval.

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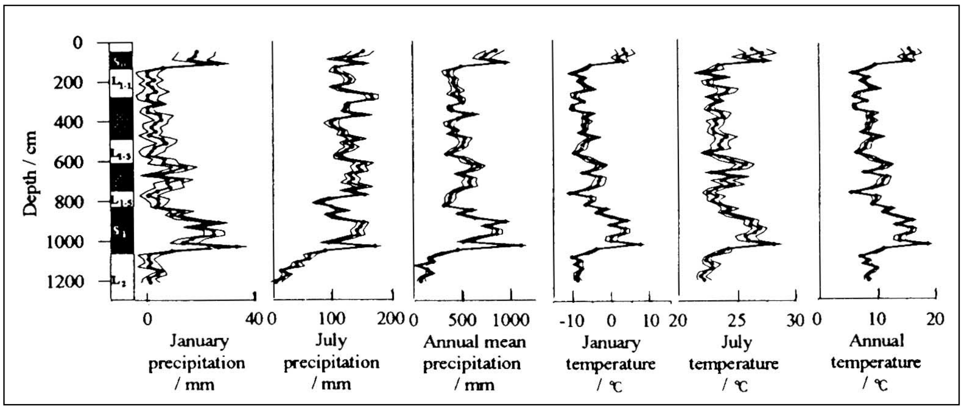

Fig. 7: Estimated temperature and precipitation variations in Baoji during the last 150 ka based on phytolith-climate transfer functions. Thick lines represent estimated regression values, fine lines are 95% confidence intervals.

Comparison of East Asian Monsoon Proxies from the Central China Loess Plateau and Lake Biwa

The pattern of climate in eastern Asia is dominated by the summer and winter monsoons (Gao, 1962). The loess-paleosol sequence on the Loess Plateau of central China constitutes an excellent proxy record of variations in East Asian monsoon climate over the past 2.5 Ma (An *et al*., 1990; 1991; Ding *et al*., 1995). Magnetic susceptibility (MS) of the loess and paleosols has been used as a proxy indicator for the summer monsoon intensity, i.e., high magnetic susceptibility values reflect increased summer monsoon intensity (An *et al*., 1991); while the median diameter of quartz (QMD) isolated from the loess and paleosols can be regarded as a proxy index of the strength of winter monsoon winds, i.e., the greater the quartz median diameter, the stronger the winter monsoon winds (Xiao *et al*., 1995). Studies on grain-size distribution, oxygen isotope composition and micromorphological features of monomineralic quartz isolated from sediments of Lake Biwa, central Japan suggested that quartz particles finer than 10 µm were derived, through the transport of the winter monsoon, from arid/semiarid regions of the Asian continent, and thereby can be regarded as eolian quartz (Xiao *et al*., 1997a). By contrast, quartz grains coarser than 20 µm in the Lake Biwa sediments were considered to be derived, through soil erosion, from the surrounding terrain of the lake (Xiao *et al*., 1997b). Eolian quartz flux (EQF) to Lake Biwa provides direct information on variations in the East Asian winter monsoon strength, i.e., the higher the eolian quartz flux, the stronger the winter monsoon winds (Xiao *et al*., 1997a); whereas the fluvial quartz flux (FQF) reflects significant changes in paleoprecipitation over the lake area, and thus can be associated with the intensity of the summer monsoon, i.e., high fluvial quartz flux values imply increases in summer monsoon intensity (Xiao *et al*., 1997b).

As shown in figure 8, the EQF and FQF records of Lake Biwa sediments can be well compared with the QMD and MS records of the Chinese loess and paleosols. The intervals of high EQF values correspond to the periods of great QMD values, whereas the intervals of high FQF values correlate to the periods of high MS values. The EQF and the QMD as winter monsoon proxies indicate that the winter monsoon strengthened during periods marked by high EQF and QMD values, and it was relatively weaker when EQF and QMD values were lower. As as summer monsoon proxies, the FQF and the MS reveal significant variations in the intensity of the summer monsoon, i.e., the higher the FQF and MS values, the stronger the summer monsoon circulation. Variations in winter monsoon strength indicated by the EQF and QMD proxies bear a general inverse relation to those in summer monsoon intensity inferred from the FQF and MS proxies.

These four proxy records of East Asian paleomonsoon climate can be correlated with the SPECMAP marine $\delta^{18}O$ stages 1 through 6 (Martinson *et al*., 1987) *(Fig. 8)*. The main intervals of low EQF and QMD values and high FQF and MS values apparently coincide with SPECMAP $\delta^{18}O$ substages 5e, 5c, and 5a, stage 3, and the early part of stage 1, while the main intervals of great EQF and QMD values and low FQF and MS values occurred during $\delta^{18}O$ stages 4 and 2.

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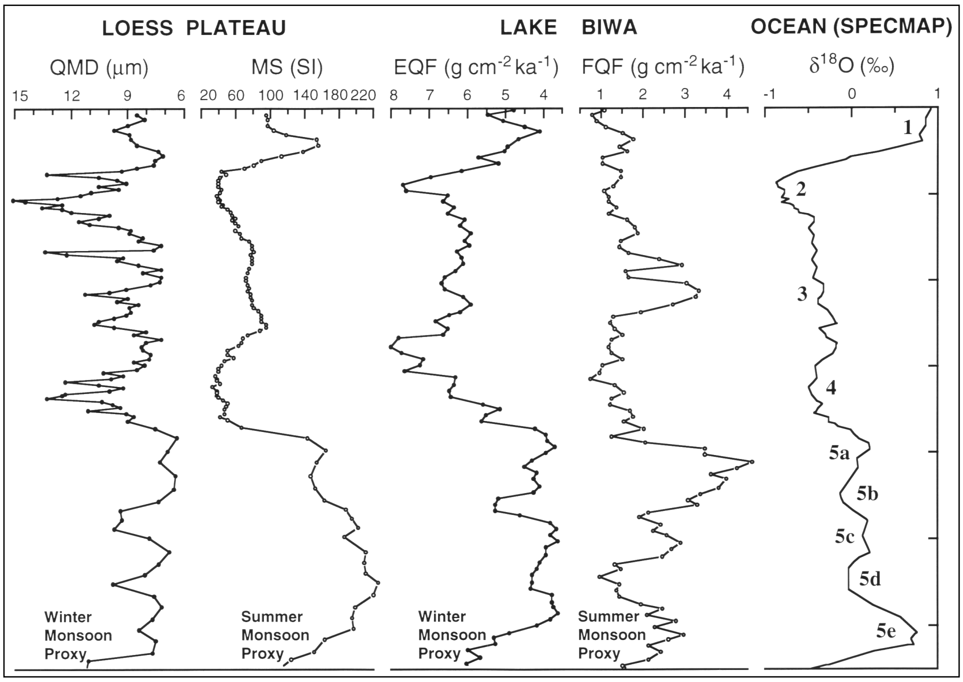

Fig. 8: Time series of the last ca. 130,000 years comparing the quartz median diameter (QMD) and magnetic susceptibility (MS) of the loess-paleosol sequence at Luochuan in the central part of the Loess Plateau and the eolian quartz flux (EQF) and fluvial quartz flux (FQF) of Lake Biwa sediments the SPECMAP $\delta^{18}O$ record (from Quaternary Science Reviews, in press).

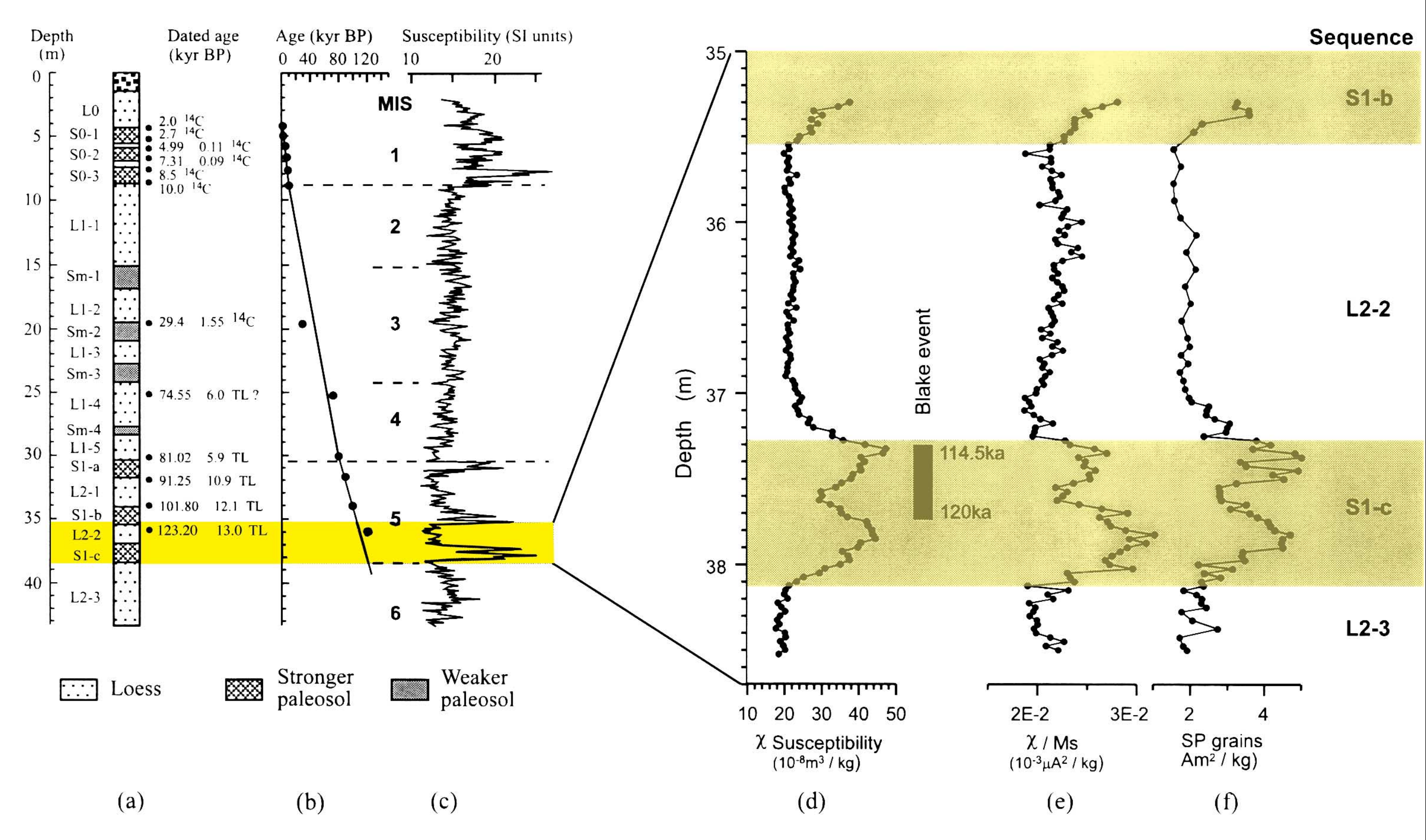

Fig. 9: Diagram showing the loess-paleosol sequence of the Jiuzhoutai well section (a) in Lanzhou on the western Loess Plateau, its age-depth relationship (b), volume magnetic susceptibility measured in the well (c), variations of mass-specific susceptibility (χ) (d), χ / Ms (saturation magnetization) (e) and super paramagnetic (SP) grains measured on MPMS in the depth 35.3-38.5m. The black bar indicates the Blake event (Fang et al., 1997). Note the covariant changes of x/Ms and SP grains (f) suggest that the summer monsoon experienced large amplitude and rapid changes during the Eemian interglacial (S1-c), which may correlate with oxygen isotope record of the GRIP ice core from Greenland (Dansgaard et al., 1993)

Last Interglacial sharp Monsoon Fluctuations: Rock Magnetic and Paleomagnetic Evidence from High Resolution Loess-Paleosol Sequence, Lanzhou, China

Climatic change during the last interglacial has become an important focus in global change research. Improved reconstructions may enhance our understanding of possible future climate change. Moreover, there are major uncertainties about the reliability of the apparent 'Eemian' instability recorded in Greenland ice cores (Dansgaard *et al.*, 1993).

The western Loess Plateau contains the thickest loess deposits in the world. The combination of rapid, often continuous accumulation and weak pedogenesis (hence limited, post-accumulation overprinting by subsequent weathering), provides one of the best opportunities to reconstruct past monsoon climatic changes with high temporal resolution. This in turn points to the area as a crucial one for shedding light on climate variability during the Eemian, Isotope Stage 5e.

A late Pleistocene high-resolution loess-paleosol sequence has been obtained from a 40-m well dug in a loess section at Jiuzhoutai in the City of Lanzhou in the western Loess Plateau of China. The last interglacial interval consists of three individual paleosols marked downwards as S1-a, S1-b and S1-c separated by two loess layers L2-1 and L2-2 *(Fig. 9a)*. Previous study has shown that paleosols S1-a, S1-b and S1-c correlate with sub-stages 5a, 5c and 5e of marine isotope records (MIS), respectively *(Fig. 9c)*. Samples were taken at 1-2.5 cm intervals for S1 series, yielding resolutions of c. 60-150 years per sample.

The Blake Event was found in the paleomagnetic record at the boundary between loess L2-2 and paleosol S1-c after thermal demagnetization and measurement on a 2G magnetometer. This provides an age estimation of 119.97 - 114.47 kyr BP for this part of sequence *(Fig. 9d)*, in good agreement with TL-dates (Fang *et al.*, 1997) *(Fig. 9b)*.

Super-paramagnetic (SP) or ultra-fine (mainly < 0.03 μm) grains have been shown to have a pedogenic origin and are highly sensitive to climatic change, thus providing a powerful tool to reveal summer monsoon. Direct measure of SP grains on MPMS by thermal decay of low temperature isothermal remanence *(Fig. 9f)* accords well with estimates from saturation-magnetization (Ms)-normalized mass-specific susceptibility *(Fig. 9e)* for the studied section. Both show that SP grains are much more abundant in paleosols than in loess and reach highest values in S1-c *(Figs. 9e and f)*. However, within S1-c large fluctuations in SP grain content are evident, characterized by three sharp peaks lasting ca. 1-3 kyr and culminating at about 128 kyr, 118 kyr and 116 kyr. The amplitude of the second of these fluctuations, lasting about 4 kyr, reaches ca. 75 percent of the full range of variation between paleosol peak and loess values and *(Figs. 9d-f)*. These results suggest that the Asian summer monsoon experienced significant climatic changes during the Eemian Interglacial (MIS 5e), in good agreement with previous conclusion derived from non-magnetic indicators (Fang *et al.*, 1996).

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High Resolution Pedogenic and Rock Magnetic Records of Asian Summer Monsoon Instability during the past 60,000 Years from the Chinese Western Loess Plateau

The 23m Shajinping loess section on the second terrace of Huang He (the Yellow River) in the City of Lanzhou has developed at least 20 layers of moderately to weakly developed paleosols each 30-50 cm in thickness, occurring at similar intervals of about 1 m (ca. 2,500 years), with several very weakly developed soil horizons, during the past 60,000 years BP Fig 1). Field observations and laboratory analyses, including soil micromorphology, have indicated that Holocene paleosols are weakly to moderately developed luvic calcisols in type, characterized by a distinct dull brown (7.5 YR 5/3) medium angular blocky ped Bw horizon relatively rich in organic matter and clay content and low in carbonates (round 9 wt %), and a clear massive Bk horizon, with carbonates up to 16 wt % as fine nodules, channel coatings and infillings. Paleosols formed during Marine Isotope Stages 2, 3 and 4 are mainly weakly developed and appear as thin, dull, yellowish brown (10 YR 5/4 - 4/3) massive-medium blocky ped ochric A horizons, or mollic A horizons slightly rich in organic matter and clay content and low in carbonates (round 9-10 wt %) in the form of fine nodules and thin coatings. However, there are six moderately developed paleosols pedogenically similar to the Holocene paleosols. The organic matter and clay content in the Bw horizons and carbonate enrichment in the Bk horizons are only slightly lower than in the Holocene paleosols. These six paleosols occur at similar intervals of 3-4 m (about half of the precession cycle, i.e. 10,000 +/ - 1000 years) and seem to correlate well with the initial warm peaks of each Bond cycle (*Fig. 10*).

Continuous sampling of the section at 2.5-5 cm intervals for measurement of carbonate content and magnetic susceptibility has yielded decadal- to century-scale climatic records. These records demonstrate that the Asian summer monsoon experienced rapid episodic 'warm pulses' lasting only about several hundred to two thousand years during Isotope Stages 2 and 3. These warm pulses form groups characterized by high initial, then subsequently declining peaks. They may correlate with 'warm' peaks in the oxygen isotope record from the GRIP ice core. Most of these warm pulses occur in non- or quasi-orbital forcing cycles and have pedogenic responses as described above. This provides evidence for changes in the Asian summer monsoon on millennial timescales during the last glacial and points to instability similar to that identified by the Dansgaard-Oeschger events and Bond cycles in the Northern Atlantic.

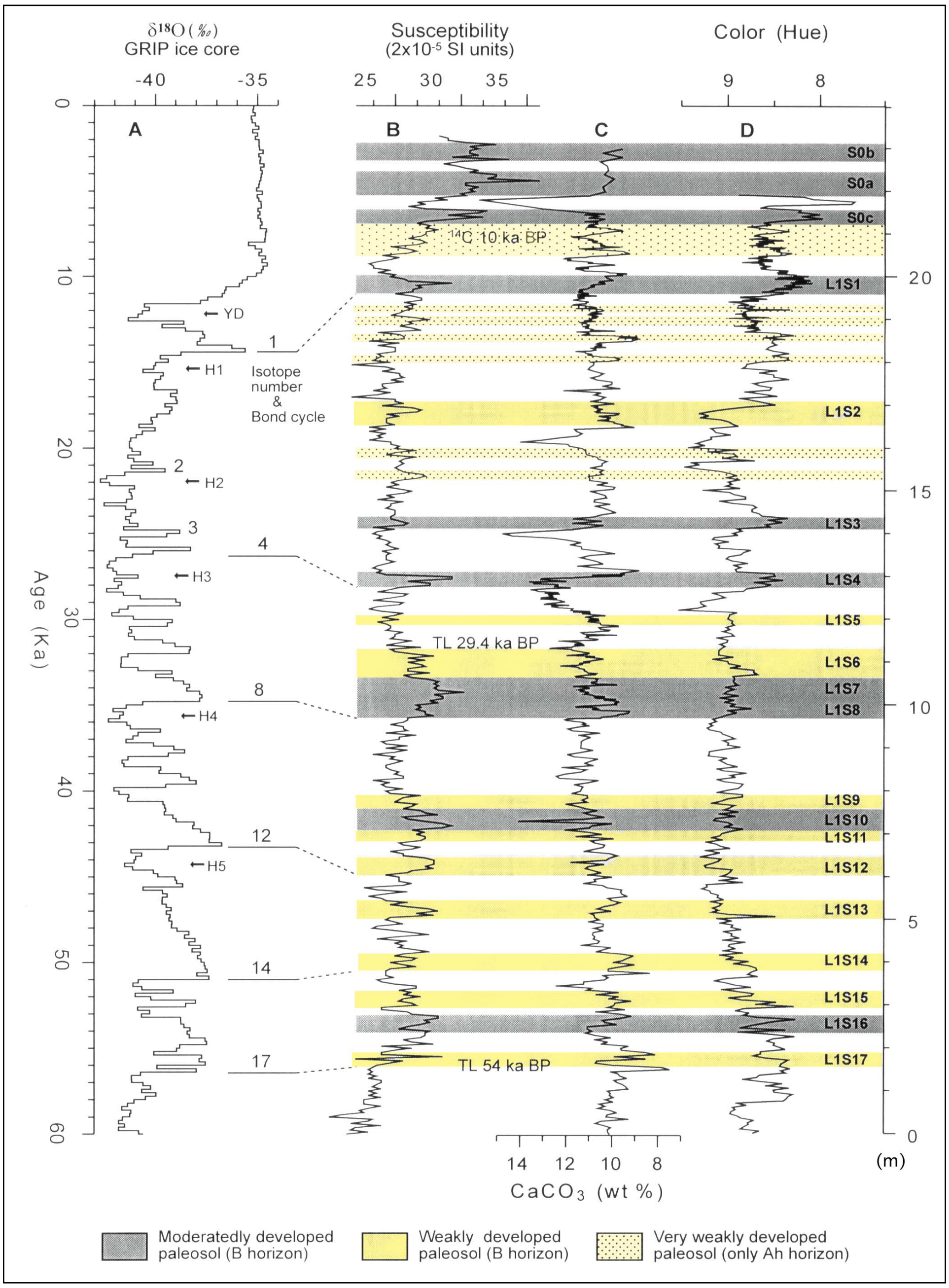

Fig. 10: Correlation of soil formation and summer monsoon enhancements revealed by magnetic susceptibility (B), carbonate content (C) and soil color (D) in the Shajinping loess section, Lanzhou, with the climatic record from the GRIP ice core in Greenland (A). Paleosol identification was independently made in field. H indicates Heinrich event. Several meters of the lower part of the section may have been affected somewhat by overbank flooding.

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The Chinese Loess Plateau — Far and Wide

The Chinese Loess Plateau (CLP), the world's largest accumulation of loess, is a major geological feature of China (4.4×10^5 km^2), and therefore a significant feature of Asia. It is generally considered to have been formed beginning around 2.5 my ago by eolian deposition of sediment from desert areas such as the Gobi and the Takla Makan which are located to the north and northwest - the direction of generally increasing bed thickness and grain size (Liu, 1985). Certainly the initial formation of this eolian feature represents a major shift in the climate of the area, as well as of the globe, in that the initial formation of the CLP is generally connected to the onset of the major continental glaciations that characterized the Pleistocene epoch. The displacement of such a huge amount of sediment over distances of hundreds of kilometers to the CLP from remote source areas implies that the atmosphere was extraordinarily dusty during periods of high transport. Even present-day, less intense dust storms originating out of the arid areas of China are sufficiently intense to have a specific name in downwind Japan — "kosha events".

That the record of modern eolian dust transport extends beyond the borders of continental deserts has been known for decades, at least since Radczewski reported eolian quartz ("Wüstenquarz") in Atlantic sediments offshore of the Sahara (1939). Similarly, the band of quartz-rich sediment across the North Pacific at about the latitude of the westerlies was attributed to desert sources by Rex and Goldberg (1958), although the latter authors did not specifically mention the deserts of eastern Asia. Subsequent research on North Pacific sediments has specifically tied the marine record of dust to eastern Asia, and has shown that the flux of desert dust to the ocean has varied significantly with time, presumably reflecting changes in the East Asian climate and in the atmospheric conditions responsible for dust deflation and transport (Nakai *et al.*, 1993; Leinen *et al.*, 1994; Rea, 1994; Asahara *et al.*, 1995).

We have more recently discovered in Greenland an even more distal record of the climate conditions associated with the CLP and its source deserts. It has been known for some time that the concentration of dust falling on high-latitude ice caps has varied greatly over time with high concentrations generally reflecting glacial periods, while lower concentrations characterize interglacial periods such as the present Holocene (Thompson and Mosley-Thompson, 1980). It was not, however, until the recent drilling of the long ice cores at Summit, Greenland, that this purely atmospheric record was discovered to contain variations in dust content of 10^3-10^2 years duration within glacial periods (and perhaps within interglacials) that are almost as great as those variations associated with glacial-interglacials and occurring on 10^5-10^4 year timescales. Furthermore, the transitions between different dust concentration levels, and the variations in climate that they represent, took place with extreme abruptness, on the order of 10 years. The causes of these extreme variations in the dust record, ranging over periods from 10^1 to10^5 years, have been the subject of more speculation than analysis.

The approach that we and our colleagues have taken to the solution of this problem is to first determine from what continental location(s) the dust originates. In previous studies we used the Sr and Nd isotopic compositions of East Antarctic dust from three glacial periods to determine that it was derived from Patagonia (Grousset *et al.*, 1992; Basile *et al.*, 1997). This connection was established by comparing the isotopic characteristics of the ice-core dusts to those of eolian samples (loesses, desert sands and dusts) from all potential source areas. For our initial work on the Greenland ice-core dusts from the GISP2 core, we added clay mineralogy, which reflects the weathering regime and hence the climate in the source area, as well as the isotopic composition of Pb, which, like Sr and Nd, reflects the lithology and geologic age of the source area, as additional tracers. We analyzed these four, largely independent tracer characteristics of the 23-26 thousand-year old dust across a range of dust concentrations that varied by about one order of magnitude. We then compared these values to the fine fraction of about one hundred loess and desertic PSA samples from more than two dozen locations around the northern hemisphere, including samples from the CLP and one of its source areas, the Gobi Desert of Mongolia.

Assuming that our PSA samples adequately represent the northern hemisphere dust source areas, the results of these comparisons shows, rather unequivocally, that the dust that fell on Summit, Greenland from 23 to 26 thousand years ago, just prior to the Last Glacial Maximum, was derived from the CLP and its source area the Gobi, and probably other east Asian desert areas to the northwest (Biscaye *et al.*, 1997). Furthermore, based on the fact that the apparent source area did not change significantly during that time interval, despite the large changes in dust concentration levels, we conclude that the differences in dustiness must have been due to changes in wind velocity, and hence the effectiveness of deflation and transportation in the East Asian source area, and not to expansion or contraction of source area size or changes in source locations (Biscaye *et al.*, 1997).

We have now correlated one glacial-age ice-core dust interval of about 3,000 years duration with the CLP, but have not yet completed analysis of other glacial or interglacial intervals. However, to the degree that the dust in the Summit ice cores represents a record of atmospheric conditions and climate in and around the region of the CLP, it constitutes a record that has a much more precise absolute stratigraphy and greater temporal resolution than any single section in the CLP. The influence of Chinese and Mongolian loess has thus been shown to extend far beyond the CLP, all the way to Greenland, and would certainly extend eastward even beyond Greenland if there were other depositories of eolian dust as well preserved as is polar ice. Perhaps we will find that the dust from the Chinese Loess Plateau and its source areas circles the entire northern hemisphere when we extend our studies to dust trapped in the ice caps of the Tibetan plateau.

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Erratum:
In the newly published PAGES Science and Implementation plan figure 10 on page 158 has an incorrect reference. The correct reference is: Tabacco, I., Passerini, A., Corbelli, F., and Gorman, M. (in press) Journal of Glaciology. *Determination of the surface and bed topography at Dome Concordia (East Antarctica).*

PAGES
PAST GLOBAL CHANGES

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Comparing the Stratigraphy of the Last Glaciation in the Loess Plateau and the Indian and Pacific Oceans

Grain size and susceptibility profiles from Wupu (approximately 250 km southeast of Yulin) and Yannchang (approximately 330 km south of Yulin) are compared with benthic foraminifera $\delta^{18}O$ records from the Maldives area of the tropical Indian Ocean (Bassinot *et al.*, 1994), and ODP 677 in the eastern equatorial Pacific Ocean (Shackleton *et al.*, 1990; Shackleton, 1996). Grain size and magnetic susceptibility profiles from the Loess Plateau are proxies for variations in winter and summer monsoon intensity, respectively. Loess grain size records show a high degree of coherency with the SPECMAP record (Imbrie *et al.*, 1984) of ice volume variations (Ding *et al.*, 1994). Hence, increases in ice volume may intensify the Siberian-Mongolian high pressure system by down stream cooling of mid-latitude air, leading to stronger winter monsoon winds and a larger overall median grain size of loess (Ding *et al.*, 1994). Further, the Mass Accumulation Rate (MAR = linear sedimentation rate times dry bulk density) of loess is a function of aridity (Rea, 1994) and the availability of loess at its source. The benthic foraminifera $\delta^{18}O$ record is commonly regarded as a proxy for ice volume variations since very little temperature and salinity fractionation should occur in the deepest parts of the oceans, and assuming that species variations are minimal. The $\delta^{18}O$ record from MD900963 is particularly well expressed owing to a local salinity effect, most likely controlled by changes in monsoon intensity (Bassinot *et al.*, 1994).

Our purpose is to contrast proxy climate records from the Loess Plateau with the oceanic records, and search for similarities and differences in the response of the proxy records to climate change. In particular we compare the proxy response of MIS 2 (loess subhorizon L1-1) and MIS 4 (subhorizon L1-5). We do not attempt to compare the amplitude of responses; nevertheless, if the proxy records from the Loess Plateau are responding to variations in ice volume then we should see some similarities in the profiles. However, differences observed between terrestrial and oceanic proxy climatic signals may be due to different responses of these proxy signals to internal and external climate forcing mechanisms, sampling variations, and proxy tool limitations.

Fig. 11 demonstrates the first order correlations of the last interglacial-glacial cycle using the MIS 5/6 transition as the datum (e.g. 'Termination II' of Broecker and Van Donk, 1970). This transition is regarded as being a reasonably synchronous global event. In figure 11 we use depth scales from each location and attempt to avoid the influence of age models that assume constant sedimentation rates between control points. While it may be true that sedimentation rates are fairly constant in geologic time, the assumption of linear sedimentation rates in high resolution studies (e.g. 1000 years per sample or less) is tenuous. For example, in the Loess Plateau loess sedimentation rates are higher during cold periods than in warmer times (Rutter *et al.*, 1995).

Subhorizon L1-1 is bordered by the Holocene soil (S0) above and a weak paleosol (L13) below. The grain size profile within loess subhorizon L1-1 shows a lower median grain size in the bottom half of the subhorizon with an abrupt transition to a higher median grain size in the upper part of the subhorizon. This profile is similar to the ocean $\delta^{18}O$ profiles indicating a high degree of coherency between median grain size (wind strength) and ice volume variations during MIS 2. Note that the base of MIS 2 in oceanic records is more commonly picked above our interpretation of the MIS 2/3 boundary, and represents a revision of the original MIS 2 boundary.

Loess subhorizon L1-5 (MIS 4) in the Wupu and Yanchang sections are about 5.3 and 4.8 meters thick, respectively, while loess subhorizon L1-1 (MIS 2) is about 2.1 and 3.0 meters thick, respectively. We presently do not know the dry bulk densities of L1-1 and L1-5 and cannot calculate a MAR. However, using SPECMAP (Imbrie *et al.*, 1984) ages for the top of MIS 2.0 (12 ka). 3.0 (24 ka), 4.0 (59 ka) and 5.0 (71 ka) the accumulation rates of L1-1 and L1-5 at Wupu are 0.175 meters/ka and 0.44 meters/ka, while the accumulation rates at Yanchang are 0.25 meters/ka and 0.4 meters/ka, respectively. Hence, loess accumulations rates are higher and ice volumes lower during MIS 4 than during MIS 2. This is apparently at odds with recent work (Shackleton *et al.*, 1995), suggesting that dust accumulation in China is highly coherent with the $\delta^{18}O$ global ice volume record. Shackleton *et al.* (1995), however, were dealing with glacial to interglacial variations over the past 2.5-3.0 million years as opposed to our loess record of the last glaciation (L1).

In conclusion, we are refining the stratigraphy of oceanic and loess records to improve understanding of climate change and the relationship between the global ice volumes and the loess record. Our revision of the base of MIS 2 provides a more coherent record of the relationship between variations in loess grain size (e.g. wind strength) and ice volumes during MIS 2. Additionally, we surmise that the higher accumulation rates during L1-5 may be related to the east European glacial record, where older glaciations on the Russian Plain were more extensive (Velichko, 1990). If our conjecture is correct, then accumulation rates during MIS 4 would be related to regional ice volumes rather than global ice volume.

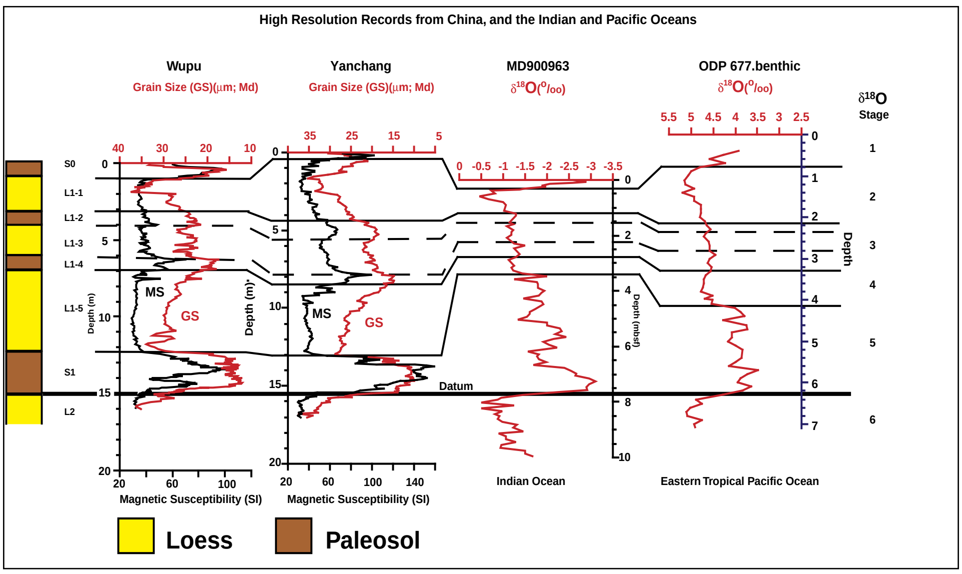

Fig. 11: Stratigraphy of the last Glaciation (Marine Isotope Stages 2, 3 and 4). Samples at 5cm intervals in the loess-paleosol sections.

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Glacial and Interglacial Patterns for Asian Dust Transport

Atmospheric interpretations based on elemental mass-particle size distributions (MSDs) have shown that the Chinese loess/paleosol sediment is composed mainly (~90% of total mass) of eolian mineral dust that originated from the major desert-sources for Asian dust situated in northern and northwestern China. The dust storms and dustfall events in inland China provide the physical basis for the eolian theory of loess origin. Seasonal peaks in dust concentrations over the open North Pacific also have been linked to the occurrence of dust storms in Asia.

Recently, we estimated the dust-derived elemental deposition rates to the Loess Plateau using data for dust storm (DS) and non-dust storm (N-DS) periods. Two major findings of the studies were (1) that dry deposition was more important than wet deposition in terms of annual dust flux; and (2) that on a long-term basis, the dry input of dust to the loess was mainly due to normal transport conditions, i.e., days on which dust was suspended in the atmosphere but dust storms were not reported as part of the routine meteorological observations. This second finding was unexpected because it contrasts with the interpretation that the loess accumulations are mainly attributable to strong dust storms and dustfall events. Furthermore, this conclusion has generated some controversy in relation to the hemispheric to global-scale transport of Asian dust.

Here we further compare data for the particle size distributions in present atmospheric aerosol samples (Al) with data for the last-interglacial paleosol (S1) and the Malan, last glaciation, loess (L1) from the well-known Luochuan loess/paleosol sequence. The major purpose of comparing the source materials with the sedimentary deposits is to evaluate the relative importance of DS vs. N-DS processes for dust transport during glacial and interglacial intervals. Particle size distributions (PSDs) also are used to evaluate the patterns for Asian dust transport over regional and greater spatial scales. The regional-scale transport of Asian dust during interglacial stages is suggested to be mainly attributable to N-DS processes and is dominated by northwesterly surface winds. Conversely, during glacial stages the impact of dust storms on the accumulation of loess is enhanced. These regional effects are in contrast to the global-dispersal of dust that is associated with transport by upper-level westerly winds and is mainly the result of desert dust storms during both glacial and interglacial conditions. Temporal differences in the dust transport patterns to the Loess Plateau suggest that the variability in the coarse particle fraction (>20 micron) during interglacial times is not directly attributable to the strong dust storms and dust fall events that have been linked to a strengthening of East Asian winter monsoonal winds. This is in contrast to the dust deposition rates that are strongly influenced by the monsoonal circulation.

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East Asian Monsoon Variations during the Last Interglacial: Evidence from the Northwestern Margin of the Chinese Loess Plateau

Climate changes during the last interglacial may serve as an analog for future global changes. However, our current understanding of the last interglacial climate is still limited. Although the Chinese loess-paleosol sequence is widely recognized as one of the best terrestrial Quaternary climatic recorders, the paleosol S1 in the central Loess Plateau area, where most of studies have been conducted, is too thin (ca. 2 m) to yield high-resolution climatic records of the last interglacial.

However, the thick aggradational paleosol S1 (6-8 m) in the northwestern margin of the Chinese Loess Plateau, has preserved high-resolution records which provide considerable insight into the temporal variations of the East Asian monsoon and thus shed new light on the forcing factors. The paleosol S1 at the two sections investigated here consists of five sub-units: three well-developed paleosols and two interbedded loess layers. According to the modeled ages based on the depth of the Blake paleomagnetic event and TL dates, the three paleosols developed in marine oxygen isotope stage (MIS) 5a, 5c, and 5e, and the two loess layers were deposited in MIS 5b and 5d, respectively. The frequency-dependent magnetic susceptibility, as well as the concentration of secondary carbonate, is used as an indicator of the summer monsoon intensity, and the median particle size as an indicator of the winter monsoon intensity.

The results suggest that the northwestern margin of the Chinese Loess Plateau experienced the strongest summer monsoon intensity in MIS 5e and the weakest in MIS 5a, among the three warmer periods during MIS 5. The summer monsoon was weaker in MIS 5b than in MIS 5d. A dusty interval interrupted the second warmer period (5c) and a soil-forming event interrupted the first colder period (5d). The results also suggest that the directions of changes in the intensities of summer and winter monsoons may not always have varied in inverse proportion. For example, the weakest summer monsoon occurred in MIS 5a during which the winter monsoon was not the strongest. We further conclude that the winter monsoon during the last interglacial was probably driven by global ice volume fluctuations, while the summer monsoon was primarily controlled by the northern hemisphere solar insolation and was probably modified by a feedback mechanism. That is, the climatic buffering effect of low latitude oceans may have distorted the response of the summer monsoon to insolation variations. Finally, our results do not contain evidence of climatic instability in MIS 5e, even though the study area is situated in a region which has been sensitive to climatic changes.

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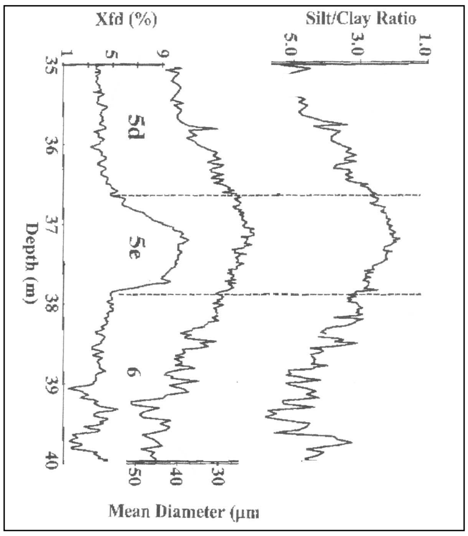

Fig. 12: Percentage frequency dependent magnetic susceptibility, mean particle diameter and clay-silt ratio variations through MIS 5e in the semi-arid Xiniang Basin. Parallel results have been obtained from the semi-humid Linxia basin (see Chen, F.H., Bloemendal, J., Feng, Z.D., Wang, J.M., Parker, E. and Guo, Z.T., Quarternary Science Reviews, in Press).

Report on Open Science Meeting and Panel Discussion

The first PAGES Open Science Meeting 'Past Global Changes and their Significance for the Future', jointly organised by PAGES and the Environmental Changes Research Centre (ECRC), University College London, was held in the University of London Senate House, April 20 – 23, 1998. The oral presentations took the form of overviews by distinguished invited speakers whose remit was to present the state-of-the-art in all the main aspects of past global change research within the context of IGBP. In addition, over 200 posters were displayed. The published output from the meeting includes a 140 page volume of Abstracts (containing over 350 items) available from the PAGES Project Office and also via the PAGES web site (http://www.pages.unibe.ch/). A double special issue of the *Quaternary Science Reviews*, containing review papers by each of the invited speakers will be published in 1999 and will also be available in book form. It is hoped to distribute a CD-ROM of the PAGES Data Base along with this volume.

The meeting culminated in a panel discussion chaired by Professor Chris Rapley, Director of the British Antarctic Survey and former Executive Director of the International Geosphere-Biosphere Programme (IGBP). Members of the panel were Sir John Houghton, co-chairman of the Science Assessment Working Group of the Intergovernmental Panel on Climate Change (IPCC), Professor Hartmut Grassl, Director of the Joint Planning Staff for the World Climate Research Programme (WCRP), Bill Hare, Climate Policy Director of Greenpeace International, Ray Bradley, Professor of Climatology at the University of Massachusetts and Chair of the PAGES Scientific Steering Committee (SSC) and Jonathan Overpeck, Head of the US NOAA Paleoclimatology Program, Director of the World Data Center-A for Paleoclimatology and member of the PAGES SSC.

The key aims of the panel discussion were to link the research agenda of PAGES, as outlined in the presentations and its recently published 'Status Report and Implementation Plan' as effectively as possible to the concerns of all those dealing with the prediction and management of future global changes and their impacts on human society. The panel members from outside PAGES made introductory statements to open the discussion.

Sir John Houghton stressed the essential role of PAGES science in:

- validating climate and other earth system models.
- increasing the quantitative understanding of climate sensitivity to different forcings.
- improving parameterisation of key earth system processes involved in climate change, for example biosphere feedbacks.
- characterising climate regimes in time and space and documenting their role in the pattern of variability at regional level.
- highlighting the importance of rapid change and of the feedbacks and non-linear processes involved.
- detailing the impacts of climate variability on other environmental systems and especially on human activities by presenting a paleo-perspective on human adaptability and on the problems involved in planning for sustainability in a future dominated by change.

Professor Grassl stressed the links between PAGES and WCRP mainly through the CLIVAR (Climate Variability and Predictability) Study. Inputs to CLIVAR from the PAGES research community should lead to an extension of the instrumental record to the whole of the last millennium through use of quantitatively calibrated proxies that achieve precise and accurate age control, annual resolution and global significance. Tree rings, varved (annually laminated) sediments, ice cores, corals and speleothems all provide this potential, as do documentary records. Grassl stressed the need for collaborative work between modellers and data researchers on the development of realistic and well validated transient models of non-linear climate change. He also emphasised the crucial role of isotope studies in global change research, stressing the need to strengthen the Global Network for Isotopes in Precipitation (GNIP) and to promote both the PAGES 'Isotope Mapping' (ISOMAP) programme and the newly established 'Isotopes in the Hydrological Cycle' (ISOHYC) initiative as complementary developments of great potential.

Bill Hare emphasised the role paleo-research must play by using the information at its disposal to identify critical environmental thresholds for rapid non-linear change and to establish the ways in which these may be influenced by different rates of forcing. In the policy-related domain, he stressed the need to understand better past natural variability and, in particular, the incidence and impacts of extreme events - a matter of major concern in risk assessment. By improving our understanding of the role of the terrestrial biosphere in past climate change, PAGES should also contribute to evaluating the potential for policy makers meeting their obligations within the Climate Convention by increasing biomass rather than reducing carbon emissions. Hare also pointed up the urgent need to use paleo-records more effectively in documenting the interlinked past variations in global ice-volume, sea-level and coastal change, so that future changes can be more effectively predicated and accommodated in policy development.

In concluding the introductory statements and inviting contributions from the floor, Chris Rapley asked to what extent and in which ways could the paleo-record contribute to our understanding of a forcing so unique and unprecedented as that currently operating.

continued on bottom of page 12

The Abstract Volume of the London Open Science Meeting contains the abstracts of 27 plenary lectures and 330 posters. Copies are available from the IPO, so feel free to order by fax, letter or e-mail or using the order form on our website: http://www.pages.unibe.ch/Publications/publications.html

Winners of the Poster Competition for Young Scientists from Developing Countries

sponsored by Environmental Change Research Centre, University College London

Maria Martha Bianchi (Argentina)
Tracing fluctuations in the strength of Westerlies at 41°S using Late Glacial - Holocene pollen records from North Western Patagonia

Vladimir O. Elias (Brazil)
A chemical tracer for the reconstruction of forest fires in the Amazonas environment and geological record

Rashit Hantemirov (Russia)
A 5,000 year larch tree-ring record from the north of West-Siberian Plain and its applications to palaeoclimatic studies

Nejib Kallel (Tunisia)
Mediterranian pluvial periods and sapropel formation during the last 200,000 years

A.K. Singhvi (India)
Synthesis of luminescence chronology of loess accumulation episodes and implications for global land-sea correlation

Jule Xiao (China)
East Asian monsoon variation during the last 130,000 years: Evidence from the Loess Plateau of China and Lake Biwa of Japan

PAGES Focus 3: A new Initiative on past Human Impacts

The main thrust of the PAGES program hitherto has been towards a better understanding of past climate change and its implications for the future. Focus 3, which is concerned with the past impact of human activity on ecological and hydrological systems, has never been fully articulated, though significant progress has been made in one specific area – human impact on fluvial systems- thanks to the efforts of Bob Wasson. At the recent PAGES SSC meeting, held in Pallanza, N. Italy, June 19-21, an overall strategy was presented and endorsed. This strategy envisages seven interlinked themes as set out below. Their coordination and their articulation as PAGES Activities and Tasks will be the responsibility of a small steering group soon to be identified. The goals of the paleoscientists involved in this exercise will include the following:

• To define, promote and pursue areas of shared interest between PAGES and other IGBP project elements.

• To contribute fully to the PAGES, and eventually IGBP, syntheses currently being undertaken.

• To push the development of these themes soundly forward toward and during the next stage of IGBP's work from the year 2000 onwards.

The themes briefly noted below have yet to be fully defined and, in some cases, leaders have yet to be identified. A workshop to develop science and implementation plans will be held in late 98/ early 99. Meanwhile, colleagues interested in contributing to this aspect of PAGES work are invited to contact the IPO and its Executive Director (oldfield@pages.unibe.ch) who will be responsible for the overall coordination of Focus 3 in its early stages.

Seven themes

The themes envisaged at this stage are as follows:

The history of greenhouse gas exchanges between the terrestrial biosphere and atmosphere

These exchanges are of major concern in relation to understanding present day and future carbon dioxide and methane fluxes and budgets. There is an urgent need to improve our insight into the way past changes in land cover and hydrology have affected the fluxes and reservoirs over the non-marine part of the biosphere. The task spans a range of themes, from the past carbon balance in wetlands, to the impact of both deforestation and reforestation on CO_2 fluxes at both regional and global scales. Moreover, there is a strong case for broadening it to include a concern with nitrogen species. One major advantage of undertaking this task for the past lies in the way in which it can be linked, on a range of timescales, to the trace gas record in ice cores. The task is seen as contributing to the GAIM led 'paleo-trace-gas challenge' and as helping to forge links between PAGES and other IGBP Project Elements, especially GCTE, BAHC and IGAC.

Past biogeochemical fluxes within fluvial systems

This theme is closely linked to the next two and it embraces the concerns of the BLOP report (Modelling the Transport and Transformation of Terrestrial Materials to Freshwater and Coastal Ecosystems) as well as one of the main tasks for PAGES within the IGBP inter project initiative on 'Continental Aquatic Systems'. It is also currently being actively promoted by the LUCIFS project (Land Use and Climate Impacts on Fluvial Systems during the Period of Agriculture) led by Bob Wasson. Further information on this project is contained in an article in this Newsletter on page 14.

The historical context of multiple threats to both aquatic and terrestrial ecosystems

Climate variability and future climate change are only one factor, and perhaps often not the most important factor, in the complex of threats facing both terrestrial and aquatic ecosystems. Studies of soil erosion, surface

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Open Science Meeting, continued from page 11

A wide-ranging discussion followed in which the issues raised included:

• lack of opportunities for developing and funding effective links between the areas of environmental and social sciences whose collaboration is essential to the emerging global change research agenda.

• the need, in an increasingly data-rich research environment, to focus on critical time intervals and processes.

• a request to IPCC for a clearer identification of the burning, unresolved questions to which paleo-research should make a crucial contribution. Suki Manabe, drawing up his own list, suggested the following:

- can we solve the problem of the 'missing carbon sink' through a concerted attack using the stable isotopes of carbon to better characterise the sinks, sources and fluxes?
- will global warming really reduce surface salinity in the North Atlantic?
- which are the key aerosols in climate feedback and what are their effects?
- what are the most important observational activities required to develop and validate models?

• the need for present day calibration to be linked to paleo-research projects. This may be one of the ways in which, given adequate coordination, essential monitoring programmes can be sustained.

• the challenge of incorporating hypothesis testing in the present research agenda, for example to test the possible role of marine biota in climate forcing.

• the urgent need, in some parts of the world, for more AMS radiocarbon measurement facilities worldwide, both for dating and for developing further the 'tracer' role of radiocarbon.

• the strong desirability of broadening the PAGES research agenda to encompass more fully other aspects of past global change than climate.

• the need to increase awareness of the relative magnitudes of changes in large scale averages. For example, the 'Little Ice Age' had major impacts, yet, over the northern hemisphere as a whole, appears to have been only 0.5 to 1°C cooler than the last few decades. In contrast, the IPCC worst case envisages a rapid warming of up to 4°C.

The leading points made by the panel members and the ensuing discussion provided ample justification for regarding PAGES research as a vital contribution to understanding future environmental change and its human implications. They also provided many pointers to the ways in which the existing research agenda can be shaped in order to increase its impact and relevance. Our central task is to use the record from the past to shed light on what predicted future changes will actually mean for a still rapidly growing world population for which the goals of sustainable development and the realities of environmental change will be intimately linked.

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water acidification and eutrophication as well as the amelioration of the effects of these processes requires that they be set in historical context. Lake sediments serve as archives of all these processes, including the more recently recognized threats posed by increased nitrogen deposition and contamination by a range of 'new' compounds. Well-focused paleodata is essential for setting present day monitoring in time context as well as for model evaluation. This may be best illustrated by work on the history of acidification and eutrophication carried out world-wide over the last two to three decades in response to urgent environmental problems. This theme clearly interacts strongly with parts of the GCTE and LUCC science agendas.

Historical perspectives on water quality/ lake ecosystems

This theme is closely linked to the ones above and is, for the moment, separated from 3 only because it represents a significant part of PAGES input to the IGBP ''Continental Aquatic Systems' inter-project already mentioned. It has now been accepted as a PAGES Activity within Focus 3, led by Rick Battarbee.

Non-linear ecosystem changes in the geologically recent past

Many researchers within the IGBP community rely on developing models of change through time by postulating temporal linkages between the different elements in a spatial mosaic. This approach has both strengths and weaknesses. One of the latter arises from the problem of rapid non-linear shifts in ecosystem function once key thresholds (e.g. in water retention or nutrient cycling) are transgressed. The paleo record is rich in evidence for such changes and there is a need to generate a better awareness of their causes and effects especially where the record from the past can be used to improve our understanding of highly stressed ecosystems at the present day.

Global and regional time-slice reconstructions

The well-developed BIOME 6000 program is an example of this type of activity. The need now is for reconstructions, especially of terrestrial vegetation and land cover, for the last 200 - 300 years, the period of rapidly accelerating change and human impact. This will call for an integration of paleorecords from sources as diverse as pollen analyses and past tax returns, and it will contribute directly to the needs of GCTE and LUCC, as well as to the theme identified under 1 above. It will be one of the themes in a joint PAGES-LUCC workshop planned for November 1998.

The historical context of contemporary and future changes in areas of high 'value' and/or vulnerability

In several cases, LUCC and GCTE, for example, envision a detailed focus on a specific region. In one case at least, the LBA in Amazonia, there is a coordinated IGBP activity across a wide range of Project Elements. Where such regions are defined, whether as transects across ecozones or as areas of concentrated research, PAGES can play an important role in placing changes in present day ecosystems and in the hydrology of the region in a longer time perspective. This can provide a dynamic baseline for future monitoring, an insight into processes operating on timescales longer than the span of available direct observations, and a quantitative estimate of the range of natural climate variability in the recent past. The capacity to do this will differ in different parts of the world, since it depends on the presence of suitable paleo-archives, ideally high resolution ones with records that come through continuously to the present day. Full exploitation of these rests on an acknowledgement that PAGES shares the task of understanding processes rather than simply providing 'historical reconstructions'. Many key processes in the climate system, at the ecosystem level and within hydrological systems, operate on decadal to century timescales. Establishing their functioning and their effects has an important role to play in understanding present and future earth system dynamics on all spatial scales.

An eye on the future

The themes outlined above must be a crucial part of the overall strategies of PAGES and the IGBP for several reasons. From the PAGES standpoint, we have to realize that no amount of paleoreconstruction can fully prepare us for future changes and future impacts operating on the present day landscape. The effects of human activity over the last ca. 200 years have led to transformations much more significant than those resulting from climate change. They have endowed us with a 'no-analogue' biosphere as the canvas upon which future climate changes and human activities will interact. Moreover, this no-analogue biosphere is the point of departure for the future part of the global experiment to which increasing greenhouse gas concentrations in the atmosphere will contribute. To consider this complex and rapidly changing canvas without regard to its antecedents is not a realistic enterprise. PAGES FOCUS 3 is therefore a research domain within which, as the messages from the past overlap the observations of the present, we may hope to develop and optimize the interactions between many aspects of IGBP's endeavors. Human activities are as much drivers of contemporary and future environmental change as are anticipated changes in climate. The interplay between the two types of forcing is of vital concern and the history of their interaction is ignored at our peril, especially in the realm of future impacts and their integrated assessment. In this respect, the proposed FOCUS 3 initiatives are a response to human needs as well as to the emerging research agendas of national and international funding agencies.

A call for participation

The various themes outlined above are closely interwoven and will require a coordinated network approach for their realization. We can illustrate this simply by identifying the key archives for many of the themes, namely lacustrine and high resolution, near-shore marine sediment records of changing land cover, associated biogeochemical fluxes and their impacts on both terrestrial and aquatic ecosystem structure and function. There are other vital linking concerns. The concept of sustainability has no realistic meaning unless it accommodates what we know of past climate variability, human activities and the consequences of their interaction. Equally, development of the themes proposed is a prerequisite for model evaluation, which, in turn serves to improve predictive capability.

The first task is to identify a cohort of potential participants ready to share the challenges implicit in this proposal. An immense volume of highly relevant data already exists. One of our main roles must be to evaluate, filter, coordinate and systematize what is already known, as it bears on the key issues already partly identified in the outlines above. This 'prospectus' therefore comes with a request that all interested scientists contact us in the PAGES Office in Bern with an outline of their own perspectives and of the potential roles they may be prepared to play. In some cases, as for example in the case of aquatic ecosystems and of human impact on fluvial systems, the leaders (Rick Battarbee and Bob Wasson respectively) have been identified and work is already in progress. In other cases, there is a pressing need to identify those who will be prepared to play a crucial, active role in coordination and leadership. Again, we are putting this proposal forward in an effort to solicit both potential volunteers and nominees. By joining in such an effort, our hope is that you will not only contribute to making the best possible use of current knowledge and ongoing research; you will also be helping to define key aspects of the global change research agenda for the future.

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Land Use and Climate Impacts on Fluvial Systems during the Period of Agriculture (LUCIFS)

Cumulative Global Change is occurring by the removal of forests, conversion to cultivation of marginal land, and intensification of cultivation. Systemic Global Change, in the form of climate change and atmospheric chemistry change, is likely to alter land use patterns during the next century. All of these changes will affect rivers and their catchments, altering flows of water, sediment, nutrients, carbon and pollutants. Past changes of land and climate are still being felt in many catchments, and are difficult to understand without a historical perspective. Future changes, when superimposed on changes triggered in the past, will produce complex responses which will be difficult to anticipate.

There is therefore a clear need for a better understanding, and a better theory, of fluvial system response to land use and climate change, to anticipate and perhaps predict future changes, and to understand current dynamics. While most scientific research has been conducted in small catchments, most interest in future responses is in large catchments. The time period over which a large catchment responds to land use or climate change is much longer than is the case for a small catchment; much longer than most instrumental time series. Therefore, the paleoenvironmental record provides a unique data repository of catchment responses, fully realised over decades to centuries. This repository, or library, is an unparalleled set of experiments already carried out. Our task is to exploit this library.

The PAGES-LUCIFS Project aims to assemble a library of fluvial system responses from around the world, using case studies selected to represent both the modern array of land use and catchment types, and the areas where land use has evolved slowly over millennia and where industrial agriculture has been transplanted to non-agricultural landscapes during the last few centuries. Modelling of this library of responses is being developed to provide the tools for anticipation and/or prediction of future change.

While Global Change impacts on fluvial systems are important, change to these systems will also affect the coastal zone by increasing the flow of materials to the coast, in some cases, and decreasing flows in other cases. The changed transport of carbon and nutrients by rivers also have a role in global biogeochemistry, particularly in the coastal zone.

Rivers therefore play a role as one of the links between the major global biogeochemical systems, but, more than that, they are crucially important to human well being and for many aquatic organisms. The importance of fluvial systems, as phenomena that are affected by Global Change and affect Global Change, is clear, along with their enormous societal and ecological significance.

The LUCIFS planning group has identified five key questions to guide research, as follows:

1. What is the sensitivity to climatic change of the spatial distribution of sediment, P and C fluxes in different climate/vegetation regions?
2. How do sediment, P, and C flux sensitivities to land use under climatic shifts reflect stages of land use history?
3. How are fluvial system response sensitivities under various land uses influenced by the direction of climatic change?
4. What are the thresholds and response and recovery of fluvial systems for different combinations of land use and climatic change?
5. How do engineering and other human-related modifications, including dams and reservoirs, levees, channel morphology alteration, and wetland drainage enhance or suppress climatic impacts on sediment, P, and C fluxes in various climate/vegetation regions?

In summary, these questions revolve around the sensitivity of fluvial systems to land use and climate change, both individually and in concert. To answer these questions globally, case studies from various parts of the world are needed.

A LUCIFS workshop is being planned for January 1999. The workshop will have the following purposes:

Review progress to date by each group presenting its scientific results and plans for the future.

1. Review progress in modelling
2. Assemble major conclusions that can be reached at this stage in the project, possibly to produce a multi-authored paper for an international journal.
3. To agree on research protocols and modelling strategies to ensure that future work is comparable and useful for the LUCIFS objectives.

Copies of the LUCIFS Project Implementation plan (R.J. Wasson ed, 1996 Land Use and Climate Inputs on Fluvial systems During the Period of Agriculture, PAGES Workshop Report, Series 96-2, 51pp) are available from the PAGES International Project Office. The first LUCIFS newsletter, from which the text of this article has been drawn, is available on-line at http://www.pages.unibe.ch/publications/publications.html.

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WORKSHOP REPORTS

Second Workshop on Global Paleoenvironmental Data

Boulder, CO, USA, February 9-12, 1998

Putting individual paleorecords into a multi-proxy, multi-disciplinary, global context is the only way to synthesize a truly global picture of past climatic and environmental change. The difficulties inherent in synthesizing research across-disciplines and between countries are well known, but not insurmountable. Many of the past successes in paleodata management, including the hot-off-the-presses Greenland Ice Core Data CD, Ocean Drilling Program Database, International Tree Ring Data Bank, and North American and European Pollen Databases have understandably been organized independently, primarily along disciplinary and geographical lines. This workshop brought together data management experts from 43 different PAGES data efforts in an attempt to produce an implementation plan for a broad set of guidelines on how to set up a regional or thematic data effort.

One of the principle conclusions of the group was the necessity for making databases consistent in terms of their required documentation and formats. Databases need to be useful to people from outside the field, who may wish to extract information for comparative purposes without excessive complications. At the same time they should serve the needs of scientists who require a detailed accounting of the raw data, any methods used to filter the data and the manner in which climatic or environmental information has been inferred from the data as well as a careful quantification of the uncertainties. It was agreed that the primary responsibility for proper interpretation of archived data lies with the individual users, just as the ultimate quality of the archived data rests with the individual contributors. Nonetheless, effort should be made to structure and maintain databases so as to maximize ease of access and submission and at the same time minimize potential pitfalls of data misinterpretation.

The group took as its starting point the World Data Center System Guide, published by the International Council of Scientific Unions in 1996, and the Global Paleoenvironmental Data report (PAGES report 95-2), which arose out of the first PAGES data workshop held in 1993. Although these documents provide an admirable foundation, the world of data management has blossomed exponentially in the past decade and an update is required. A two part report entitled "The PAGES Data Guide" is being prepared by the meetings co-conveners David Anderson and Robin Webb with input from all of the attendees. The first part will primarily consist of a compendium of data centers within PAGES and in overlapping fields. The second part will present guidelines on how to set up a regional or topical data center. Although the document will be produced in hardcopy, available from the WDC-A in Boulder and the PAGES IPO in Bern, it will also be put on the PAGES and WDC-A Internet sites, where it will be maintained more dynamically and thus remain an invaluable research tool into the future.

For more information on the evolving PAGES Data Guide contact David Anderson (dma@paleosun.ngdc.noaa.gov) or look for updates on the PAGES and WDC-A web sites (http://www.pages.unibe.ch/ and http://www.ngdc.noaa.gov/paleo/paleo.html).

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PEP1: Paleoclimate of the Americas

Merida, Venezuela, March 16-20, 1998

Over seventy scientists from all over the world, studying paleoclimate from Argentina to Alaska, assembled to address interhemispheric linkages in past climatic and environmental change in the Americas. The meeting began with a session on the human dimensions of climate change, a topic well deserving of this prime time billing given that the Americas transect, and in particular the Andes region, has seen an intricate interplay of human habitation and environmental change for over ten thousand years. The rise and fall of pre-Colombian civilizations in coastal regions, lowlands and the Andes were measured alongside records of pollen assemblages, lake level reconstructions, volcanic history and levels of snow deposition on high altitude glaciers. The interplay of technological, economic and social changes with environment and climate did not end in the distant past. In more recent decades, urbanization and poverty have dramatically effected local ecosystems and at the same time led to increases in the human vulnerability to environmental change.

Discussion of Holocene climate variability in the Americas was understandably dominated by the influence of El-Niño, the signal of which was discussed in records as diverse as Andean lake levels, Galapagos corals, tree rings and historical accounts. In the late glacial session an issue which permeated many of the talks was synchroneity of the Younger Dryas. A general consensus was reached that the term 'Younger Dryas' describes a European event and should not be forced upon the rich tapestry of climate variability which is being uncovered in the Americas like a square peg into a round hole. Interhemispheric comparisons of Greenland and Antarctic ice core records seemed to indicate that the temperature anomalies are out of phase, such that the Antarctic Cold Reversal coincided with the Allerod-Bolling warming and anomalous warmth in the Antarctic coincided with northern hemisphere cool periods associated with Dansgaard-Oeschger variability. Ocean data were presented which seemed to support these ice core results, in addition to suggesting perhaps a slight southern hemisphere lead. The monkey wrench thrown in this picture was the recent Taylor Dome record, from a coastal Antarctic site, which appears to match the Greenlandic and not the Antarctic pattern. Polynyas were suggested as one possible cause for this anomalous record. The full glacial session centered around re-evaluation of tropical temperature changes during the Last Glacial Maximum and the climatic effects of changes in the ocean thermohaline circulation.

A more detailed reporting of the PEP1 meeting will appear in a future PAGES newsletter. A limited number of extended abstract volumes and further information on PEP1 programs are available from Vera Markgraf (markgraf@spot.colorado.edu). The full meeting program can be found at http://instaar.colorado.edu/misc/pep.html.

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ScanTran

Rovaniemi, Finland, March19-23, 1998

ScanTran is the name adopted for the IGBP high latitude terrestrial transect (Koch *et al.*, 1995) through Scandinavia and northern Europe. The workshop in Rovaniemi represented the third in a series of workshops leading to the development of the ScanTran Science Plan that will be submitted to IGBP later this year. The initial workshop in Høvik (April 1996) was organised by the Norwegian IGBP Committee; as a result of the positive response of participants in that workshop to the proposal to develop an integrated science plan for a Fennoscandian terrestrial transect a second workshop was organised. This second workshop, held in Trondheim (June 1996), developed a clear outline of the science plan for the transect, and produced a report (Heal *et al.*, 1997) identifying both the key features of the proposed transect and the foci for the proposed integrated research programme. The Rovaniemi meeting was an open meeting to which a wide international audience of scientists and social scientists was invited. The objectives of the meeting were to inform this wider audience about ScanTran, to confirm in greater detail the objectives of the proposed long-term programme of research in order to produce the Science Plan for submission to IGBP, and to identify individuals who would carry forward the process of establishing ScanTran as a recognised IGBP high latitude transect.

Some 90 or so participants registered for the meeting. Although registration was strongly biased towards the terrestrial ecology (GCTE) community, other IGBP core projects were also clearly represented (BAHC, IGAC, PAGES). One session of the formal presentations to the meeting was dedicated to Past Changes, with a keynote presentation by Brian Huntley and Richard Bradshaw that explored some of the key evidence of Holocene environmental and ecological changes in the ScanTran region, and an invited presentation by Matti Eronen that discussed especially the dendroclimatological evidence for Holocene and recent climatic and other environmental changes in northern Fennoscandia. A series of offered papers then discussed a wide range of paleoenvironmental topics. One of the Working Groups during the workshop sessions also was dedicated to Past Changes; the report from this Working Group will form part of the report from the meeting as a whole that is due to be published later this year. This report also will include extended abstracts of the papers presented at the meeting.

The meeting recognised a number of important features of the region encompassed by ScanTran that give added strength to the proposed terrestrial transect study. Amongst these, the established network of research sites with field stations and infrastructure to support field research is a key asset. Similarly, the existence of a large body of existing knowledge that can underpin any new research initiatives is of very great value; such knowledge includes, in the PAGES context, data from ice cores, from sediments both of the surrounding ocean basins and of lacustrine basins in the region, from studies of peat deposits, from dendroclimatological investigations and from archaeological studies at sites within the region. The long-term presence of human populations in the region, and the records of their impacts both from archaeological studies and from research into their indigenous knowledge, are a special feature of this region that will differentiate ScanTran from the other IGBP high latitude transects. The complementary environmental gradients of latitude and continentality also are a special feature of this region. These

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features, and their investigation, will be incorporated explicitly into the Science Plan for ScanTran.

In the final plenary session of the meeting agreement was reached as to the identity and structure of ScanTran and its scientific priorities. It is proposed that the Science Plan will be structured around three themes: 1. Understanding the processes and mechanisms of ecological change in response to environmental changes, with a clear focus upon the three principal ecotones of the region as identified at the Trondheim meeting (Nemoral and Boreal forest, forest and tundra, continuously and discontinuously vegetated tundra); 2. Integrating and synthesizing the likely responses of ecosystems to scenarios of potential environmental change, with landscape- to regional-scale modelling, GIS and remote-sensed data underpinning the assessment of the consequences of these responses for, for example, water supply, trace-gas fluxes, the forestry industry, reindeer husbandry, etc.; and 3. Examining the options for adaptation to changes and/or for the mitigation of undesirable changes, including the policy and other options. It also is clearly envisaged that there will be feed-forward and feed-back processes whereby results from each theme will then influence further research in the other two themes.

In order to carry forward the development of the Science Plan and of the ScanTran concept, a Steering Committee was established at the meeting. Nils Roar Sælthun (NIVA, Oslo) and Janne Hukkinen (Arctic Centre, University of Lapland) were nominated as the Chair and Vice-chair respectively of this committee. It also was proposed that the Steering Committee should have representatives from the series of relevant IGBP Core Projects (GCTE, BAHC, IGAC and PAGES at this time) as well as seeking representation from the IHDP; Brian Huntley is for the present the PAGES representative on the Steering Committee. In addition to the establishment of the Steering Committee, an offer was received from the CIRC (Kiruna) to host the ScanTran office and secretariat facilities; pending an application for funds to support this adequately at least some limited facilities would be made available immediately.

Members of the PAGES scientific community with research interests in Fennoscandia, the northern parts of European Russia or the European Arctic from east Greenland to Franz Josef Land should look out for future news of ScanTran that will be disseminated from time to time through further reports in this Newsletter as well as via a ScanTran home page that will be established later this year. If all goes according to the schedule outlined at the meeting then the Science Plan should be published by IGBP in 1999. This will identify priority research targets with respect to past environmental and ecological changes in the region; implementing the research towards these targets then will be a task for the PAGES community who will need to seek funding for their work in the usual ways.

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Changes in the Geosphere-Biosphere during the last 15,000 Years

Bonn, Germany, February 6-7, 1998

A fundamental understanding of the processes which have governed the terrestrial ecosystem and its evolution during the most recent period of Earth history has yet to be achieved. Natural archives, viewed within an archaeological context, provide a unique glimpse into the evolution of natural changes alongside the influence of mankind. In these records lie the clues required to disentangle past natural changes from those due to anthropogenic influences. In addition, they provide a spatial and temporal framework of past terrestrial ecosystem change upon which to base understanding of modern and potential future changes. These are the overriding goals of the multidisciplinary Deutsche Forschungsgemeinschaft priority program, designed as a contribution to PAGES research, funded from 1994 through 2000. Three time slices are defined within this program: (1) the transition from last glacial to early Holocene, (2) the postglacial climatic "optimum" and (3) the beginning of intensive use of natural resources by humans (ca. 1500 BC to 500 AD).

The Bonn workshop, which followed up on the initial agenda setting meeting of January 1995, concentrated on improving inter-project collaboration and dissemination of initial results through the establishment of the PANGAEA (PaleoNetwork for Geological and Environmental Data) database. Representatives of the more than 40 individual projects within this program were in attendance presenting results from a diverse suite of records in coastal sediments, peat, lake sediments, fluvial records and tephras. One of the key topics of discussion was the importance of comparison of the continental records being investigated under the auspices of this project with the variability which has been found in nearby marine sediment records from the North Atlantic. Another key message, especially in terms of the most recent records, was that the problem of separating and understanding natural vs. anthropogenic change provides a challenge to develop new and innovative thinking, methods, and techniques for using paleoarchives.

Representatives from comparable projects in Great Britain, Switzerland and the Netherlands were invited to put the project in the larger European context while presentations from representatives of the PAGES WDC-A database in Boulder and the PAGES IPO stressed the need for compatibility and sharing with existing international paleoclimate databases. The German IGBP office announced during the meeting the availability of three travel grants to support participation of young German scientists at the PAGES Open Science Meeting.

PANGAEA is an information system to archive, publish and distribute data from Global Change research with special emphasis on paleoclimatic, marine and environmental sciences. Data are stored with related metainformation in a relational database, accessible through a client/server system. The web client requires a browser with JAVA capabilities and write permission to the individual user's hard drive. Examples, help menus, and geographical plotting routines are provided to facilitate ease of operation and data retrieval. The guest user interface allows access to published data while a login is required for inter-project use of as yet unpublished data.

PANGAEA is physically housed at the Alfred Wegener Institute in Bremerhaven and is involved as the data management system for numerous German, European Union and international projects including:

- ADEPD Atlantic Database for Exchange Processes at the Deep sea floor (EC)
- CRP Cape Roberts Project (International) Ice sheets and climate (EC)
- Natural Climate Variability (BMBF)
- QUEEN Quaternary environments of the Eurasian North (ESF)
- SFB 261 The South Atlantic in the Late Quaternary: Reconstruction of tracer composition and current systems (DFG)
- Changes in the Geosphere-Biosphere during the last 15,000 years (DFG)

For further information on the "Changes in the Geosphere-Biosphere during the last 15,000 years" project contact the project coor-

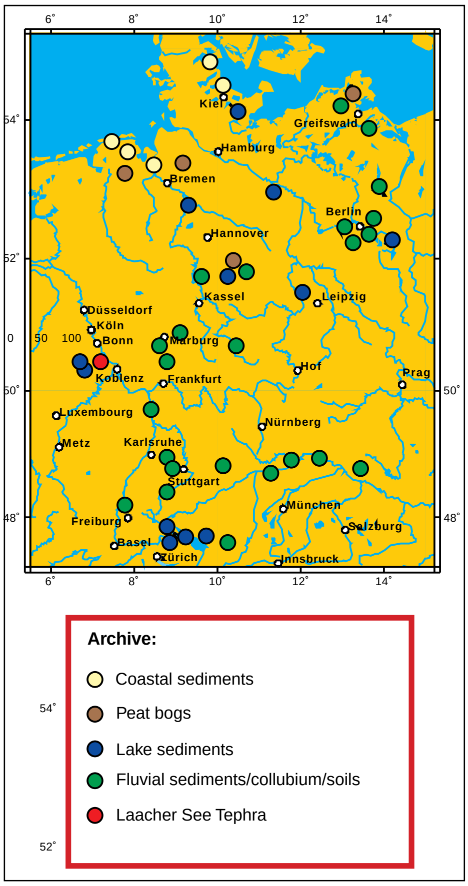

Fig. 13: Archive site locations for the "Changes in the Geosphere-Biosphere during the last 15,000 years" project.

dinator Prof. Dr. Wolfgang Andres (andres@em.uni-frankfurt.de) or access the internet site http://www.rz.uni-frankfurt.de/FB/fb17/ipg/spp/ (an English version of this site is under construction). For further information on PANGAEA e-mail info@pangaea.de or access the internet site http://www.pangaea.de.

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Global Change Research in Mountain Regions

Pontresina, Switzerland, April 15-19, 1998

Mountain regions worldwide present a set of unique challenges and opportunities for the study of past and future global climatic and environmental change. An exciting new potential IGBP inter-core project on Mountain research is currently taking shape. Several documents highlighting the mountain research agenda have recently been published. IGBP report 43, "Predicting Global Change Impacts on Mountain Hydrology and Ecology: Integrated Catchment Hydrology/Altitudinal Gradient Studies", documents the results of an international workshop held in Kathmandu, Nepal in April 1996. Initial development of this document arose primarily from the combined interests of BAHC and GCTE with some input from LUCC and PAGES. The report was complemented by documents from two follow-up meetings: a LUCC Workshop on "Dynamics of Land Use/Land Cover Change in the Hindukush-Himalayas" in Kathmandu, Nepal (April 1997), and the "European Conference on Environmental and Societal Change in Mountain Regions" in Oxford, UK (December 1997).

At the Pontresina workshop, a small group of about a dozen scientists, including representatives from all four of the above IGBP core project communities gathered to discuss implementation of a mountain workplan. The outcome of these discussions, taking the above publications as a starting point, is envisioned to be a clear set of tasks to be solved and proposals for action that will provide guidance for coordinated mountain research around the globe. In order to provide a truly global view, complementary monitoring efforts are required in all different types of mountain regions around the globe including polar regions, temperate zones and the tropics, coastal regions and dry continental interiors. PAGES has a well developed suite of mountain research projects reconstructing both climate and ecosystem change along altitudinal gradients spanning each of the PEP transects. Participating in this ongoing mountain research coordination effort could provide a mechanism for comparison amongst all of the latitudinal PEP transects along a "vertical transect." In addition, PAGES input into any new climate and ecosystem monitoring efforts which may arise out of this initiative could ensure that present day monitoring complements, both geographically and thematically, ongoing efforts in paleoreconstruction.

Any PAGES scientists interested in taking the lead in formulating potential PAGES participation in this project should contact Keith Alverson at the pages IPO (contact below). Further information and copies of the European Conference report on Global Change in the Mountains are available from Martin Price (martin.price@ecu.ox.ac.uk) Copies of IGBP report 43 are available on request from the IGBP secretariat (http://www.igbp.kva.se/). Further information on the potential intercore project mountain initiative can be obtained from Harald Bugman (bugmann@ucar.edu) or Alfred Becker (becker@pik-potsdam.de).

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Calibration of Historical Data for Reconstruction of Climate Variations

Barcelona, Spain, July 6-8, 1998

An international workshop titled, "Calibration of Historical Data for Reconstruction of Climate Variations" was held in Barcelona, Spain, on 6–8 July, 1998. The meeting attracted 22 participants from 12 countries. The aim of the conference was to focus attention on the availability of documentary materials containing high quality observations of weather and climate phenomena that could be used to reconstruct climatic variability prior to the availability of instrumental records.

Participants were asked to present talks on two major topics. The first major workshop theme dealt with calibration of the historical proxy record. That is, with the transformation of documentary written evidence (DE) about weather events and related phenomena into quantitative climatic indices. Sessions focused on the kinds of evidence available, weaknesses and strengths, temporal and spatial resolution, accessibility, etc., with emphasis on the development of extreme occurrences. A second major theme concerned the evaluation of time series of temperature and precipitation indices from DE, and comparison of DE-derived indices with other high resolution proxy data. That is, this latter focus was aimed at engaging in a discussion of methodological approaches to climatic reconstruction from DE and other proxy climate records, such as weighted and unweighted indices, cross-calibration, validation and some verification approaches.

The broader context for this meeting was to: 1) discuss scientific questions regarding the calibration and use of historical DE and other high resolution proxies such as tree-ring records to reconstruct past climatic variability, 2) discuss results of climatic reconstructions based on these proxy records in the context of PAGES and WCRP goals of defining climatic variability for the last 2000 years, and 3) to encourage the development and use of centralized archives for paleoclimate data, such as the World Data Center system, for enabling greater access by the scientific community to original source material, as well as the calibrated climatic indices.

A key question addressed by the participants was the following: How well can critical elements of past climate—frequency of occurrence of past climatic extremes, such as, floods, droughts, storms, etc.—in the past 500 to 1000 years, be reconstructed from the available historical record, and with what certainty? In particular, the time and spatial synchroneity of major climatic episodes was recognized as an important goal of historical climate recon-

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struction; i.e., the participants considered the issue of large-scale versus regional representativeness of the reconstructions.

Methodological issues were an important concern of this meeting, and considerable attention was paid to discussing the capabilities associated with various proxies for climate reconstruction. For example, DE sources from places in Europe and the Americas contain daily narrative records of temperature and precipitation from which it is possible to develop dryness and wetness indices with reasonable quantitative validity back to the 1600's, and in some regions, prior to that time. Other proxies are associated with economic (e.g., agricultural) activities, highly sensitive to seasonal and intraseasonal climatic variability. Other DE records contain detailed references to floods, hail, gales, tropical cyclone landfall, etc., from which long-term frequency changes of various types of climatic synoptic events could be derived.

A major impetus for these discussions was the recognized need to develop quantitative climatic indices from DE (and other proxy records) that would be readily interpretable outside of the immediate discipline of historical analysis of climate-related documentary records. It was agreed that a common mathematical language needed to be applied to all climatic reconstruction work, in order for the results to be readily comparable in other climatic reconstruction contexts, and enhance its usefulness to the broader climate research community. Initital emphasis is for reconstructing temperature and precipitation on monthly, seasonal and annual time scales. Selected high quality daily proxy records are acknowledged to be very useful, but they are fewer in number, not generally continuous for more than 2 or 3 decades, and require considerable researcher effort to convert into valid quantitative climatic indices. A consensus emerged on developing a standard unit index (-3, -2, -1, 0, 1, 2, 3) for monthly temperature and precipitation anomalies, corresponding to categories of extreme, much below/much above, above/below, and near normal conditions. These indices could then be aggregated into lower temporal resolution indicators (seasonal, annual) through summation or averaging of individual monthly indices.

Some of the difficulties inherent in the transformation of qualitative observations of weather and climate phenomena to quantitative indices of these variables were discussed. Among these are the credibility of the historical (DE) records and the subjective nature of both the observations and their interpretation, and questions regarding the homogeneity of historical series (non-continuous records, biases toward recording of outstanding values, changing biases as to what normal or abnormal weather conditions may have been, etc.). Means to standardize the information published by researchers in different places and using somewhat different translation systems (i.e., calibration techniques) were discussed. In particular, the consistent choice of a normal reference period was acknowledged to be of critical importance for comparison of DE-derived climatic indices across space and time. One suggestion is that climatic indices of deviations from a standard reference period (say, 1901-60) be produced for intercomparisons with other proxy sources. Also suggested was the development of indices of extreme event occurrences. These could be tallies of particular unusual phenomena occurring through time, or based on the exceedance of certain threshold values in the data record.

The question of what climatic signal is being reconstructed was also discussed. That is, what frequency band—interannual, decadal, centennial—is being more accurately reproduced in the reconstruction. Also, an effort is needed to develop meaningful confidence intervals for the reconstructed climatic indices, similar to what is routinely done with tree-ring reconstructions. Other discussions centered on development of good regional reconstructions, using both single (DE) proxy records and multiple or weighted indices utilizing a mix of proxy data sources.

It was agreed that research into climate reconstruction from historical records would benefit from a general focus into issues of importance to international scientific programs, such as CLIVAR, and PAGES. In particular, questions related to the impact on climate from large volcanic eruptions, solar variability, El Niño-Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO) and greenhouse gas forcing of climate change should be a focus of much of this type of research. As noted above, cross-checking of DE reconstructions with other proxy records is likely to improve the accuracy and interpretation of both types of records. Much more effort is needed to improve the calibration and validation of the DE-derived climate reconstructions.

To help the process of calibration, validation and verification of DE climatic reconstructions, the following procedures were suggested that largely follow the standard procedures being used today for climatic reconstruction using high resolution proxy records, such as tree rings, ice cores, and varved sediments. The steps are: 1) calibration and validation of index values, 2) context setting by comparison of local signal with regional, and large-scale indices, 3) connecting the signal to known forcing periods (volcanoes, ENSO, etc.), and 4) synthesis of individual reconstructions into a hemispheric or globally coherent picture.

Recommendations

A number of suggestions were made to advance the level of scholarship and the scientific utility of climatic reconstructions from historical records. One recommendation is to focus the community's efforts toward ongoing or newly emerging international efforts, such as the Earth System History's (ESH) annual records of tropical systems (ARTS), reconstruction of the climate of the 19th century and/or 18th centuries, and natural hazards reduction activities being supported under the International Decade of Natural Disaster Reduction (IDNDR) initiative.

In regards to improvements in the quantitative representation of climatic reconstructions from historical records, major tasks would involve: 1) statistical characterization with reference to relevant instrumental data, 2) strengthening relationships to natural hazards research, 3) the identification of key, or sensitive, regions from a climatic point of view, and 4) developing appropriate methods for intercomparison with other proxy records. There are also linkage possibilities to the botanical community that should be explored. Through such efforts it may be possible to identify areas or regions with high potential for extracting climate proxies from historical sources (including phenological observations), where special efforts could be applied to implement "observational campaigns" in order to extract the information and make it useful for climate researchers worldwide.

There are a number of areas where opportunities for interdisciplinary research on climate and societal impacts exist at present. For many reasons research on climatic reconstruction from historical documentary records has been very poorly supported in the United States in the past couple of decades. While much greater scholarship in this area has been evident in Europe and parts of Asia, partly for obvious "historical reasons", as a whole, the discipline is in dire need of an infusion of fresh talent and fresh ideas. It is hoped that this workshop will serve not only to advance the study of climatic variability in general, but also to spur an interest in the study of historical climate reconstruction.

Acknowledgments

The workshop on "Calibration of Historical Data for Reconstruction of Climate Variations" was supported by the U.S. National Science Foundation, the U.S. National Oceanic and Atmospheric Administration's Office of Global Programs and the IGBP/PAGES International Project Office in Bern, Switzerland. Local support was provided by the University of Barcelona, the Catalán Meteorological Service and the Diputació de Barcelona, which graciously provided meeting facilities. The organizers gratefully acknowledge their support.

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Global Climate Change and the South African Flora: Past, Present and Future

The National Botanical Institute, Kirstenbosch, in conjunction with the University of Cape Town, Botany Department are undertaking the biodiversity component of the South African Country Study on Climate Change (SACSCC) project. The specific objective of the project is to provide future plant diversity scenarios given changes in climate, combined with UV-B flux and atmospheric CO_2 changes. The question of biodiversity is highly relevant to South Africa, due to its extremely rich, unique flora with high levels of endemism. For example, the Cape Floral Kingdom (CFK) is the smallest floral kingdom in the world, covering approximately 90,000 square kilometers, with approximately 8,600 species of plants. Of these plants 5,800 are endemic to the CFK. Four fifths of the CFK is composed of the world famous Cape Fynbos vegetation (*Fig. 14*). This vegetation type is characterized by four growth forms: tall protea shrubs (proteoids); heath like shrubs (ericoids); reed-like plants (restioids); and bulbous herbs (geophytes). Adjacent to the Cape Floral Kingdom is the Succulent Karoo Biome, which is home to almost 60% of the world's succulent flora (Cowling and Richardson 1995). Assessing the effects of future global warming on the flora of South Africa is thus an important task in light of the high plant diversity in the region.

As part of this study, a database of all the paleobotanical information (predominantly pollen and charcoal remains) since the last glacial maximum (18k BP) available for South Africa is being compiled. Unfortunately, the paleobotanical legacy in this region is poor, unlike the northern hemisphere where conditions associated with glacier retreat have allowed good estimation of vegetation movement. We have recorded the taxa present at approximately 30 sites in South Africa at various times in the past. All the relevant literature on past plant (Family, Genus or Species level) occurrences is being collected. A database of all the identified plant occurrences in South Africa is being compiled. We are attempting to compile a complete list of similar projects which are being conducted (Prentice 1996, Partridge *et al.* in prep) such as the Biome 6000 project (Prentice 1996) which aims to product a global data set of past vegetation for 6,000 radiocarbon years ago, based on pollen and plant macrofossil records. Unlike the Biome 6000 project the information which we are assembling for the SACSCC project is only for South Africa. This information will allow us to assess past distributions of important taxa and vegetation groupings to provide estimates of rates of movement in the past. The database has been linked to a Geographical Information System (GIS) in order to provide a visual means of displaying the sites and taxa. Using this program an attempt will be made to determine the movement of taxa over the past 18,000 years.

As part of this project we will also be modelling the future movement of plant taxa in South Africa based on the climatic scenarios which have been provided for the country. This is a refinement of the one step distribution changes of previous work in South Africa (Rutherford *et al.* 1995 a & b). The changes in distribution of vegetation types and some specific taxa at selected intervals of time over the next approximately 50 years will be mapped in an attempt to determine how terrestrial biodiversity will be affected by future climatic changes. This project is novel in South Africa, incorporating past vegetation changes with future changes in plant distribution and assessing the changes in biodiversity.

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6. Partridge, T.C. et al. Synthetic reconstructions of southern African environments during the Last Glacial Maximum (21 – 18 kyr) and the Holocene altithermal (8 – 6 kyr). In prep.

PAGES Science and Biodiversity

It is difficult to define any direct contribution from PAGES-style paleo-science to biodiversity issues, at least in relation to terrestrial ecosystems, The concept is only meaningful at the biological species (or 'lower') hierarchical level. Taxa tend to respond to environmental change rather individualistically and the level of taxonomic resolution we can achieve, using pollen analysis for example, is rarely adequate. At least we can contribute insight into past variations in physico-chemical conditions; perhaps also some indication of biotic responses from the recorded changes in distribution of a few, possibly 'indicative' taxa. The questions then are:

- if this is the most we can realistically do, is it useful in any discourse about the maintenance of future biodiversity?
- if we set out with 'biodiversity' as a priority issue, might we find ways of addressing it more effectively?

The article by Allsopp *et al.* illustrates the way in which the paleo-science dimensions are being considered within the context of one of the world's richest and most fascinating regions from the point of view of higher plant biodiversity. We hope to take up the issue with regard to aquatic biodiversity in a subsequent Newsletter.

Frank Oldfield

Fig. 14: Fynbos with Ericaceae and Proteaceae and Restionaceae (Photo: Percy Sergeant Memorial Collection, Janet Allsopp)

INSIDE PAGES

Changes in PAGES SSC and at the Office in Bern

PAGES SSC welcomed three new members at the start of 1998:

Jose (Pepe) Boninsegna is a senior researcher of the National Scientific Council of Argentina (CONICET) based in Mendoza, Argentina. His expertise is in dendrochronology and dendroclimatology. During the course of his career he has established numerous international collaborations and has been a visiting scholar in France, The United States, and Great Britain.

Anne de Vernal is a professor in the Research Centre in Isotope Geochemistry and Geochronology (GEOTOP) in the Earth Science Department at the Université du Québec à Montréal in Canada. Her research interests include paleoceanography, paleoclimatology, paleoecology and marine palynology. One major research project is the reconstruction of the paleoceanographic conditions (temperature, salinity, and sea ice distribution) in the northern North Atlantic ocean during the last glacial maximum using the distribution of dinoflagellate cysts in sediment cores.

Matti Saarnisto is currently research director of the Geological Survey of Finland. His expertise is in quaternary and environmental geology. He has served in several international science organizations including the IGCP (International Geological Correlation Programme) and INQUA (International Union for Quaternary Research) and is also currently on the steering committee of the European Science Foundation QUEEN (Quaternary Environment of the Eurasian North) Project.

Alongsinde welcoming these new SSC members, we would like to thank the three departing members for their outstanding contributions over the past years: Bill Ruddiman of the University of Virginia, USA, Marin Iriondo from Argentina and Eugene Vaganov, of the Institute of Forestry, Krasnoyarsk, Russia.

Cindy Jones, the publications officer responsible for the design of PAGES workshop reports and this newsletter over the past two years, has left the PAGES office. Her fine eye for artistic design will be greatly missed. We hope, largely by continuing to employ the formats developed by Cindy, to continue to produce aesthetically, as well as informationally, pleasing reports and newsletters.

START Young Scientist Awards to Daniel Olago and Nathsuda Pumijumnong

Two of the recently announced 1998 START Young Scientist Awards were made to paleoscientists from within the PAGES community. Daniel Olago of the University of Nairobi was recognized for his recent paper on long-term temporal characteristics of paleomonsoon dynamics in equatorial Africa based on a continuous sediment core sequence from Sacred Lake on the slopes of Mount Kenya. In the study, Olago et al. use mineral magnetics and stable carbon isotopes as proxies to demonstrate strong precipitation variability at 23,000 and 11,500 yr periods since the last interglacial. Nathsuda Pumijumnong was cited for her tree ring research on teak *(Tectona grandis)* in northern Thailand. Tree growth was shown to be controlled primarily by rainfall from April to June, demonstrating that these trees may provide a promising new proxy for climatic reconstruction in this area for at least the past 3 centuries.

The START Young Scientist Awards program was initiated to recognize the achievements of outstanding young scientists from developing countries in Asia and Africa. Recipients receive a prize in the amount of $1,000 and a certificate of award.

PAGES CALENDAR

(* indicates open meetings. All interested scientists are invited to attend)

***September 7–11, 1998, "Climate and History: Past and Prsent Variability–A Context for the Future" Norwich, UK**
Contact: Susan Boland, Climatic Research Unit, University of East Anglia, Norwich, NRA 7TJ, England
Tel: +44 1603 456161, Fax: +44 1603 507784
s.boland@uea.ac.uk; http://www.cru.uea.ac.uk/cru/conf/

*** September 29-30, 1998, "Quaternary volcanism, climate and society: forcings and feedbacks" Cambridge, UK**
Contact: David Pyle, University of Cambridge, Department of Earth Sciences, Downing Street, Cambridge, CB2 3EQ, England
Fax: +44 1223 333 450
dmp11@cam.ac.uk; http://www.esc.cam.ac.uk/QV.html

October 10-11, 1998, "PEP3 African Crater Lakes Workshop" Gent, Belgium (this workshop is invitation only)
Contact: Dirk Verschuren, Department of Biology, University of Gent, K.L.Ledegankstraat 35, B-9000 Gent, BELGIUM; Tel: 32-9-2645262; Fax: 32-9-2645343; dirk.verschuren@rug.ac.be

***October 26-30, 1998, "3rd Annual Conference of the International Geological Correlation Programme Project 396: Continental Shelves in the Quaternary" Goa, India.**
Contacts: Dr M. Veerayya and Mr K.H. Vora, National Institue of Oceanography, Dona Paula, Goa, India; Fax: 91(0) 0832 223340 / 239102; Tel: 221322 / 226253; veerayya@csnio.ren.nic.in or veerayya@darya.nio.org; vora@csnio.ren.nic.in or vora@darya.nio.org
http://www2.env.uea.ac.uk/gmmc/igcp/goa/igcp98.html

***December 1-4, 1998 "WMO/IOC/ICSU Conference on the WCRP ClimateVariability and Predictability Study (CLIVAR)" Paris, France.**
Contact: CLIVAR Conference Secretariat c/o Max Planck Institut für Meteorologie, Bundesstr. 55, D-20146 Hamburg, Germany,
Tel: +49 40 41173 412; Fax: +49 40 41173 413;
clivar@clivar.dkrz.de; http://www.dkrz.de/clivar/hp.html

January 26-28, 1999 "Marine Environment, the Past, Present and Future". Kaohsiung, Taiwan.
Contact: Chen-Tung Arthur Chen, Institute of Marine Geology and Chemistry, National Sun Yat-Sen University. Kaohsiung, Taiwan;
Tel: +886-7-525 5146; Fax: +886-7-525 5346;
ctchen@cc.nsysu.edu.tw

May 6-14, 1999 "IGBP Congress (with PAGES Scientific Steering Committee Meeting)" Yokahama, Japan.
IGBP Contact: IGBP Secretariat, Royal Swedish Academy of Sciences, Lilla Frescativägen 4, Box 50005, S-104 05 Stockholm, Sweden;
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***August 3-11, 1999, "The Environmental Background to Hominid Evolution in Africa - INQUA XV International Congress", Durban, South Africa.**
Contact: Dr D.M. Avery - Secretary General, South African Museum, P.O. Box 61, Cape Town 8000, South Africa;
Tel: +27-21-243330; Fax: +27-21-2467;
mavery@samuseum.ac.za; http://INQUA.geoscience.org.za/

***November 15-19, 1999, "International Symposium on Multifaceted Aspects of Tree Ring Analysis" Lucknow, India.**
Contact: Dr. Amalava Bhattacharyya, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India;
Tel: 91-0522-333620; Fax: 91-0522-381948
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