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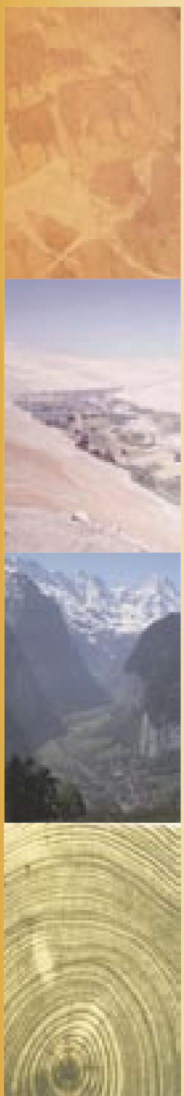
PAGES News
PAST GLOBAL CHANGES

Pinxian Wang, Yucheng Chai, Zhengtang Guo and Christoph Kull, Editors

Vol.13, N°2 – August 2005



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Chinese Paleoscience

With the highest and largest plateau in the world, the world's thickest loess, marvelous karst formations, and nearly 20,000 km of coastline, China has paleoenvironmental records at many different time resolutions and over a wide range of time periods, from climate zones with tropical to sub-zero temperatures and from moist coastal to dry continental regions.

Contents

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Editorial: PAGES in China

It is a delightful event for the world's paleoscience community that the 2nd PAGES Open Science Meeting (OSM) will be held in Beijing, 10-12 August 2005. This meeting is entitled "Paleoclimate, Environmental Sustainability and Our Future", and will focus on the understanding of past environmental processes, natural variability and human impacts that are indispensable for developing predictive models.

The current issue of PAGES News is dedicated to this important event. The excellent manuscripts presented here recall to my mind the history of how paleo-studies in China have progressed, how Chinese scientists have strived and contributed, and how we have numerously benefited from the international community.

Twenty years ago, loess research represented one of the main themes in paleoclimatology in China, and has significantly contributed to the understanding of the history of the Earth's climate system. Since then, major progress has been made for a variety of other records. Marine and lake drilling carried out in the past years have provided a wealth of new information on various timescales. The Tibetan ice-cores, the speleothem and tree-ring records with quite a good temporal and spatial coverage have documented a detailed history of climate change in China at millennial-to-decadal scales. The abundant historical data in China, unique in many aspects, provide an excellent record for past human-nature interactions. The contributions in this special issue highlight part of this progress and also point out the liveliness of these domains. It is also worth mentioning that a loess record has been traced back to 22 Ma BP and a continuous marine record covering the last 24 Ma has been recovered from the South China Sea. These will also provide new possibilities for addressing the past land-sea interactions. Over the last years, encouraging efforts have also been made in the study of biogeochemical processes and data-model comparisons.

Although major progress has been made, there are still many open questions that require new or future answers. We are encouraged that PAGES study has constantly received great support from various national funding agencies over the past two decades, and is considered a priority research field in the future strategy plans of these agencies. This provides a solid basis for paleoresearch in China to reach a higher level and to contribute more to international efforts.

I would like also to take this opportunity to express a warm welcome to all the scientists attending the upcoming PAGES OSM. The 1st PAGES OSM was held in London in 1998 and has led to numerous international collaborations and interdisciplinary exchanges. I hope the 2nd PAGES OSM will be equally successful.

Prof. Dr. Liu Tungsheng
PAGES 2nd OSM Local Organizing Committee Vice Chair
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Climate Change: The Karst Record KR IV

Theoretical and Applied Karstology - Int. Symposium (XIXth edition)

26 - 29 May, 2006, Baile Herculane, Romania

Chairs: Bogdan Onac and Silviu Constantin (Romania)

The "Theoretical and Applied Karstology" (TAK) International Symposium has a long tradition in gathering scientists from all fields related to the science of karst and caves, ranging from theoretical ones (such as karst geology, caves mineralogy, physics and chemistry of karst processes, geomorphology) to applicative studies (hydrogeology, show-caves management, sustainable development in karst regions, etc). We would like to bring together again colleagues from all over the world sharing an interest in using cave deposits for paleoclimate reconstructions. All presentations dealing with speleothem records (chronology, geochemistry, isotopic, paleomagnetic, petrographic, etc.) as well as other cave deposits (detrital, archaeologic, palaeontologic) relevant for climate history, evolution of karst regions and cave systems, as well as present-day cave conditions monitoring in relation with climate are welcome. We also welcome theoretical approaches and models relevant for cave deposits interpretation (e.g. speleothem growth models, accumulation rates of cave sediments, etc.).

Further Information:
- http://www.karst.ro/
- Scientific committee: Bogdan Onac (bonac@bioge.ubbcluj.ro)
- Organizing committee: Silviu Constantin (silviu.constantin@geo.uib.no)

Inside PAGES

The major focus at the PAGES IPO over the past few months has been the preparations for PAGES 2nd Open Science Meeting, to be held in Beijing, from 10-12 August 2005. Another area of focus has centered around the future direction of PAGES. Discussions in the scientific community have already resulted in the launch of new PAGES activities (see PAGES News 2005/1). Further new and adapted activities are expected to develop during the upcoming year. We will keep you updated via the PAGES website (www.pages-igbp.org), via future issues of PAGES News and e-news bulletins.

PAGES 2nd OSM:
PAGES has received a large number of truly outstanding abstracts and the meeting promises to be a milestone in the history of the PAGES program. All accepted abstracts are now available online at www.pages2005.org. Even if you can't come to the meeting, you can take advantage of this searchable database to read the latest results in paleoscience.

PAGES would like to take this opportunity to express its deep gratitude to the Local Organizing Committee in China for all their hard work and to the international sponsors of the meeting for providing generous financial support.

PAGES Office:
After the OSM, IPO staff will turn their attention to the preparation of a new grant proposal for 2006-2010 to the Swiss and US National Science Foundations. A modified structure and new, more proactive agenda will form the basis of this submission. At the same time, the IPO will continue its work in improving web services, and communication and networking activities. We are always open to contributions from the paleo-community, especially with regard to suggestions for new PAGES activities. We also encourage you to consider a short stay at the PAGES IPO as a guest scientist (see page 28).

PAGES Newsletter:
The next issue of PAGES News will be devoted to highlighting PAGES/CLIVAR activities. It will be published jointly by PAGES and CLIVAR and will therefore have a slightly different layout and content structure. The scientific focus will be on forcings in the climate system.

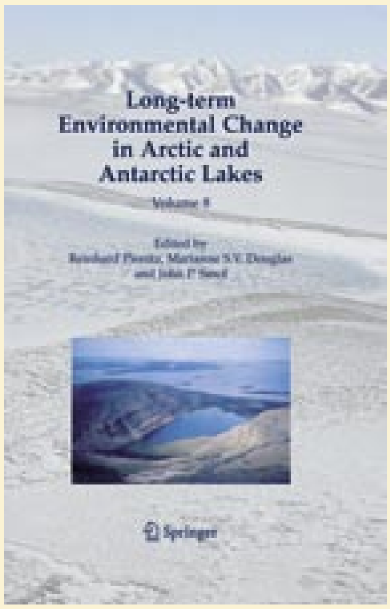
Please note that we have recently changed our policy on special issues. Unlike in the past, all future special issues will contain a section for open contributions. We therefore welcome your submissions of science highlights year-round, as well as program news, workshop reports and humorous tales from the field. Guidelines can be found at www.pages-igbp.org/products/newsletters/instructions.html. Feel free to contact Christoph Kull (kull@pages.unibe.ch) with any questions.

New on the PAGES Bookshelf:

Long-Term Environmental Change in Arctic and Antarctic Lakes

Reinhard Pienitz, Marianne S.V. Douglas, John P. Smol (editors)
Developments in Paleoenvironmental Research Series, Vol. 8, 2004
Springer, 562 pp. ISBN 1-4020-2125-9, 99 Euro

Concerns over the effects of global climate change have focused attention on the vulnerability of circumpolar regions. Long-term historical data are needed to predict the magnitude and direction of future environmental changes. The paucity of instrumental data requires that proxy methods be used. The abundance of lakes throughout the Arctic and Antarctic makes paleolimnological approaches especially powerful tools to assist interpretations of environmental change. This book provides a synthesis of the broad spectrum of techniques available for generating long-term environmental records from circumpolar lakes, in addition to providing overviews of the geographic extent of paleolimnological work completed thus far in these regions. It explores the diverse ways in which paleolimnology is used to address the pressing and emerging environmental issues of high-latitude regions. By providing both an introduction and in-depth reviews, this volume is of interest to students and advanced researchers alike who are studying Earth, atmospheric and environmental sciences.



INTIMATE: Integration of Ice core, Marine and Terrestrial Records of the Last Termination in the North Atlantic Region and Elsewhere

Zicheng Yu[1], Wim Z. Hoek[2] and Rewi Newnham[3]

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INTIMATE is a core project of the INQUA Palaeoclimate Commission. It was initiated during the XIVth INQUA Congress held in Berlin in 1995 by John Lowe (Royal Holloway, London) and Mike Walker (University of Wales, Lampeter). The project's primary goal has been to encourage collaboration between members of the ice-core, marine and terrestrial communities and to synthesize records during the last glacial-interglacial transition, with initial focus on the North Atlantic region. A milestone for the project was the development of an event stratigraphy for the last termination in the North Atlantic region based on the Greenland Ice Core isotope record and chronology (Björck et al. 1998).

INTIMATE has organized annual workshops since its initiation during the inter-congress periods as well as during the last two INQUA congresses in Durban, South Africa in 1999 (XVth) and in Reno, Nevada in 2003 (XVIth). Around the central goal of correlation of ice cores, marine and terrestrial records, the specific objectives for the project have changed over the years. As chronology is fundamental for the correlation and integration, the project has always strived to develop better ways for more precise and accurate dating of climatic events.

During the last four years INTIMATE has been successful in enlarging its North Atlantic scope in order to explore the issue of global synchroneity of the abrupt climate changes during the last glacial-interglacial transition. After the Reno INQUA Congress, the Australasian INTIMATE Project was established, and the original INTIMATE has become the North Atlantic INTIMATE Project. We are in the process of expanding the project to other regions to facilitate global synthesis.

The overall aims of the North Atlantic INTIMATE project are (a) to explore the potentials of different time-stratigraphic marker horizons in ice-core, marine and terrestrial records; (b) to reduce the uncertainties in timing of events (e.g. spatial and temporal differences in marine reservoir ages); (c) to determine spatial patterns of events and gradients; and (d) to compare the data of spatial and temporal reconstructions with palaeoclimate model results.

Fig. 1: Participants to the 7th International (North Atlantic) INTIMATE Workshop, held in Bonn, Germany on 15-18 September 2004. The photo was taken on September 17 at Meerfelder Maar in the Eifel Volcanic Field, Germany.

The 7th International (the first North Atlantic) INTIMATE Workshop was held in Bonn and the Eifel Region, Germany on September 15-18, 2004, hosted by Thomas Litt (Friedrich-Wilhelms University, Bonn) and attended by 38 participants from 12 countries. The excursion to the Eifel Volcanic Field and the type locality of the Laacher See Tephra was memorable (See Fig. 1). At the Workshop, the participants reviewed the progress during the 1999-2003 inter-congress period and refined the specific objectives of the North Atlantic INTIMATE group for the 2003-2007 inter-congress period. The workshop participants also decided to extend the time frame to cover the last glacial and early Holocene (30–8 ka). A representative from the Australasian INTIMATE project (Rewi Newnham) attended the workshop to facilitate synergy between two groups and between two hemispheres. The next North Atlantic (8th) INTIMATE International Workshop will be held September 10-14, 2005 in Mýrdalur, Iceland, which will be hosted by Jón Eiríksson along with his colleagues. This Workshop will focus on the synthesis of paleoclimatic records in the North Atlantic Region during the last Glacial and early Holocene (30-8 ka). The topics of discussion include correlations of paleoclimate records using tephrochronology and the new INTCAL04 calibration data-set, identification and mapping of the key records in the region, and the new NGRIP timescale for the last Termination.

During the next (XVIIth) INQUA Congress in Cairns, Australia in 2007 the plan for the INTIMATE projects is to provide regional overviews and a joint global synthesis of reconstructions. We welcome inputs from paleo-scientists working on ice cores, marine and terrestrial records. If you have suggestions, please contact one of us. For additional information and the INTIMATE projects please visit the web site: http://www.geog.uu.nl/fg/INTIMATE/Welcome.htm.

Reference

Björck, S. and others., 1998: An event stratigraphy for the Last Termination in the North Atlantic region based on the Greenland Ice Core record: a proposal by the INTIMATE group. *Journal of Quaternary Science*, **13**: 283-292.

Regional Multiproxy Climate Reconstruction for Southern South America: A new Research Initiative

Martin Grosjean[1] and Ricardo Villalba[2]

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Fig. 1: Laguna Negra, high Andes of Central Chile. The potential contribution of sediments from small glacial lakes to high-resolution multiproxy climate reconstructions for the last milennium is currently explored in a joint Chilean -Swiss project (M. Grosjean U Bern, Micha Herzog UGZ Magdeburg).

Regional high-resolution multi-proxy climate reconstructions and associated uncertainties for the last ca. 1000 years is a priority area of future research within IGBP-PAGES (Wanner 2005). Considerable progress has been made in the reconstruction technique, in the handling of a wide range of high- and low-frequency proxy data, and in the quantity and quality of proxy data sets available at continental and northern hemispheric or global scale (e.g. Mann et al. 1998; Jones et al. 2001; Esper et al. 2002; Briffa and Osborn 2002; Luterbacher et al. 2004; Moberg et al. 2005). Regional reconstructions are particularly important since regional climate change and extremes exhibit much larger amplitudes than hemispherical and global reconstructions. The monthly to seasonal temperature multiproxy reconstruction for Europe since 1500 AD (Luterbacher et al. 2004; Xoplaki et al. 2005) and the drought reconstruction for the western US (Cook et al. 2004) have set new standards for regional scales. Similar studies are missing for other regions of the world.

Starting in October 2005 under the umbrella of PAGES, a collaborative longterm initiative will seek (i) to collate the large number of disperse already existing and new paleoclimate data sets (documentary data, early instrumental data, data from tree rings, glaciers and ice cores, high resolution marine and lake sediments, pollen data of peat cores etc.) for the last ca. 1000 years available for South America, and (ii) to use the Mann et al. (1998), Luterbacher et al. (2004) and Moberg et al. (2005) methodologies to work towards a regional reconstruction at different temporal and spatial resolution with associated uncertainties for southern South America.

This project is conceived as a collaborative initiative that will involve many research groups from different countries working within a common frame for a common goal. A first coordinative meeting will take place at Mendoza in October 2005 to set up the organizational frame and to discuss participation of groups in the project and contributions of data sets. A formal announcement and invitation for collaboration will follow thereafter. A first science meeting is planned for October 2006.

The initiative is coordinated by Ricardo Villalba (IANIGLA Mendoza, Argentina, PAGES SSC member) and Martin Grosjean (NCCR Climate, University of Bern, Switzerland).

If you wish to be on the mailing list, please contact Ricardo Villalba (ricardo@lab.cricyt.edu.ar) or Martin Grosjean (grosjean@giub.unibe.ch).

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Wanner H., 2005: Call for a PAGES Initiative on Past Regional Variability, *PAGES News*, **13**: 19-20.

Contribute:

Is this your field of expertise? Scientists interested in getting further information on this effort should contact Ricardo Villalba (ricardo@lab.cricyt.edu.ar) or Martin Grosjean (grosjean@giub.unibe.ch).

China

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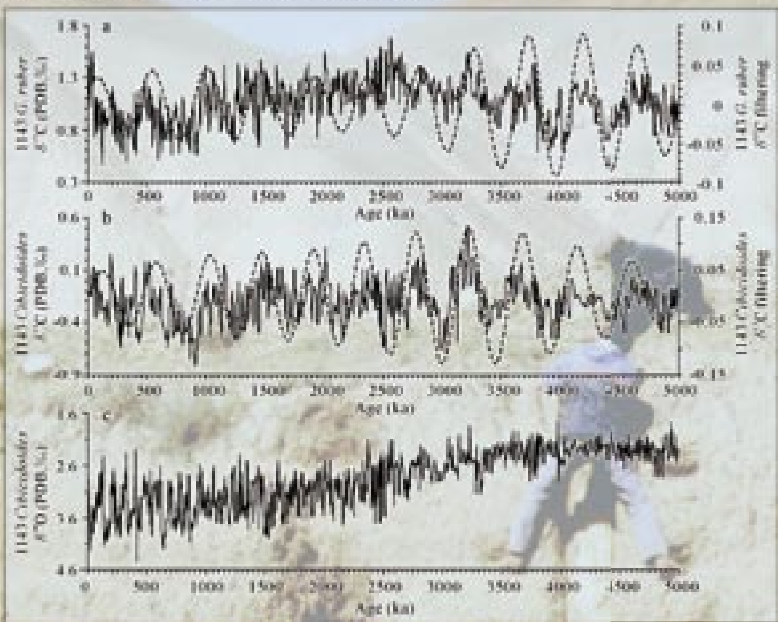
Welcome

With the highest and largest plateau in the world, the world's thickest loess, marvelous karst formations, and near twenty thousand kilometers of coastline, China has paleoenvironmental records at many different time resolutions and over a wide range of time periods, from climate zones with tropical to sub-zero temperatures and from moist coastal to dry interior precipitation. The monsoon climate regime governs most natural processes in very large part of China. With the oldest continuous civilization, human activity has been influencing environmental change significantly and over a wide area. The paleoenvironmental research community and scientists in China are willing to collaborate with others globally to investigate the past of our planet and supply data for future climate simulations

National Science Highlight: Analyses of the deep-sea sediment sequence recovered from ODP Site 1143, southern South China Sea

Pinxian Wan (Dept. of Marine Geology, Tongji University)

Analyses of the deep-sea sediment sequence recovered from ODP Site 1143, southern South China Sea, and comparisons with long sequences from over the global ocean reveal a series of ~500 kyr cycles in $\delta^{13}C$ records. These "supercycles" also appear in carbonate preservation records, and the $\delta^{13}C$ maxima are inferred to reflect episodes when the carbon reservoirs and the upper ocean structure in the global ocean experienced profound reorganization, probably induced by changes in phytoplankton and the oceanic "rain ratio," associated with "giant diatom" blooms in the open ocean. Prediction of the future natural changes of the global climate is compromised without understanding the physical and climatic meaning of the long-term carbon cycles.



Reference: *500 kyr "supercycles" in $\delta^{13}C$ records from ODP Site 1143, southern South China Sea (Wang P. et al., Paleoceanography, 2004)*

Research Institutions

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  www.igcas.ac.cn/english/index.htm
- **School of Ocean and Earth Science, Tongji University**
  www.tongji.edu.cn/english/depart/depart.htm
- **Institute of Geographic Sciences and Natural Resources Research, CAS**
  www.igsnrr.ac.cn/index.jsp
- **Institute of Earth Environment, CAS**
  www.ieecas.cn/EngIndex.htm

Funding Agencies

- **The National Natural Science Foundation of China (NSFC)**
  www.nsfc.cn/
- **The Ministry of Science and Technology of China (MSTC)**
  www.most.gov.cn/eng/
- **The Chinese Academy of Sciences (CAS)**
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Holocene Climatic Variability Inferred from Lacustrine Deposits in Arid China

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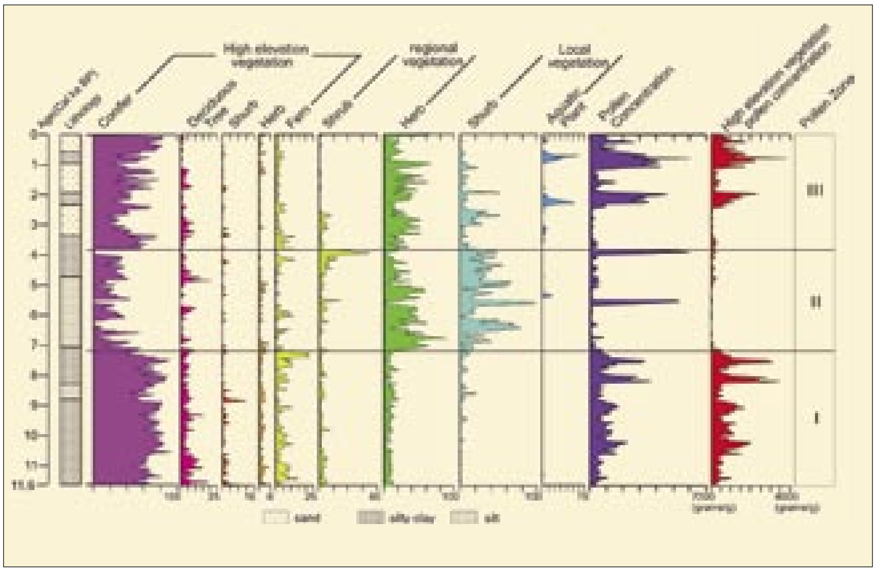

Fig. 2: Pollen diagram from Zhuyeze Lake (SJC section) presented ecological groups, with calibrated age. Pollen concentrations and pollen zones are also shown.

The arid history of the Holocene interglacial could provide an analog for future climatic variations in the interior of the Eurasian continent. Previous research has revealed an unstable climate with distinct periodicity (O'Brien et al., 1995) and rapid change events (Bond et al., 2001) that are probably of global scale (Mayewski et al., 2004). In China, the prevailing concept is that a wet and warm period, the so-called "Holocene Optimum", existed in the mid-Holocene across China (Shi et al., 1994), during which the area had high precipitation and a humid climate. However, recently published data suggest a geographic differentiation of the Holocene climate in arid and semi-arid China (An et al., 2005). Here we attempt to further address this issue by reporting lacustrine depositional records in arid China that support our previous finding that the Holocene climate in arid and summer monsoon margin regions was generally unstable, with a very strong drought during the mid-Holocene (Chen F. H. et al., 2003). Lacustrine sediment cores from Juyanze Lake and Zhuyeze Lake in the south Mongolian Plateau, and Bosten Lake in the Tarim Basin, were collected to reconstruct climatic variations during the Holocene.

Geographical Settings and Laboratory Methods

Bosten Lake (86°41′-87′E, 41°56′-42°14′N) is the largest freshwater body in arid China, adjacent to the largest desert in China, the Taklimakan. Both Juyanze Lake (101°34′E, 42°00′N) and Zhuyeze Lake (103°20′E, 39°00′N) are terminal lakes of rivers originating on the northern side of the Qilian Mountains. These lie on the present margin of summer monsoon regions in arid western China. The average annual precipitation near these three lakes is less than 100 mm.

The lithology of the Bosten Lake core is shown in Figure 1. Sediment samples were taken every 2 cm. TOC and $CaCO_3$ content were analyzed using two methods: loss on ignition (LOI 550°C and LOI 880°C) (Ströhlein instrument). Five radiocarbon-AMS dates on terrestrial plant residues provide age control. Core G36 was drilled on the flat lake floor of Juyanze Lake. Lithology varies within the core, with frequent alternations of clay, silt/sand and salt. Five radiocarbon-AMS dates on terrestrial plant remains indicate that this core covers almost all of the Holocene (Fig. 1). TOC was analyzed at 2-5 cm intervals using the same method as samples from Bosten Lake. The lacustrine sediment at the SJC section, located at the western margin of Zhuyeze Lake, consists of silty-clay, silt and sand, with thin black

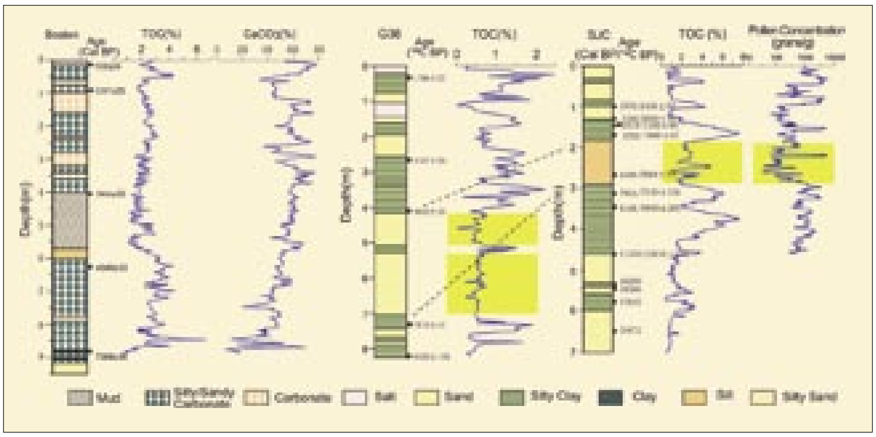

Fig. 1: The lithology and proxy variations of Bosten Lake, Juyanze Lake (G36 core), and Zhuyeze Lake (SJC section). Radiocarbon dates are alongside the lithological column (squares = terrestrial plant remains or pollen concentrates; circles = bulk organic matter). The dates from bulk organic matter at SJC have been corrected by 530 years to account for a carbon reservoir effect (Chen F.H. et al., 2003). The shaded areas indicate the mid-Holocene dry event and generally shallow lakes around ca. 7-5 cal yr BP. Dashed lines show the correlation between different lakes.

layers of high organic matter. The chronology of this section is established by thirteen radiocarbon dates that show the base of the section dates to the Last Glacial Maximum, while the upper 4.6 m formed during the Holocene (Chen F.H. et al., 2003). Standard pollen analysis techniques were used to analyze 232 pollen samples collected at 2-cm intervals (ca. 50 yr/sample) for the Holocene. With some exceptions, over 300 pollen grains and spores per sample were counted.

Results and Discussion

Variations of proxies obtained from these three lake cores are shown in Figure 1. Figure 1 clearly shows that TOC generally declined but $CaCO_3$ generally increased during the Holocene in Bosten Lake. It is safe to say from the sandy lithology that the early Holocene (before about 8.5 yr BP) is characterized by a dry climate. More detailed and accurate analyses are ongoing. The TOC of core G36 illustrates the stratigraphic variation: clay/silt corresponds to high TOC values, while sand/salt corresponds to low TOC values, indicating that the drilling site was covered by alternations of deep water and shallow water from 9420 to 6500 14C yr BP. Very shallow water, as shown by littoral sand-silt and fluvial sand, was deposited between 6400 and 4605 ^{14}C yr BP. Deep water returned and lasted until 3120 ^{14}C yr BP, with alternations of shallow water, salt deposition, a deepening lake and dry conditions throughout. In the SJC section, over 50 pollen taxa were identified in the samples. Based on the relationship between pollen assemblages and the distribution of modern vegetation in the drainage, the pollen taxa can be divided into three ecological groups: high-elevation vegetation taxa coming mainly from the forest vegetation zone; regional vegetation taxa, and; the local vegetation taxa coming mainly from the desert vegetation zones (Zhu et al., 2003). Pollen concentrations were generally high in the early Holocene before 7000 cal yr BP but had century-scale variations (Fig. 1). Large-scale variations can be seen in the concentration curve, with three minima at 7000-5000 cal yr BP, ca. 3000 cal yr BP, and ca. 1200 cal yr BP, separated by three peaks of relatively high concentration (Fig. 1 and Fig. 2).

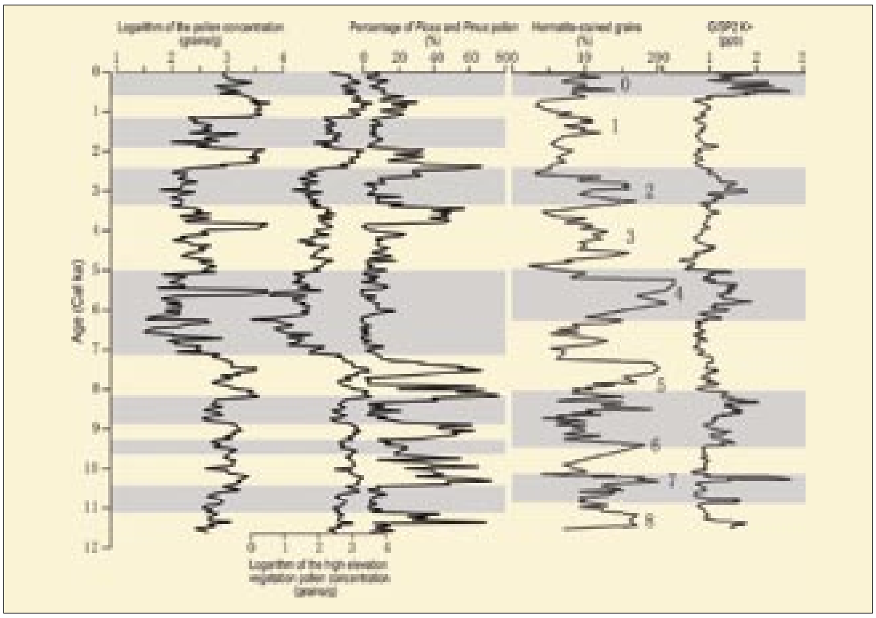

Fig. 3: Correlation of total pollen concentrations, high-elevation vegetation pollen concentrations and Picea-Pinus percentages at the SJC section with percentages of hematite-stained grains of Core VM29-191 in the Northern Atlantic Ocean (Bond et al., 2001) and potassium ion content in the GISP2 ice core (Mayewski et al., 1997). The episodes of high hematite-stained grain counts are marked in sequence from No. 0 to No. 8, (right panel, Bond et al., 2001). The shaded areas indicate weak summer monsoon and thus dry climate events in the study area, and periods of a strong Siberian High.

Three pollen zones during the Holocene period can be clearly shown in the pollen assemblage (Fig. 2).

Zone I: (460-282 cm; 11.6-7.1 ka): The pollen concentration of this zone is the highest in the entire section, with a peak value of 2,000-3,000 grains/g and a mean value of 400-1,500 grains/g. Conifer pollen, mainly *Sabina*, *Picea* and *Pinus*, which contribute 50-90% of the pollen sum, dominates the pollen assemblages (Fig. 2). In the high-elevation pollen group, broadleaf tree pollen also has a relatively high value of between 1% and 11%, while regional and local pollen have quite low percentages.

Zone II: (282-152 cm; 7.1-3.8 ka): Pollen concentrations, especially those of high-elevation pollen, are at their lowest value for the entire section. *Xerophyte* pollen dominates the pollen assemblage and is at its peak for all of the Holocene. Regional vegetation pollen also has high percentages, while *conifer* pollen decreases to a low value (Fig. 2). *Nitraria* pollen increases to 90% in some samples. The remarkably high pollen concentrations, with values reaching 5,000 grains/g in exceptional layers, is due to the rapid growth of xerophytes, especially desert plants such as *Nitraria*, indicating a possible dry lake at the section site for a short period.

Zone III: (152-0 cm; 3.8-0 ka): Pollen concentrations vary greatly in this zone (Fig. 2) and there are two types of pollen assemblages. One type is similar to Zone I, with a pollen assemblage dominated by conifer pollen in a range of 38% to 80%, and with high pollen concentrations 2.4-1.9 cal ka and 1.1-0.5 cal ka. The other type is similar to Zone II, with a pollen assemblage dominated by steppe and *xerophyte* pollen and relatively low pollen concentrations (Fig. 2). A difference from Zone II is that conifer pollen in these layers continues to be 11-70% but is mainly *Sabina* pollen, from a tree that prefers a drier climate than does *Picea* in this region.

The pollen record from the SJC section indicates that the climate in the early Holocene (11.6-7.1 cal ka) and late Holocene (3.8 cal ka-present) was humid and markedly variable. There was a generally dry climate in the area during the mid-

Holocene with a decreasing summer monsoon. In arid northwest China, high Holocene lake shorelines normally date to before 7 cal ka. This accords with a period of high lake-levels reported from Mongolia and central Asia (e.g. Lehmkuhl and Lang, 2001; Grunert et al., 2000). The strongest drought interval, shown clearly in Figure 2, was from 7.2 cal ka to about 5.0 cal ka. Generally, lakes in the southern Mongolian Plateau were found to have undergone low lake levels or even dry lake bed sequences during the mid-Holocene (Chen C-T. A. et al., 2003). In addition, a Holocene soil (paleosol S_0) was interrupted by a dust deposit layer around 6 ka ago in the Chinese Loess Plateau (Huang et al., 2000). All of this supports the notion that a mid-Holocene drought existed in regions of the Chinese Loess Plateau and southern Mongolian Plateau.

This mid-Holocene drought was only the most intense and longest of a number of droughts that occurred throughout the Holocene (Fig. 1). Seven droughts, lasting a few centuries to a few millennia, are recorded in pollen proxies in the SJC section during the Holocene. The droughts are shown by changes in pollen concentrations representing total drainage vegetation coverage, high-elevation vegetation pollen concentrations representing mainly forest vegetation coverage, and *Picea-Pinus* pollen content representing moisture (Fig. 3). The seven droughts were at 0-0.5 cal ka, 1.2-1.9 cal ka, 2.7-3.2 cal ka, 5.0-7.2 cal ka, 8.3-8.8 cal ka, 9.2-9.7 cal ka and 10.4-11.2 cal ka, based on our chronology. A possible eighth drought occurred at 7.7 cal ka. The droughts correlate well with changes in hematite-stained grains of core VM29-191 in the Northern Atlantic Ocean, a proxy of ice-rafting events and, thus, temperature (Bond et al., 2001), and with potassium ion content in the GISP2 ice core (Mayewski et al., 1997), a proxy of change in the Siberian-Mongolian High and atmospheric dust (Mayewski et al., 2004). This supports a hemisphere-scale correlation of central and millennial climatic events during the present warm interglacial.

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Grain-size Record of Stepwise Expansion of the Mu Us Desert for the Past 3.5 Ma

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The Mu Us Desert lies immediately north of the Loess Plateau in northern China (Fig. 1). A reconstruction of the desert environment has demonstrated that the southern margin of the desert migrated several hundred km north of its Last Glacial Maximum (LGM, ~20 ka BP) limit in response to increased monsoon rainfall during the Holocene Optimum (~8-4 ka BP) (Sun et al., 1998). However, little is known about the long-term evolution of this monsoon-sensitive environment because of the sparseness of directly extractable geological evidence of suitable type and quality to be found within it. In this report, we'll first show, on the basis of the spatial grain-size changes of three north-south loess transects across the Chinese Loess Plateau, that sand-sized particle content within loess can be used to assess the shift of the southern desert margin. We then present a grain-size record of loess-red clay deposits from the desert-loess transitional zone to provide insight into the evolutional history of the Mu Us Desert during the Plio-Pleistocene period. The three loess transects are

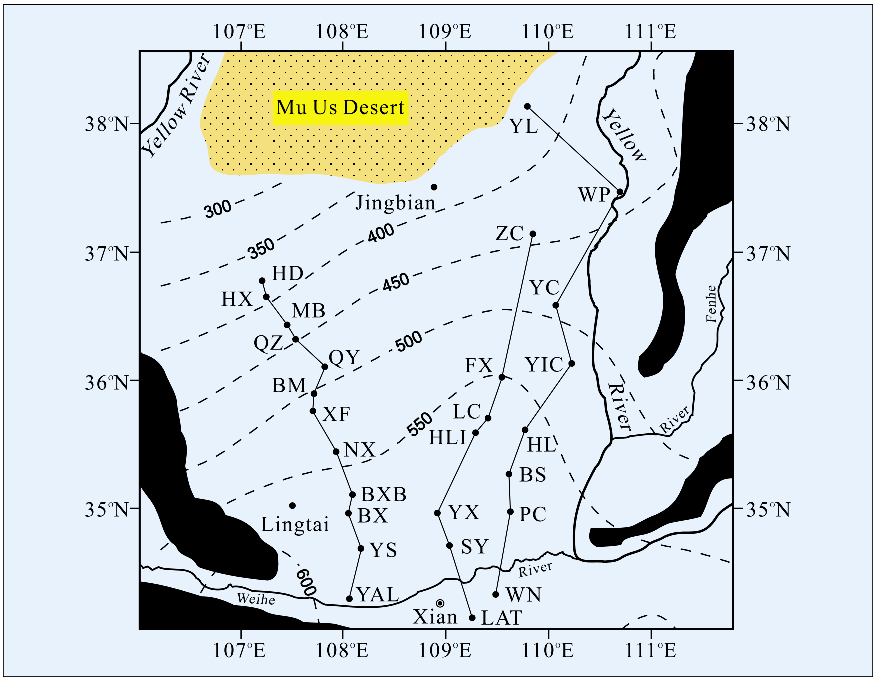

Fig. 1: The sampling localities and annual precipitation isopleths (mm) in the Loess Plateau.

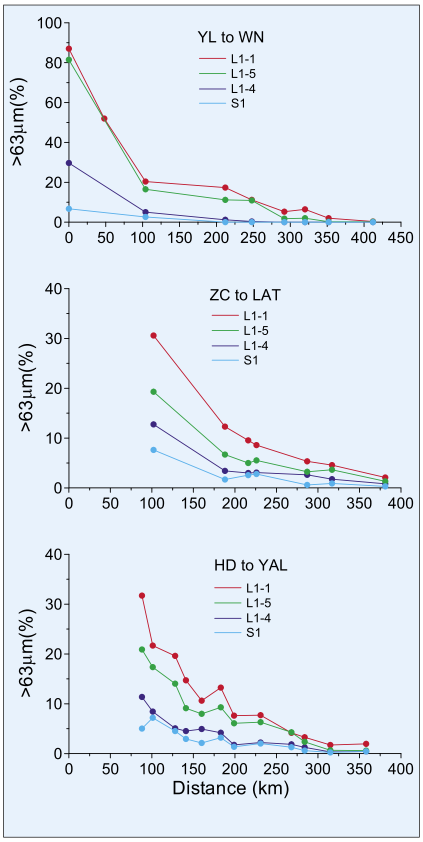

Fig. 2: Changes in the content of sand-sized particles southward from the southern border of the Mu Us Desert (Fig. 1) for L1-1, L1-4, L1-5 and S1.

from Hongde (HD) to Yangling (YAL), Zichang (ZC) to Lantian (LAT), and Yulin (YL) to Weinan (WN) (Fig. 1), and respectively consist of 12, 8, and 7 sections covering the last glacial cycle. Closely-spaced samples were taken and analyzed for all the sections, and the grain-size curves are well-correlated among the sections (not shown). Theoretical and experimental studies by Pye (1987) and Tsoar and Pye (1987) concluded that during low-level atmospheric dust storms, sand-sized particles are usually transported by saltation or modified saltation near desert surfaces, and that any sand particles transported in suspension quickly settle back onto the ground surface. We thus plotted changes in sand-sized particle content within loess with increasing distance southward of the present southern desert margin for four representative stratigraphic units: L1-1, L1-4, L1-5 and S1 (Fig. 2). Loess units L1-1, L1-4, L1-5 and S1 accumulated respectively in marine isotope stages 2, 3, 4 and 5. As shown in Fig. 2, all horizons exhibit a consistent southward decrease in the sand particle content, the rate of decrease for L1-1 and L1-5 being more rapid than that for L1-4 and S1. Both the L1-1 and L1-5 records show an abrupt decrease near the desert margin and a gradual decrease beyond. According to the reconstruction of Sun et al. (1998), the southern border of the Mu Us Desert during the cold-dry LGM (L1-1) was broadly similar to that of today, whereas it retreated several hundred km to the north during the warm-humid Holocene Optimum. This implies that this desert margin experienced wide-ranging advance-retreat cycles in response to climatic oscillations at orbital time-scales. It is clear that significant increase in sand percentages in L1-1 and L1-5 relative to S1 and L1-4 were controlled at the first order by the desert advance during their accumulation. Using the sand content-distance relation of L1-1 (Fig. 2), it is therefore inferred that sand particle contents of ~30% and ~15% within the loess indicate a distance from the desert margin of ~100 km and ~200 km, respectively.

The Jingbian section (37°40′54″N, 108°31′15″E), at 1,370 m a.s.l., is located only ~12 km south of the present margin of the Mu Us Desert. The section is composed of a ~252-m-thick Pleistocene loess-soil sequence resting on a ~30 m Pliocene red clay deposit. A previous magnetic polarity study showed that this sequence has a basal age of 3.5 Ma (Ding et al., 1999). Field observations have demonstrated that the Pleistocene loess-soil stratigraphy correlates well with the classic loess sections. To the best of our knowledge, the Jingbian section is the only desert margin eolian sequence known to cover the whole Pleistocene and the late Pliocene. Its proximity to the dust source region makes it ideal for the study of long-term desert changes.

The Jingbian magnetic susceptibility and grain-size records, plotted on the Chiloparts timescale (Ding et al., 2002), are shown in Fig. 2, together with a composite marine oxygen isotope record (Shackleton and Pisias, 1985; Shackleton et al., 1990, 1995). The >63 µm% and >125 µm%

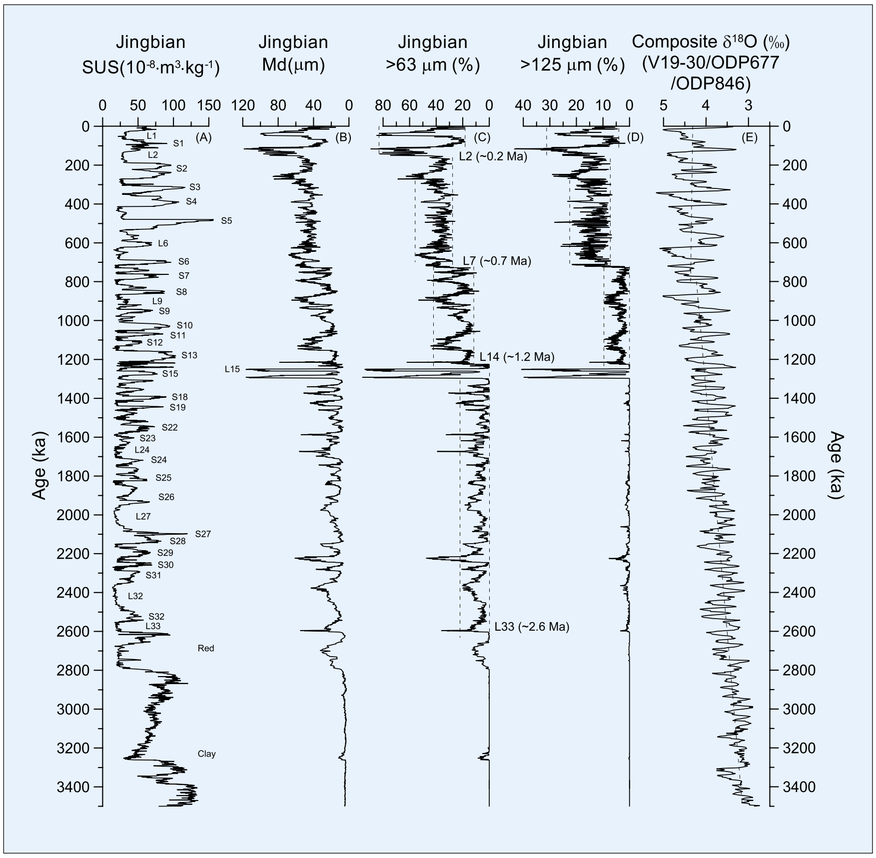

Fig. 3: Changes in magnetic susceptibility (A) and grain size data (B, C, D) at Jingbian, and correlation with a stacked marine $\delta^{18}O$ record (E) (Shackleton and Pisias, 1985; Shackleton et al., 1990, 1995). The timescale of the Jingbian section was developed by correlating the loess-soil units with the Chiloparts record (Ding et al., 2002).

records (Fig. 3C and D) at Jingbian show four stepped increases in sand-sized particle content. The late Pliocene red clay (below L33) contains few sand particles, indicating that the dust was transported in suspension, mainly from a remote source. From ~2.6 to ~1.2 Ma, sand content in interglacial soils remains low, whereas it varies generally between 18% and 25% in glacial loess, except for the case of L15 and L16. This suggests that during glacial periods, the desert environment advanced to a location no more than 200 km from the present northern margin of the Loess Plateau. In the part of the section deposited between ~1.2 and ~0.7 Ma, sand content increases to ~12% in soils and to ~43% in loess, with a substantial increase in >125 μm particles, implying a large-scale advance of the desert margin during both glacial and interglacial times. Throughout, material deposited in the interval ~0.7-0.2 Ma, >63 μm particles range from ~30% in soils and ~55% in loess units, with the >125 μm particles exceeding 8%. This suggests that the distance between the Loess Plateau and the present desert margin was less than 100 km. During the last two glacial periods, eolian sand was directly deposited at Jingbian, indicating a further southward desert shift.

The Jingbian sand-sized particle record clearly demonstrates that, superimposed on the glacial-interglacial oscillations, the Mu Us Desert experienced significant expansion at ~2.6, ~1.2, ~0.7 and ~0.2 Ma, directly implying a stepwise southward retreat of the monsoon rainfall belt, associated with a complementary reduction in summer monsoon strength, in the past 3.5 Ma. This evolutionary pattern may be causally linked to the Plio-Pleistocene increase in global ice volume, as shown in the marine oxygen isotope record (Fig. 3E).

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Human-induced Changes of Organic Carbon Storage in Soils of China

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In the last two centuries, land use has been a significant source of atmospheric CO_2 through conversion of natural vegetation to farming land (Houghton, 1999; Lal, 2004). It has been estimated to be about half of the CO_2 emission from the combustion of fossil fuels over the period from 1850 to 1990 (Houghton, 1999). In terrestrial ecosystems, soil organic carbon (SOC) is the largest terrestrial carbon pool. Because SOC generally has a slower turnover rate, it may be preserved for a longer time (IGBP Terrestrial Carbon Working Group, 1998). The huge carbon pool of soils and the significant changes of SOC related to land use by human activity suggest a considerable potential to enhance the rate of carbon sequestration in soils through suitable management, and thereby to decrease the atmospheric CO_2 level.

A number of efforts have been carried out to determine the changes of SOC storage induced by land use at regional and global scales. However, because of the high inherent natural variability in the world's soils and variable dynamics of carbon loss under different land uses, accurate estimates of the historic loss are usually hampered by the lack of the required baseline data on soils. More exact estimates on the size of the human-induced changes of SOC storage from natural to current conditions at regional scale are very much needed, especially based on greater data density with direct field measurements. This would provide a basis for a better understanding of the future SOC sequestration from the atmosphere, as well as its role in carbon cycles.

Currently, China has ~137.5 million ha of cropland (NSSO, 1998), and the long history of agricultural exploitation and the changes of land use suggest that the terrestrial ecosystem of China would have played an important role in the global carbon cycle. In this study, the spatial patterns of soil organic carbon density and storage under natural conditions and those under present-day conditions are investigated comparatively, based on the 34,411 soil profiles analyzed from China's second national soil survey (NSSO, 1998). Among these, 2,553 profiles were considered the most representative based on their geomorphological units, hydrothermal conditions, morphological peculiarities, physicochemical characters, and land-use conditions. According to the land-use conditions, they were then divided into two basic groups. 923 profiles are regarded in this study as natural profiles as they were not cultivated in the land-use history and the profiles had not experienced disturbance by human activity. Their current vegetation are ecologically consistent with the climatic conditions. The other 1,630 profiles were all considered cultivated profiles, including the present-day cultivated soils and those cultivated in the past; they were used for evaluating the SOC changes by land use compared to their natural counterparts. The present-day SOC were calculated using the data from the total of 34,411 soil profiles. The difference between the reconstructed SOC under natural conditions and that of the present-day would permit an estimation of SOC changes due to historical land use in China.

Under natural conditions, SOC density decreases from east to west, and a general increase is obvious from north to south in western China, while it decreases from north to south in eastern China (Fig. 1a). Because SOC density is dependent on the bioproductivity and the mineralization intensity of organic matter, this pattern is mainly controlled by hydrothermal climate conditions of China. SOC density values vary from 0.9 to 91.2 kg C m^{-2} in terms of soil groups and mostly range from 4.0 to 13.0 kg C m^{-2}. The reconstructed average SOC density is ~8.8 kg C m^{-2}, and the total SOC storage is ~77.4 Pg C (1015g C) with ~38.0 Pg C in the organic horizons and ~39.4 Pg C in the mineral horizons. Under present-day conditions, the basic distribution pattern of SOC density is, thus, roughly similar to that under natural conditions (Fig. 1b). The present-day total SOC storage is ~70.3 Pg C, including 32.5 Pg C in the organic horizons and 37.8 Pg C in the mineral horizons. The average carbon density is ~8.0 kg C m^{-2}.

Comparing the spatial distribution and storage of SOC in the above two kinds of soils (Fig. 1d-f) reveals that ~31% of the total soil surface (~57% of the cultivated soil subgroups) has experienced a significant carbon loss, ranging from 40% to 10% relative to their natural counterparts. The most significant carbon loss is observed for the non-irrigated soils (dry farmland, Fig. 1c) within a semi-arid/semi-humid belt from northeastern to southwestern China, with the maximum loss occurring in northeast China. Conversely, the SOC in ~5% of land surface (~26% of the cultivated soil subgroups) has increased, most in the paddy and irrigated soils in northwest China. Insignificant changes are observed

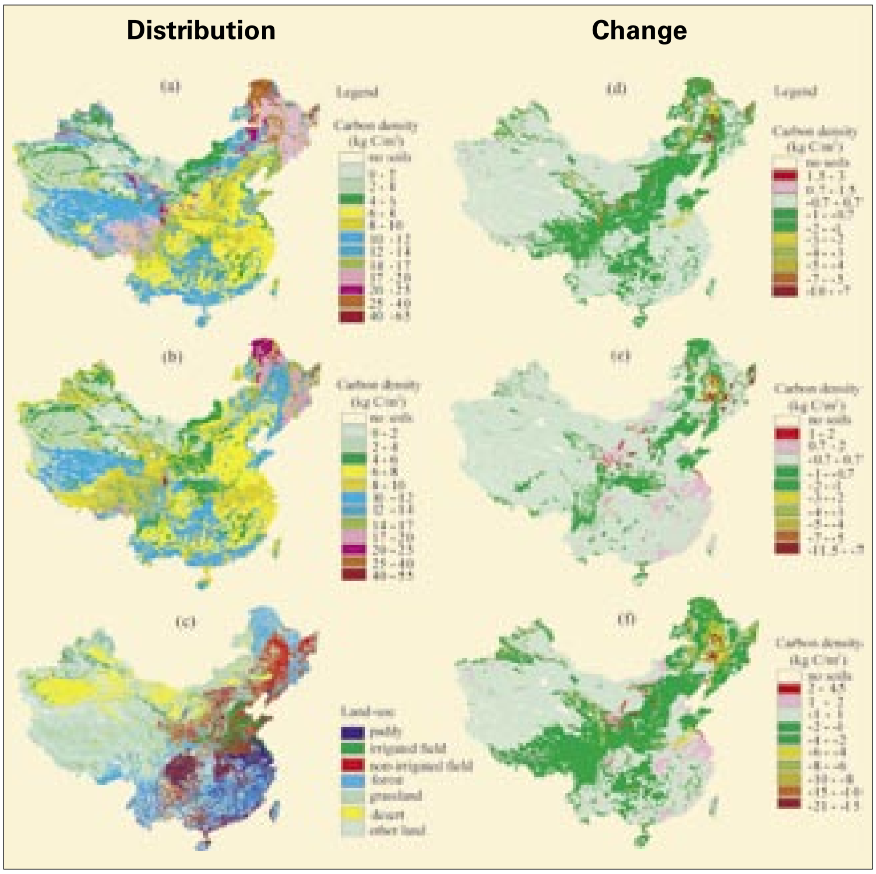

*Fig. 1: Spatial distribution of SOC density, changes of SOC density and land use in China. (**a**) Distribution of SOC density under natural conditions, (**b**) Distribution of SOC density under present-day conditions, (**c**) Distribution of land use in China, (**d**) Distribution of SOC density changes in organic horizons, (**e**) Distribution of SOC density changes in mineral horizons, (**f**) Distribution of profile SOC density changes.*

within ~64% of the considered surface, mostly corresponding to forest soils in southern China, grassland and desert soils in northwest China, as well as irrigated soils in eastern China. Overall, ~7.1 Pg C of SOC storage has been lost and ~0.8 kg C m^{-2} SOC density has been decreased due to increasing human activities, in which the loss in organic horizons has contributed to ~77% (Fig. 1d). This total loss of SOC in China induced by land use represents ~9.5% of the world's SOC decrease. This amount is equivalent to ~3.5 ppmv of the atmospheric CO_2 increase.

Because ~78% of the currently cultivated soils in China have been degraded to a low/medium productivity (NSSO, 1998) and most of the SOC loss has occurred in cultivated soils without irrigation, improved land management, such as the development of irrigation practices, conservation tillage and other systems of sustainable soil management, would have considerable potential for restoring the SOC storage. Assuming a restoration of ~50% of the lost SOC during the next 20-50 years, the soils in China would absorb ~3.5 Pg C of carbon and thus might significantly contribute to carbon sequestration from the atmosphere under the global warming scenario.

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Long-term Cycles in the Ocean Carbon Reservoir: Records From the South China Sea

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The carbon isotope sequence at ODP Site 1143, southern South China Sea reveals a 400-500 kyr long-term cyclicity that is superimposed on glacial cycles and present in long $\delta^{13}C$ sequences from all oceans. As seen from Figure 1, the Quaternary $\delta^{13}C$ record is punctuated by four $\delta^{13}C$ maximum events: δ^{13}Cmax-I (from MIS 3 around 50-60 kyr onward), δ^{13}Cmax-II (MIS 13, 470-530 kyr), δ^{13}Cmax-III (MIS 25-28, 0.95-1.00 myr) and δ^{13}Cmax-VI (MIS 53-57, 1.55-1.65 myr], while the earlier $\delta^{13}C$ maximum events occur at the long eccentricity minima with a regular 400 kyr periodicity. As the same periodicity is also found in carbonate curves, the δ^{13}Cmax events denote major reorganization in carbon reservoirs of the global ocean.

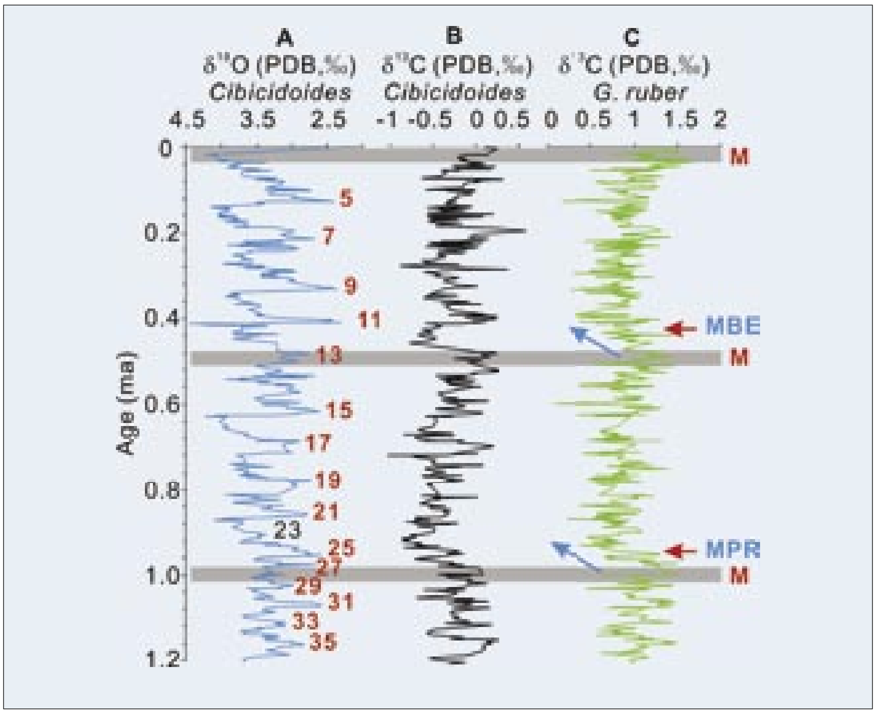

*Fig. 2: Oxygen and carbon isotopic records spanning 1.2 myr from ODP Site 1143. (**A**) benthic $\delta^{18}O$; (**B**) benthic $\delta^{13}C$; (**C**) planktonic $\delta^{13}C$. Numbers labeling $\delta^{18}O$ curve indicate marine oxygen isotope stages (MIS), grey bars denote carbon isotope maximum (δ^{13}Cmax), MBE stands for Mid-Brunhes Event, MPR for Mid-Pleistocene Revolution. Arrows show that δ^{13}Cmax preceded the transition in glacial cyclicity and expansion of ice-sheet.*

Shifts in carbon reservoirs at the times apparently affecting global climate, and at least two δ^{13}Cmax events led to major changes in glacial cyclicity: δ^{13}Cmax-II led to the Mid-Brunhes Event (MBE) and δ^{13}Cmax-III to the Mid-Pleistocene Revolution (MPR) (Fig.2). At the beginning of the Mid-Brunhes Event, ca. 430 kyr ago, the global ocean experienced the largest amplitude change in $\delta^{18}O$ over the past 6 myr. This $\delta^{18}O$ event recorded a major expansion of ice sheet size, which cannot be explained by the small changes in orbital forcing, but is preceded by δ^{13}Cmax-II. The δ^{13}Cmax-II event was marked by extremely warm and humid conditions in the low latitudes around the world: an exceptional ^{18}O -depletion peak in the equatorial Indian Ocean, abnormal occurrence of a thick sapropel layer in the Mediterranean, extremely heavy precipitation and erosion in the Amazon drainage basin, and unusually deep weathering in the Loess Plateau. This climate event was accompanied by widespread changes in the upper ocean structure and in phytoplankton productivity, and obviously resulted in disturbance in carbon reservoirs that in turn led to major growth of ice-sheet size. Similar events happened during δ^{13}Cmax-III at about 1.0 myr, and again the drastic changes in carbon reservoir

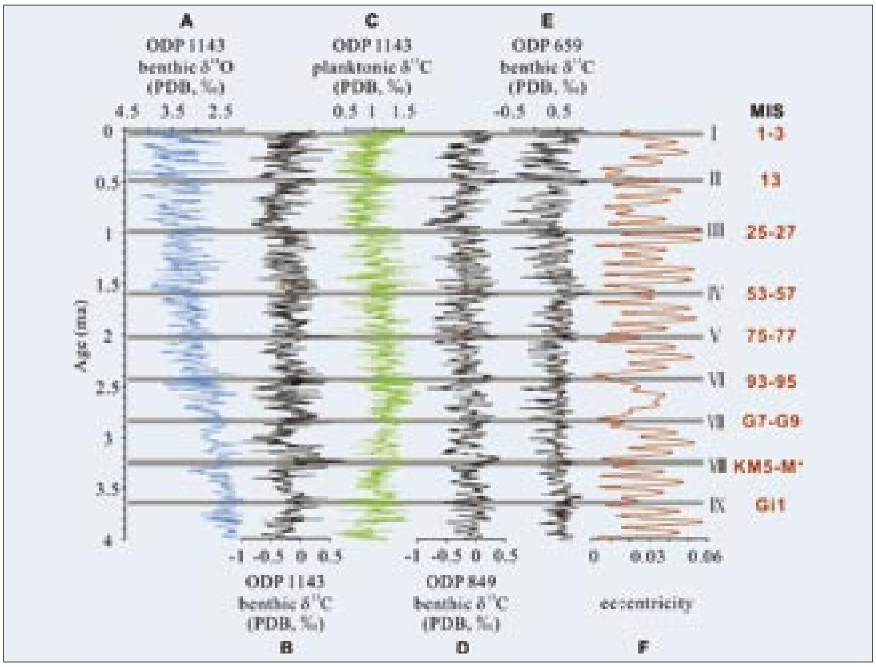

*Fig. 1: Carbon isotope records over the last 4 Ma. ODP 1143, South China Sea: (**A**) benthic $\delta^{18}O$; (**B**) benthic $\delta^{13}C$; (**C**) plankton $\delta^{13}C$. Eastern Pacific: (**D**) ODP 849 benthic $\delta^{13}C$. Northern Atlantic: (**E**) ODP 659 benthic $\delta^{13}C$. (**F**) eccentricity. Gray bars denote carbon isotope maximum events (δ^{13}Cmax) showing 400-500 ka periodicity, and δ^{13}Cmax corresponds to eccentricity minimum (k) before the Quaternary. I-IX on the right show the succession of δ^{13}Cmax.*

preceded the Mid-Pleistocene revolution at 0.9 myr when the boreal ice sheet increased in size and the prevailing glacial cyclicity changed from ~40 kyr to ~100kyr.

Before the Quaternary, δ^{13}Cmax usually occurred at times of minimal eccentricity forcing, and the long term-variations in δ^{13}C and δ^{18}O display the same 400 kyr cycles; but in the Quaternary, δ^{13}Cmax-II and δ^{13}Cmax-III are out of phase with this astronomical cycle (Fig.1). Therefore, prior to the formation of large ice sheets in the Northern Hemisphere, δ^{13}C co-varied with δ^{18}O in the ocean records but in Quaternary times the 400-kyr cyclicity waned in the δ^{18}O records and apparently "stretched" into 500 kyr in δ^{13}C.

The origin of the δ^{13}Cmax episodes in the Quaternary and the nature of the long-term cycles remain unclear. Our working hypothesis suggests that the long-term cycles in weathering intensity in tropical areas may give rise to increased flux of Si from land to ocean, which may change the diatom/coccolith ratio in phytoplankton and subsequently the organic/inorganic carbon ratio in sediments. There is strong evidence for the 400-kyr cyclicity in monsoon climate and in opal production in the ocean that is well-correlated with the δ^{13}C record. However, more work is needed to find out the mechanism behind the observed changes in carbon cycling. A common practice in Quaternary climate history studies is just to peruse ice-volume variations as exhibited by δ^{18}O, by considering carbon system changes as the consequences of ice-volume changes. The new discovery shows that long-term changes in carbon reservoirs on the Earth have their own periodicity and their own history, and do not simply follow ice cap variations in the Northern Hemisphere. The Quaternary period has passed through three major stages defined by four δ^{13}Cmax events, and each appears to represent a further step in ice-cap development. Now the Earth is passing through a new carbon isotope maximum, δ^{13}Cmax-I. It is therefore crucial to understand the physical and climatic significance of the long-term carbon cycles, if we are to predict the natural long-term changes of global climate.

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A 1437-year Precipitation History From Qilian Juniper in the Northeastern Qinghai-Tibetan Plateau

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High-resolution proxy records of climate spanning multiple millennia are needed to understand natural climate variability of the past. The native Qilian juniper (*Sabina przewalskii*) growing in the mountains of arid and semi-arid areas in the northeastern Qinghai-Tibetan Plateau exhibits a great potential for climate reconstruction. Based on well-replicated and cross-dated specimens from living trees from 11 sites (Fig. 1) at Delingha, Wulan and Tianjun, Qinghai Province, a 1600-year-long regional composite ring-width chronology was developed. This chronology was compared with the Dulan chronology (Zhang, et al., 2003), which is located approx. 65-150 km south of our sites. It was found that there were two more rings in our chronology than in the Dulan chronology in the common interval of AD 404-2000. One ring occurred at either AD 874 or 875, and another one at AD 711, rather than at AD 682 as indicated

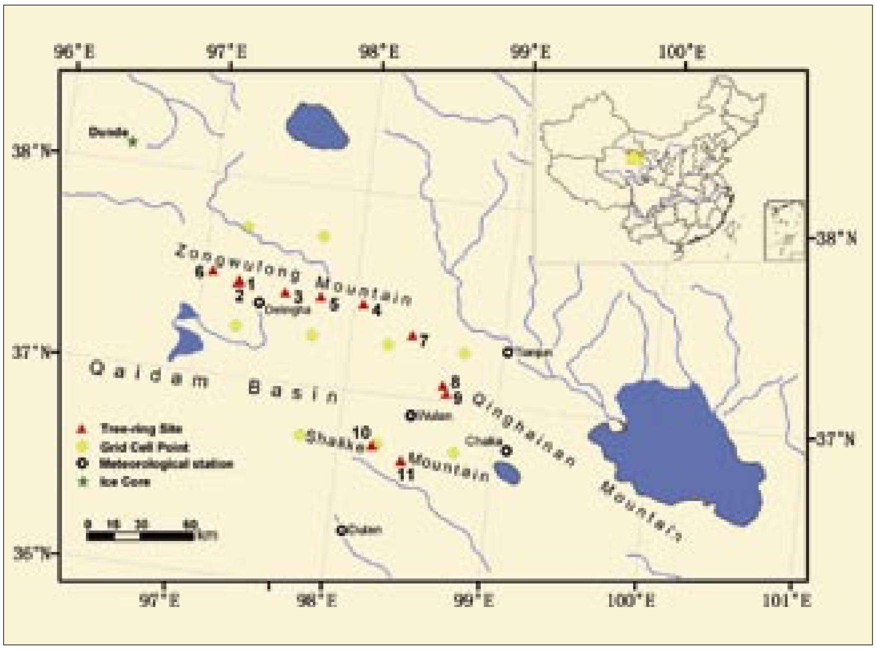

Fig. 1: Location of tree-ring sites, grids of precipitation data and meteorological stations.

by Tarasov et al. (2003) and Sheppard et al. (2004). Besides the reconstruction of past climate as reported here, this multi-site chronology will serve as the master chronology to cross-date archeological specimens excavated from tombs of the Tubo Kingdom in Delingha County, a potential that has been demonstrated by Sheppard et

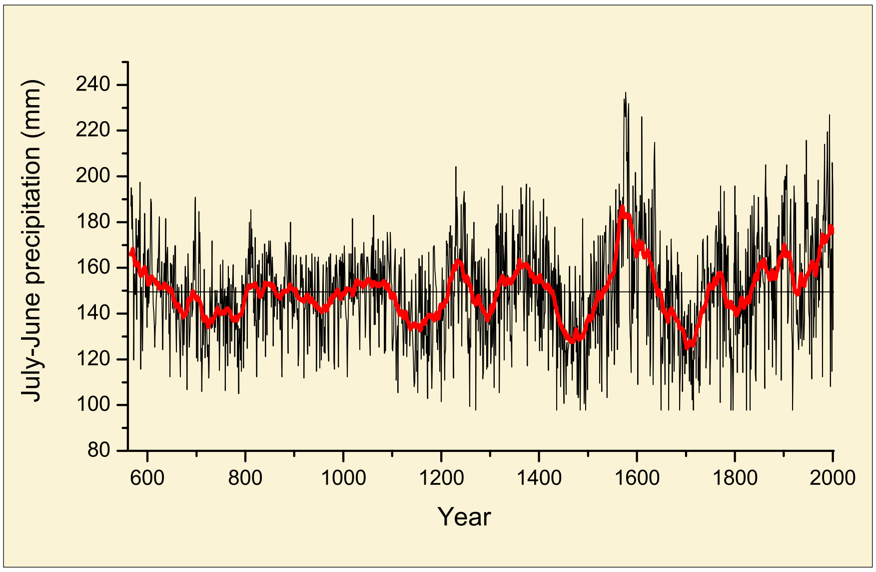

Fig. 2: Precipitation reconstructions. The 31-year running means (red) and long-term mean (horizontal line) are also shown.

al. (2004), who also reconstructed precipitation but using material from fewer sites.

In developing the regional chronology (RC), samples with more than 1,050 rings, and with good correlation with the mean series from each site were selected. Negative exponential or linear regression models with negative coefficients were used to fit and remove the growth trend. The sample depth of the RC is 6 cores from 5 trees in AD 566, 9 cores from 7 trees in AD 700, 22 cores from 16 trees in AD 800 and more than 50 cores from 36 trees in AD 900. Based on the subsample signal strength of 0.85, the chronology was truncated at AD 566 for the climate reconstruction. The average length of cores is 803 years, indicating that the chronology should capture decadal- up to centennial-scale variability.

In our preliminary study (Shao et al., 2004), we found that Qilan juniper growth in the study area was mainly limited by moisture conditions in May and June and that a significantly positive correlation was found between the RC and the total precipitation from July of the previous year to June of the current year. Therefore, the annual precipitation summed from July of the previous year to June of the current year was reconstructed. The climate data we used were from CRUTS 2.1, available at www.cru.uea.ac.uk. In order to make the climate data more regionally representative, monthly precipitation data from 9 0.5° x 0.5° gridpoints (Fig. 1) were averaged into a regional dataset. Since the effect of low precipitation on tree growth is more profound than that of high precipitation in the arid area, the precipitation series was transformed into a logarithmic scale. The calibration model explained 65% of the variance in the calibration period 1955-2002, and the correlation coefficient was 0.79 for the cross-validation. The reduction of error, product means test and sign test statistics also support the validity of the model. Since the correlation coefficient of July-June precipitation with January-December precipitation could even reach 0.95 after the 5-year running mean was performed for both series, it is clear that low frequency variability in the reconstructed precipitation series can very well represent the variations of the instrumental record.

The 1,437-year reconstruction of precipitation (Fig. 2) is characterized as follows:

1. Climate in the calibration period was relatively moist in the context of the past 1,437 years; only during the period AD 1563-1590 was annual precipitation higher than the present.
2. Dramatic oscillations of precipitation occurred during the Little Ice Age. Before AD 1400, the magnitude of variation in annual precipitation was about 15 mm but it was up to 30 mm during the period of 1400-1750. After 1750, the magnitude of variation decreased. The most pronounced wet intervals centered around the late 16th century, and the most severe and prolonged dry periods occurred in the late 15th century and early 18th century. These two dry periods corresponded to the Spoerer and Maunder sunspot minima, respectively.
3. Compared with the Little Ice Age, variations in the low frequency domain of precipitation during the Medieval Warm Period were less dramatic, and the variance in the high frequency domain was also low in the period 800-1200. A decreasing trend was observed in the period 566-800.
4. Spectral analysis indicated that the reconstructed precipitation contained significant low frequency (150-250 years) cycles. The 200-year period was indicated clearly in the Little Ice age by wavelet analysis and singular spectrum analysis.

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Preliminary Calibration of Stalagmite Oxygen Isotopes from Eastern Monsoon China with Northern Hemisphere Temperatures

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Changes in stalagmite oxygen isotope ratios that are related to the India Monsoon during the Holocene have been widely discussed (e.g., Neff et al., 2001, Fleitmann et al., 2003). The number of stalagmite oxygen isotope series from the Holocene in China that have been reported is limited but increasing (Hou et al., 2003, Zhang et al., 2003, 2004, Wang et al., 2005). However, the relationships between the oxygen isotope ratios of stalagmites from northeastern and southeastern China have not been discussed. In this preliminary report, we compare the stalagmite oxygen isotope records from the Eastern Monsoon China (East of 108°E), and focus on two questions:

1. What is the range in values and the time series pattern for stalagmite oxygen isotope ratios from Eastern Monsoon China?
2. What is the signature represented by the change in stalagmite oxygen isotope records from Eastern Monsoon China within the entire Holocene?

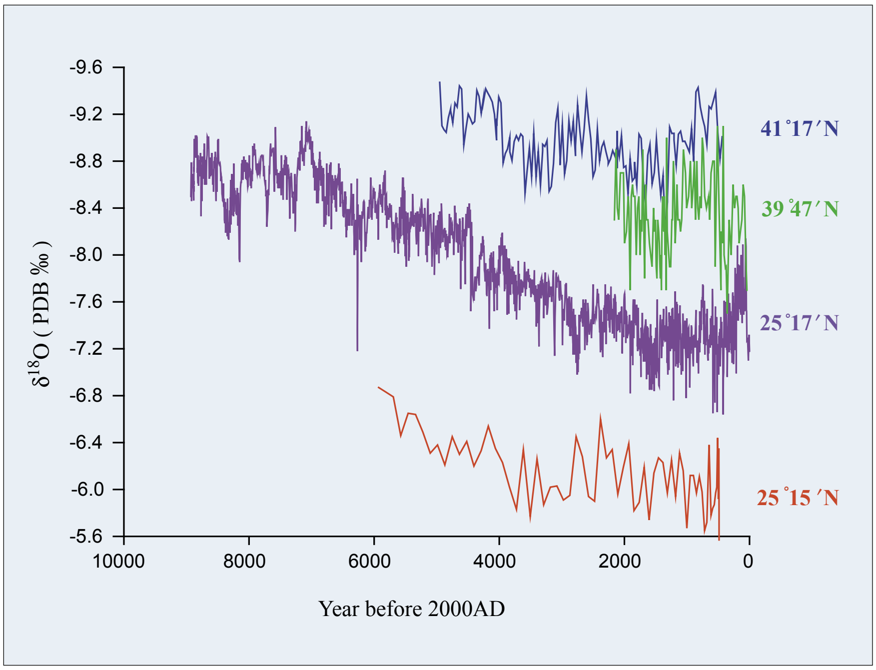

Fig. 1: Comparison of stalagmite oxygen isotope record from Water Cave (blue) with that from Shihua Cave (green), Dongge Cave (purple) and Xiangshui Cave (red).

Data and Methods

Here, we present and compare four stalagmite oxygen isotope records from Water Cave (unpublished), Shihua Cave (Hou et al., 2003), Dongge Cave (Wang et al., 2005) and Xiangshui Cave (Zhang et al., 2003, 2004), respectively (see Table 1 for details).

The timescale of the stalagmite from Water Cave was derived by fitting the uranium dates (511±80, 2081±73, 3845±45, 5227±83 years before AD 2000) with the distance of the dated site (2.09, 49.63, 96.96, 157.23 mm) from the top of the stalagmite. The fit function is:

$Y = -0.0011X^3 + 0.2155X^2 + 24.829X + 458.22$ (where Y is age, X distance from the top; $r^2 = 1$).

For the stalagmite from Shihua Cave, we used counting chronology to recalibrate the oxygen isotope time series. Since the age of the top layer is known, we can measure the distance of each isotope sub-sample site from the top and calculate an age by summing annual layer thicknesses to match the distance measured. Finally, we can accurately use the layers counted as the age of each site.

For the stalagmite from Xiangshui Cave, we recalibrated the timescale for the oxygen isotope series by fitting the four uranium dates to the distances of each sample site dated from the top, based on data in Zhang et al. (2003, 2004). The fit function is:

$Y = -0.0095X^3 + 1.8735X^2 + 5.1317X + 489.89$ (where Y is age, X distance from the top; $r^2 = 1$).

The four stalagmite oxygen isotope records are compared in Figure 1.

Table 1: Sample-specific details

Cave location	Latitude and longitude	Oxygen isotope ratio range (per mill PDB)	Time interval covered	Availability of data
Water Cave: Benxi, Liaoning Province	41° 17′N, 124° 04′E	−8.2 to −9.5	About 5000 years (from about 3000 BC to 300 years before present)	unpublished
Shihua Cave: Beijing	39° 47′N, 115° 56′E	−7.5 to −9.1	About 2200 years (from about 200BC to present)	Tan et al., 2003
Dongge Cave: Libo, Guizhou Province	25° 17′N, 108° 05′E	−6.64 to −9.14	About 9000 years (from 6930BC to 2000AD)	Wang et al., 2005
Xiangshui Cave: Guanyang, Guangxi Province	25° 15′N, 110° 55′E	−5.6 to −6.5	About 6000 years (from about 4000BC to 500 years ago)	Zhang et al., 2004

Results

As shown in Figure 1, the oxygen isotope ratios become lighter from south to north. This pattern matches the observed pattern of the summer monsoon. Starting from the South China Sea and going northward, the summer

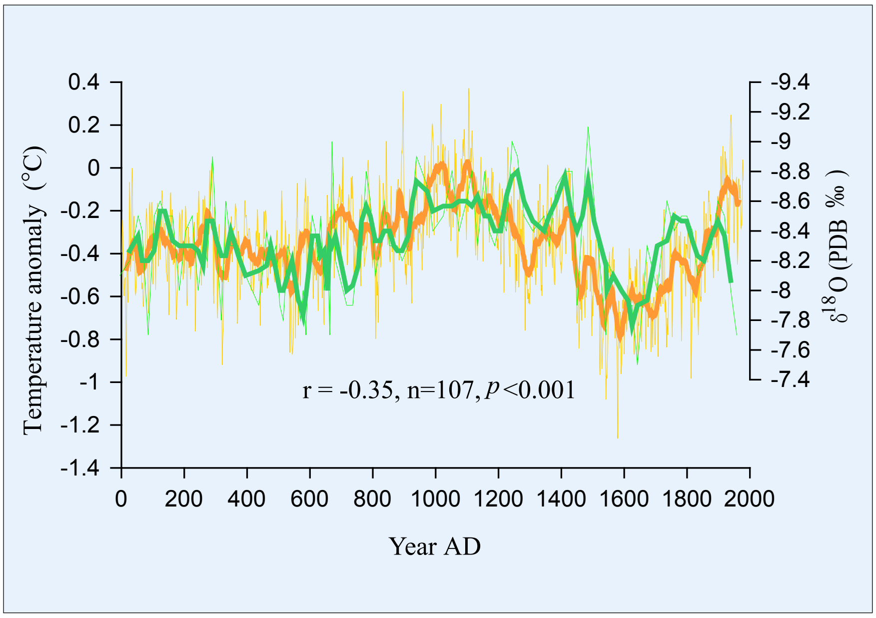

Fig. 2: Oxygen isotope of the stalagmite from Beijing Shihua Cave (green, thick line: 3-point running mean) and the northern hemisphere temperature over the last 2,000 years (yellow, thick line: 31-year running mean, Moberg et al., 2005).

monsoon supplies rainfall from the south to the north, and oxygen isotope ratios become lighter with precipitation. Our comparison of oxygen isotope ratios reveals that in Eastern China, stalagmite oxygen isotope records show similar fluctuation patterns on centennial-to-millennial scales. All of them contain a multi-millennial trend towards heaver ratios since 9000 Yr BP, responding to a reduced insolation of the Northern Hemisphere (Berger, 1978, 1991). This suggests that the change in patterns recorded in these ratios in Eastern China results from a single water source (i.e., the summer monsoon just travels northward from the South China Sea, isotopic ratios become lighter, and there is no, or limited, mixing with water with a different oxygen isotopic signature).

To understand what these oxygen isotope time series datasets represent, we compared the record from Shihua Cave, which has ready been age-controlled by counting chronology, to regional- and large-scale quantitatively reconstructed annual proxy records (e.g., Tan et al., 2003; Mann et al., 2003; Moberg et al., 2005). Data is available at: http://wdc.cricyt.edu.ar/paleo/data.html). We find that our re-dated oxygen isotope series has a statistically significant relationship ($r = -0.35$, $n = 107$, $p < 0.001$) with the recently reported 2,000-year-long Northern Hemisphere temperature series developed by Moberg et al. (2005). This indicates that the lighter oxygen isotope ratios in the stalagmite from Beijing Shihua Cave correspond to higher temperatures (Fig. 2). Based on this comparison, the stalagmite oxygen isotope ratios from Eastern Monsoon China may be responding to large-scale temperature changes. What should be mentioned is that the stalagmite from Beijing Shihua Cave and its isotope and layer thickness data used here are independent and different (i.e., unique) from another stalagmite from the same cave (Tan et al., 2003) that is included in the Moberg et al. series. Therefore, the relationship shown in Figure 2 is not a circular argument.

Conclusion and Discussion

It is difficult to obtain long temperature proxy records with annual resolution, such as from tree rings, stalagmite layers, etc. The calibration of the oxygen isotope ratios of cave deposits with millennial-long annually resolved temperature records has great potential to semi-quantitatively establish long-term temperature records (e.g. oxygen isotope based themperature reconstructions of the Northern Hemisphere for the entire Holocene).

The oxygen isotope records from stalagmites before and within the Holocene in Eastern Monsoon China have been interpreted as a signature of the strength of the East Asia Summer Monsoon (Wang et al., 2001, Yuan et al., 2004, Wang et al., 2005). Do our findings contradict this interpretation? No. In fact, the observed temperature record of Beijing has a statistically significant relation (-0.33 from AD 1881 to 1995) with the East Asia Summer Monsoon Index (Shi et al., 1998. Here, the lower the index, the stronger the East Asia Summer Monsoon).

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2,000-year Methane Record in a High Altitude Himalayan Ice Core

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Ice core methane reconstructions are believed to reflect atmospheric methane concentration fluctuations with time and to reveal past changes in terrestrial methane emissions (Blunier et al., 1993, Chappellaz et al., 1990, 1993). It has been proposed that past natural methane fluctuations were mainly due to changes in source strength, through variability of the wetland extent in tropical regions. Dasuopu ice core, recovered from the Dasuopu Glacier (28°23' N, 85°43' E) in the center of the Himalayas (Fig. 1), provides a unique opportunity to obtain a sub-tropical latitude methane reconstruction because of its high altitude (7200 m a.s.l), low ice temperatures and limited summer melting.

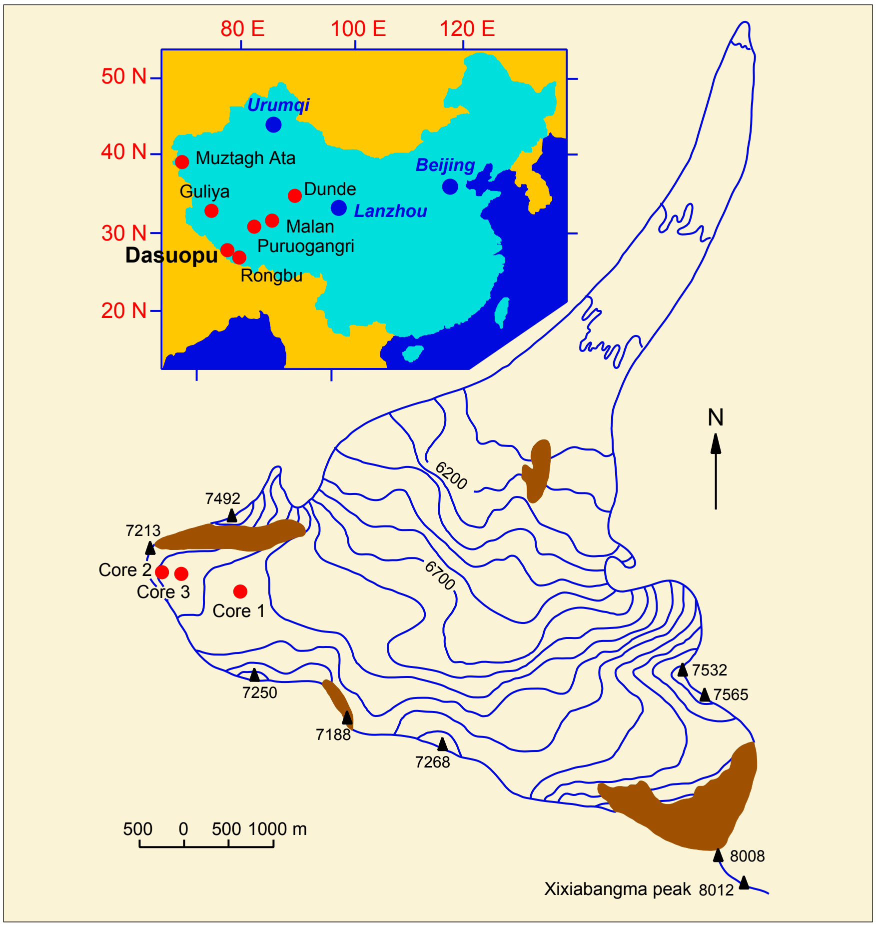

Fig. 1: Location of the Dasuopu Glacier relative to the Guliya, Dunde, and Tanggula sites where previous ice cores were recovered. The enlargement of the Dasuopu Glacier shows the ice core sites on the glacier.

Measurement and Air Dating

Two laboratories performed the methane measurements. At the Laboratory of Cryosphere and Environment (LEC), CAS, we used a melt extraction method similar to the one originally developed at LGGE in France. The agreement between the two methane data sets generated by LEC and LGGE was tested at two levels. First, a glass flask filled with the LGGE standard gas was measured at LEC. Second, the Antarctic D47 ice core was cut lengthwise and analyzed several times in both laboratories. The excellent agreement between the LEC and LGGE methane data confirms the validity of the inter-calibration performed between the two laboratories. As the pre-industrial methane trend has already been determined from Greenland (Eurocore, GRIP) and Antarctic (D47) ice cores measured at LGGE using the same technique as for the Dasuopu samples, we are confident that the results presented here can be directly compared to the polar records for determining the difference in the methane mixing ratio between sub-tropical and polar regions.

The upper 550 years to a depth of 122 m of the Dasuopu ice core were dated using a comprehensive method of counting the seasonal variations in $\delta^{18}O$, dust and chemical components, such as nitrate. From 122 to 149 m, we determined the timescale by extrapolating the depth-age relation established for the upper 122 m and by assuming a constant annual accumulation rate.

For the Dasuopu core, ice density, bubble volume and ice structure were all analyzed to determine the specific gas trapping conditions for this site. Our study indicates that pores close off below a depth of about 40 m, and the air forms rapidly into bubbles in the depth interval of 40-47 m. Bubble volume at the firn-ice transition indicates a maximum at a depth of 47 m, which means that half of the bubbles close off at the depth of 45 m. The corresponding ice age at 45 m is 60 years. Taking into account an estimated 10 years for methane diffusion through the firn column, the age of the trapped methane is approx. 50 years younger than the age of the surrounding ice in the Dasuopu ice core (Xu and Yao, 1999). Estimates of the past accumulation rate on the Dasuopu Glacier come from annual layer thickness measurements and an ice-flow model allowing calculation of the thinning of the ice with depth. This leads to changes in the gas age-ice age dif-

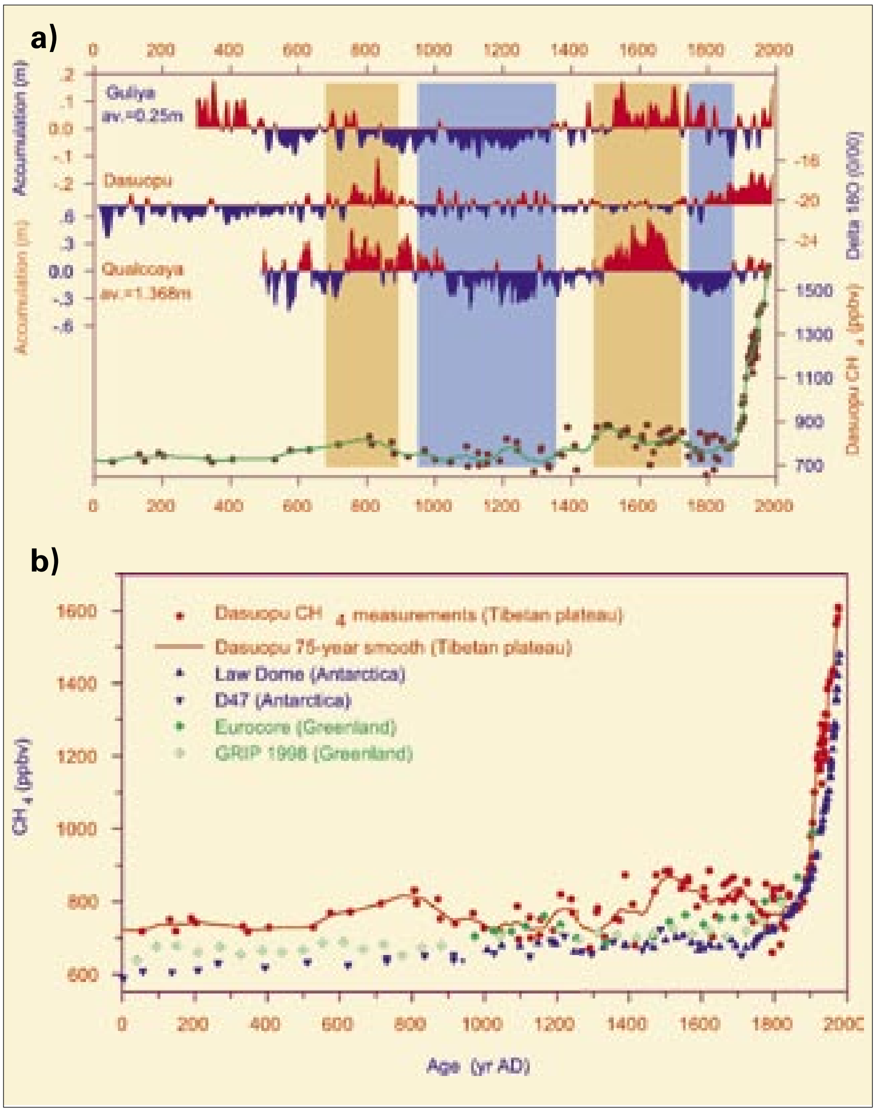

*Fig. 2: (**a**) The Dasuopu methane and $\delta^{18}O$ record, as well as the accumulations in Guliya and Quelccaya ice cores (Thompson et al., 1985) for the last 2,000 years; (**b**) A comparison of methane concentration from Dasuopu, Greenland (GRIP and Eurocore) and Antarctica (Law Dome and D47) ice cores.*

ference of about 40~70 years, which are taken into account in the gas chronology presented here.

Results and Discussion

Figure 2a shows the Dasuopu methane and $\delta^{18}O$ record, as well as the accumulations in the Guliya and Quelccaya ice cores for the last 2,000 years. Methane concentration changes coincide with accumulation fluctuations. Guliya, located in the western Tibetan Plateau, and Quelccaya, located in the central Andes, show variations of the methane and $\delta^{18}O$ records similar to those in the Dasuopu ice core. This suggests that past natural methane fluctuations were mainly due to changes in source strength, through variability of the wetland extent in tropical regions. The last low concentration period in methane appeared around 1800 AD. Although some polar ice cores appear to record a very early (1750 AD) signature of anthropogenic methane, we do not see this in the Dasuopu ice core. In the polar region, the study of Rasmussen and Khalil (1984) concluded that a rapid and significant methane concentration increase started about 150 years ago, which corresponds with our results. They also found that the methane concentration in the atmosphere 250 years before was about 45% of current values (700 ppbv) and was not significantly influenced by human activities.

Our study concluded that the $\delta^{18}O$ in the Dasuopu ice core is also a good indicator of temperature (Thompson et al., 2000; Yao et al., 2002). The temperature record over the past 2,000 years, based on the $\delta^{18}O$ curve in Figure 2a, shows dramatic changes. Early in the first century, temperatures were low, followed by a significant increase until 700 AD. Temperatures reached their maximum during 700~900 AD, then lowered again, on a trend that persisted until 1850 AD. The Dasuopu ice core reconstruction reveals an obvious positive correlation between methane concentration and temperature. For instance, high methane concentrations occurred during the warm period between 700~900 AD. When the Little Ice Age began, around 1500 AD, there was a corresponding decrease in methane concentration. The methane concentration decrease continued to its lowest level of 660 ppbv during the coldest period indicated by $\delta^{18}O$ (around 1800 AD). Petit et al. (1999) and Raynaud et al. (1993) conclude that the remarkable correlation between methane and temperature implies a contribution of methane to the glacial-interglacial changes by amplifying the orbital forcing, along with albedo feedbacks and other possible changes. The Dasuopu ice core shows a close positive correlation between methane and $\delta^{18}O$, even on the very recent timescale.

Comparing the results from the mid-low latitude with that from the polar region reveals some interesting features. The most important feature of the Dasuopu ice core record is that the methane concentration and temporal variation amplitude are greater than in the polar ice core records during the pre-industrial period. The average methane concentration in the Dasuopu record is 782 ppbv, and the maximum temporal variation exceeds 200 ppbv, which has not been found in polar ice records for the period from 0-1850 AD. The Antarctic Law Dome cores (Etheridge et al., 1998) combined with the D47 (Blunier et al., 1993) core, the Greenland GRIP core (Blunier et al., 1993), and the Eurocore (Etheridge et al., 1998) provide a very detailed methane reconstruction for the last 2,000 years. Figure 2b shows the gradients of methane concentration among the Dasuopu core, the Greenland cores, and the Antarctic cores. The Dasuopu values differ by an average of 66 ppbv from the Greenland values and 109 ppbv from the Antarctic values. The average difference between the Greenland and Antarctic records is 44 ppbv in the time interval of 0-1850 AD. The higher methane gradients between the Dasuopu core and the polar region suggest that the low-middle latitude acted as the most important methane source in the pre-industrial period.

Conclusions

We have produced a high-resolution record of atmospheric methane over the past 2,000 years from a sub-tropical and high-altitude ice core. The Dasuopu ice core record indicates an apparent trend of climatic warming and methane concentration increase over the past 2,000 years. An abrupt decrease in methane concentration appeared around 1800 AD., which is the coldest period of the Little Ice Age. After the cold period, methane concentrations again dramatically increased. The most important feature of the Dasuopu ice core record is that methane concentrations are higher than in the polar ice core records. This suggests that the low-middle latitudes act as an important methane source, at least during the last 2,000 years.

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Recent Progress and Further Potential: High-resolution Holocene Climate Reconstruction with Coral Reefs in the South China Sea

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Coral reefs, excellent archives for the environmental history of tropical oceans, are widely distributed in the South China Sea (SCS), which is the biggest enclosed marginal sea of the western Pacific, covering over 16° in latitude and different climate conditions. The total area of the coral reefs in the SCS is about 7,300 km^2, ~2.5% of the world's coral reefs (Zhang et al., 2005). Recent research in the SCS focuses mainly on coral-based high-resolution climate reconstruction and coral reef ecological responses using geochemical and U-series geochronological tools, which reveal further potential for understanding of Holocene climate processes and events.

High-resolution Geochemical Proxies for Sea Surface Temperatures (SST) and Salinity in the Mid-late Holocene

Combined monthly-resolution skeletal $\delta^{18}O$, $\delta^{13}C$, Sr/Ca and Mg/Ca records for corals from the SCS reveal annual cycles similar to instrumental SST. Theoretically, skeletal Sr/Ca is a SST proxy, whereas skeletal $\delta^{18}O$ is a function of both SST and salinity. Our results show that the Sr/Ca-SST relationship is a reliable thermometer, with calculated SST consistent with other independent evidence. By removing the SST-related component in the $\delta^{18}O$ variation based on calculated Sr/Ca-SST values, one can obtain the residual $\delta^{18}O$ that reflects the deviation of the past seawater $\delta^{18}O$ from the modern value. Thus, the combination of coral Sr/Ca and $\delta^{18}O$ provides a powerful tool for past SST and salinity (related to evaporation and rainfall) reconstruction.

Unlike Sr/Ca, Mg/Ca is not a reliable proxy for SST despite the fact that its annual cycles are well-correlated with instrumental SST. Using the empirical Mg/Ca-SST relationship, we obtained calculated Mg/Ca-SST values for the Holocene corals that are significantly lower than the calculated Sr/Ca-SST values for the same samples, and Mg/Ca-SST values are also in conflict with coral reef ecology. The unreliability of coral Mg/Ca as a thermometer can be interpreted as being due to the presence of a trace amount of microbialites (with MgO up to 17%, Sr only 100-300 ppm). Preferential loss of Mg during meteoric dissolution of cryptic Mg-calcite-bearing microbialites in the exposed fossil corals (Yu et al., 2005a) will result in reconstructed Mg/Ca-SSTs being too low.

Using combined $\delta^{18}O$ and Sr/Ca measurements from five Porites corals, mid-late Holocene climate was reconstructed, revealing a general decreasing trend in SST in the SCS from ~6,800 to 1,500 years ago (Yu et al., 2005b), despite shorter climatic cycles. Compared with mean Sr/Ca-SST in the 1990s, 10-year mean Sr/Ca-SSTs were 0.9-0.5°C higher during 6.8-5.0 kyr BP, dropped to the present level by ~2.5 kyr BP, and reached a low of 22.6°C (2.2°C lower) by ~1.5 kyr BP. Such a decline in SST is accompanied by a similar decrease in the amount of monsoon moisture transported out of SCS, resulting in a general decrease in seawater $\delta^{18}O$

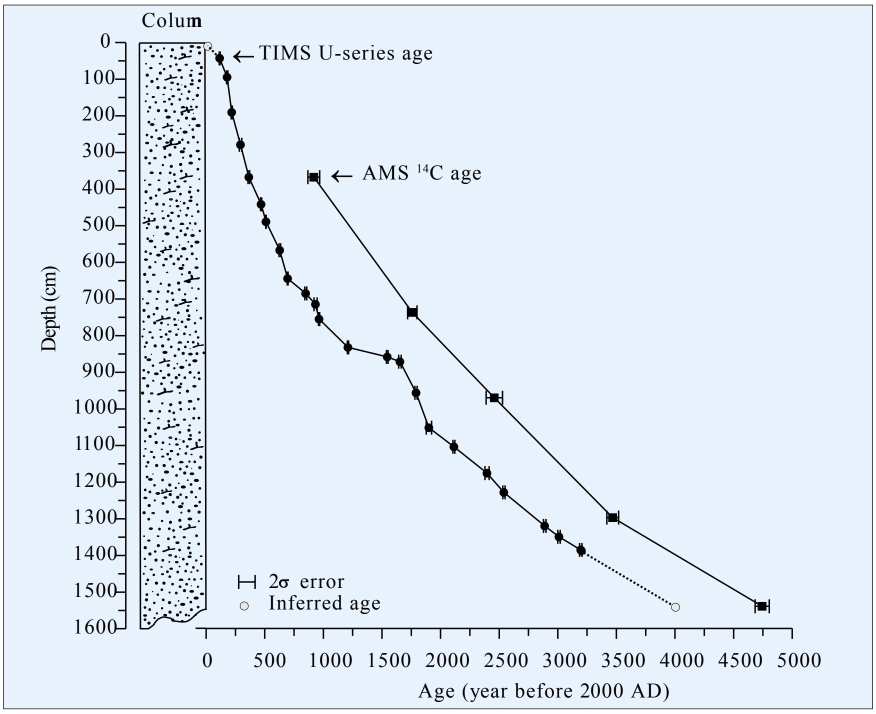

Fig. 1: Lagoon sediment column from Yongshu Reef (9°32'-9°42'N, 112°52'-113°04'E), southern South China Sea and TIMS U-series and AMS ^{14}C age distribution. The age offset between TIMS U-series and AMS ^{14}C age sequences should be related to radiocarbon reservoir effect.

values, reflected by offsets of mean $\delta^{18}O$ relative to that in the 1990s. This observation is consistent with general weakening of the East Asian Summer Monsoon since the early Holocene, in response to a continuous decline in solar radiation, which was also found in pollen, lake-level and loess/paleosol records throughout mainland China.

In contrast to the general cooling trend of the monsoon climate in East Asia, SST has increased dramatically in recent times, with that in the 1990s being 2.2°C warmer than ~1,500 years ago. This might suggest that the increase in the concentration of anthropogenic greenhouse gases has played a dominant role in recent global warming, which has reversed the natural climatic trend in the East Asian monsoon regime. If more corals are analyzed for the last 1,500 years, a clearer picture of environmental response to human activities in the South China Sea can be obtained.

Over 200 samples from different reef areas of the SCS, each covering a 30- to 150-year growth history, were dated for U-series ages with high-precision thermal ionization mass spectrometry (TIMS). The ages of these corals cover the entire last 7,500 years, providing a unique archive for us to reconstruct mid-late Holocene climate history in the SCS using combined high-resolution multi-proxy records. These ages and their elevations also reveal that multiple sea-level highstands of ~2 m above the present sea-level occurred at 7100 to 6300, 5717±27, 5009±54, 4156±23 to 3675 ±23, 2795±14 to 2509 ±10 yr, and 1511±23 yr BP, respectively. This suggests a possible linkage between high-latitude climate fluctuating cycles and low-latitude coral reef development.

High-frequency Winter Cooling and Coral Cold Bleaching During Mid-Holocene Warm Period

A detailed ecological, micro-structural and skeletal Sr/Ca study of a 3.42-m-thick Goniopora reef profile from an emerged Holocene reef terrace at the northern SCS reveals that at least nine abrupt massive Goniopora stress and mortality events ("cold-bleaching") occurred in winter during 7.0~7.5 cal ka BP (within the Holocene climatic optimum, Yu et al., 2004a). Whilst calculated Sr/Ca-SST maxima during this period are comparable to those in the 1990s, Sr/Ca-SST minima are significantly lower, probably due to larger seasonality and stronger winter monsoons. Such generally cooler winters, superimposed by further exceptional winter cooling on inter-annual-to-decadal scales, may have caused stress (cold bleaching) and mortality of the corals about every 50 years. Modern cold bleaching was reported to have occurred on Heron Island in the Great Barrier Reef in 2003.

This study provides the first prehistoric evidence for cold-bleaching of reef corals at higher latitudes and adds new dimension to the understanding of coral bleaching. The results also show that it took about 20-25 years for a bleached Goniopora coral reef to recover, which greatly aids our understanding of the present global warming-induced bleaching phenomenon and the recovery process.

During this period of reef growth, sea level rose by ~3.42 m, present sea-level was reached by ~7.3 ka BP and a sea-level highstand of at least ~1.8 m occurred at ~7.0 ka.

High-precision TIMS U-series and AMS 14C Dating of a 4,000-year-old Coral Reef Lagoon Core from Southern South China Sea

Worldwide, corals have contributed significantly to the understanding of global climate change, however few corals cover continuous records of several hundred years. The lack of continuous long records for the Holocene has greatly impeded systematic high-resolution climate reconstruction of tropical oceans. Although some deep-sea cores have been archived from tropical oceans, the time resolution is far too low to resolve the annual-to-decadal scale climate changes due to their lower sedimentation rates. Coral reef lagoon profiles, with high sedimentation rates, have great potential for recording long-term high-resolution continuous environmental change but their widespread application has so far been limited by the lack of accurate dates.

Our new research, based on 26 high-precision TIMS U-series dates (for 25 coral branches) and 5 AMS ^{14}C dates (for foraminifera) for a 15.4-m-long lagoon core from Yongshu Reef, southern SCS, show that all the dates are in the correct stratigraphical sequence, although the smallest sampling interval is only 13 cm, and they reveal a ~4,000-year continuous depositional history (Fig. 1). The results indicate that the deposition rate varied in the range of 0.8 and 24.6 mm/yr, with an average of 3.85 mm/yr. Two fast deposition periods, one from 103 to 305 AD and the other for the last 1,000 years, are identified. Episodes of elevated depositions within the last 1,000 years correlate well in timing with strong storm events identified from U-series dates of storm-relocated coral blocks in the area (Yu et al., 2004b). Therefore, coral reef lagoon profiles provide great potential for high-resolution (4-10 years) and continuous climate and environmental reconstruction in the tropical oceans.

Apart from the above outlined research topics, we are also undertaking research on U-series dating of recent coral mortality history, sea-level fluctuation on millennial-to-century scales, and radiocarbon reservoir age change in the SCS since the mid-Holocene.

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Sorting Chinese Climate Records from the 13th Century BC to 1911 AD and their Latest Applications

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A myriad of historical documentary records in China preserves one of the paramount sources of paleoclimate data marked by definite description of place and time of climate events over thousands of years, and is thus of particular importance to chronologically calibrating such proxy data as tree rings, ice cores and sediments, not to mention their strong humanism inference. Chinese researchers began in 1985 to assemble and sort systematically the meteorological records from historical documents, and have recently finished a book entitled "A Compendium of Chinese Meteorological Records of the Last 3000 Years" (Zhang, 2004).

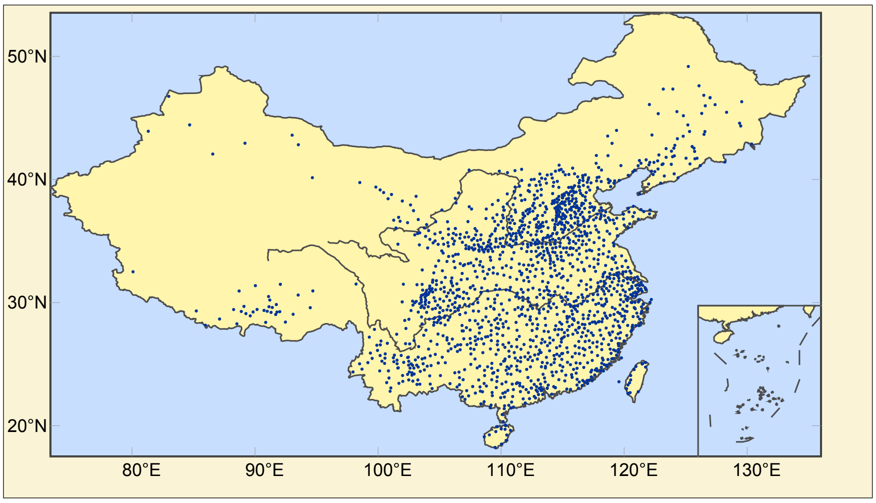

Fig. 1: Distribution of places of the historical climate records in the Compendium.

Compiled on a chronological basis, this collection represents a splendid archive of ancient Chinese cultural heritage and scientific contributions, covering various weather/climatic conditions, atmospheric physical phenomena, and other written records related to meteorological conditions over 3,000 years, from the 13th century BC to 1911 AD (Fig. 1).

This compendium is composed of four volumes. Each volume contains the following records: (1) descriptions of weather, climate, and atmospheric physical phenomena, including flood, drought, rain, snow, cold, heat, icing, freezing, frost, hail, wind, dust and haze, storm, thunder and lightning, atmospheric optical phenomena, and the time and location of these phenomena; (2) spatial coverage and degree of damage caused by meteorological disasters and the relief and tax waiver afterwards, and; (3) phonological, crop yield, insect damage, plague and famine records that are related to meteorological conditions. Because of the very large quantity of records starting from the Ming Dynasty, records of the same year in the Ming and Qing Dynasties (1368-1911 AD) are further sorted according to their provincial locality. Modern names for the recorded localities are also given for convenience.

The original data came from 65 libraries and archives in 37 cities of the country, and they were collected according to different categories prepared in advance. We have read through all the books and records for seeking and selecting, with the materials made into various duplications (photocopies, microfilms and hand-written copies). The books and records selected amount to 8,228, of which 7,835 were chosen, including 7,713 local chronicles, 28 kinds of chronicles and many official docu-

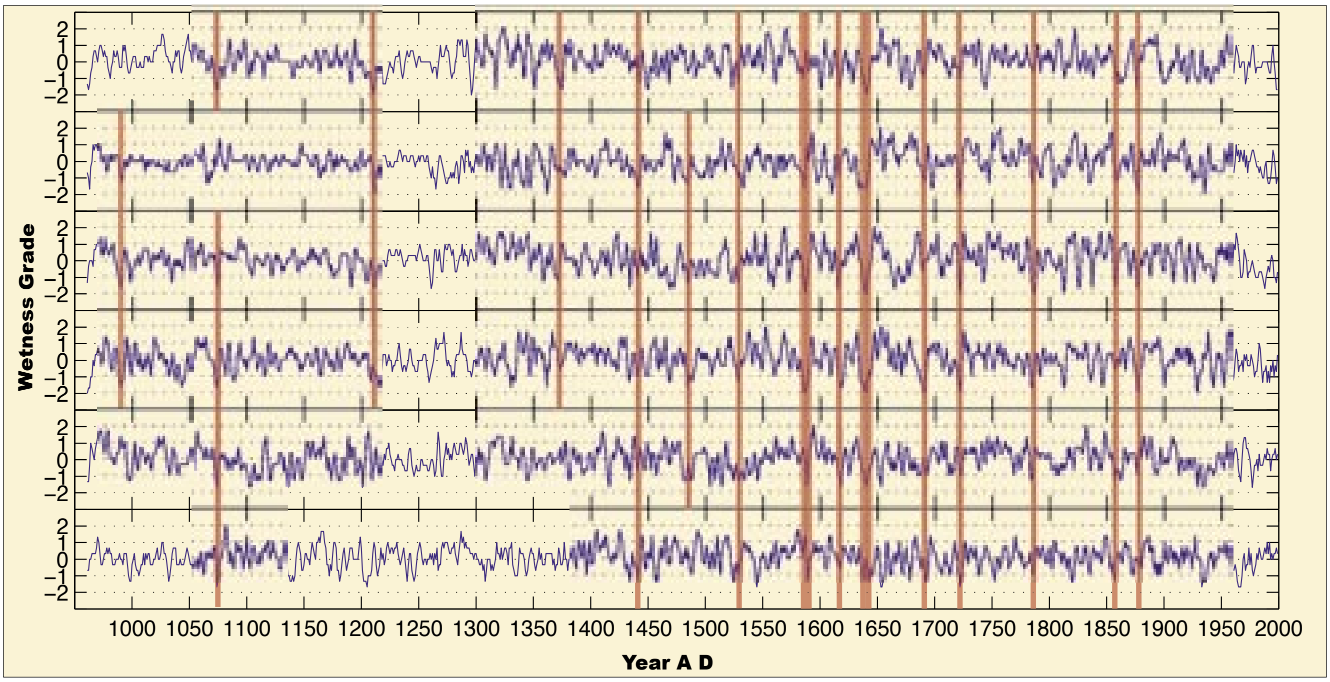

Fig. 3: Yearly wetness grade series (with 3-year running mean) for the 6 regions I-VI in eastern China for 960-2000 AD and 15 severe droughts marked by brown stripes (Zhang, 2005).

ments, scholars' prose volumes and tablet inscriptions over a very long period. It is worth mentioning that the duplications comprise more than 10,000 volumes, forming an unprecedented centralized collection of Chinese historical climatic data, and they will serve as a reference database of historical climate records for researchers undertaking various studies in the country. Records of personal diaries and from the Royal Archives of the Qing Dynasty are not included because of their different style. The materials included in the more than 200,000 records collected initially underwent careful checking and correction against other data, with the source of each piece investigated, and verbal errors arising from multiple sources of publications and/or quotations being corrected. During compilation, if an event appeared more than once in the records, the earliest source was generally taken. An event found in a number of books was selected only from a reliable source after careful examination. Each event is given with its source, with errors in time, place and verbal description corrected as much as possible.

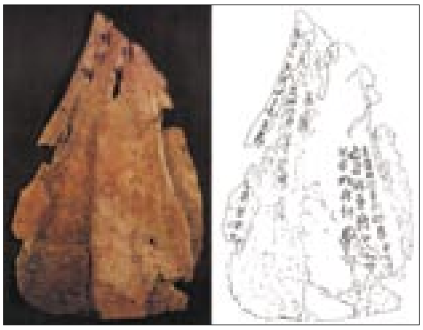

Fig. 2: The earliest meteorological record (photo, left; hand-craft, right) inscribed on a bone with "cloud" and "rainbow" characters in the 13th century BC. It is explained to the effect that clouds are moving from the east ... and a rainbow appears in the north at sunset of day eight.

At the front of the text, oracles inscribed on animal's bones and tortoise shells during the 13th-11th centuries BC (later Shang Dynasty) are given. Recorded 3,000 years ago, these represent the earliest Chinese characters on meteorological phenomena. A total of 358 oracle bone meteorological records are sorted into 12 meteorological categories: wind, cloud, rain, snow, hail, frost, thunder, drought, clear, haze, daily weather and multiple day weather. Each record is given in Mandarin and explained in modern Chinese (Fig. 2).

Now, a compendia-based historical climate data recall system has been established for the purposes of reconstructing historical climate sequences and restoring real conditions of climate events, e.g., severe droughts, excessive precipitation, extreme cold season and heat wave. A study on large-scale drought events indicates that 15 cases lasting in excess of 3 years and affecting more than 4 provinces have occurred in the past 1,000 years, in relatively warm or cold climate backgrounds, and 5 of them covering both east and west China are supported by tree-ring records (Fig. 3). Inference from the restored events as regarding their domains, duration and rainfall reveals that these persistent drought events were more severe than those that occurred in the past 50 and even 100 years (Zhang, 2005). In addition, the historical records are used to construct a chronicle of events both for dust-fall and locust disaster, and particularly, the recorded volcanic ash events discovered in the collection are a useful supplement to the chronology of volcanic eruptions of the world (Stimkin & Siebert 1994).

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What Drives the Climate: Man or Nature?

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Traditionally, human-environment interactions are discussed in terms of the influence of climatic changes and catastrophes on civilizations (Battarbee et al., 2004; Yasuda and Shinde, 2004). Recently, a hypothesis suggesting the onset of the "anthropogenic greenhouse era" about 8 ka ago as a result of forest clearance and agriculture was proposed to explain the pre-industrial rise in CO_2 and CH_4 concentrations (Ruddiman, 2003; see also PAGES *News* 2004/1). Consequently, man was deemed the "rescuer" of the Earth from a new Ice Age, otherwise predicted at about 4 ka ago. Opponents of this hypothesis argued that natural forces were responsible for the pre-industrial increase in greenhouse gases (Broecker and Clark, 2003, Joos et al., 2004).

These contradictory views and the current discussion they have provoked (Claussen et al. 2005; Crucifix et al. 2005; Ruddiman, 2005; Broecker and Stocker, 2005) are far more than a scholastic debate with only theoretical value. We regard integrative palynological and archeological studies in combination with modeling as a promising path towards a better understanding of the mechanisms and forces driving the Holocene climate. This understanding is crucial for reliable projections of climate in the future.

Palynological and Archeological Records

Except for desert areas, arboreal pollen (AP) percentages represent well the tree-cover around the sampling site. Figure 1 presents pollen-based cases of the Holocene forest dynamics from several regions with a strong anthropogenic impact on vegetation.

Case 1: Easter Island
Figure 1a shows changes in AP percentages on Easter Island, settled by people about 1,600 years ago (Kirch, 2000). Flenley (2001) suggested the island—originally covered with palm forest—was completely deforested during the subsequent thousand years. A distinct decrease in AP from 90% at 10 ka to 55% at 2 ka implies a "deforestation" that is not related to human activity, long-distance pollen transport or species competition (Flenley, 2001) and requires an alternate explanation. Rolett and Diamond (2004) suggested that even Easter Island's eventual forest extinction "was not because its people were especially improvident but because they faced one of the Pacific's most fragile environments."

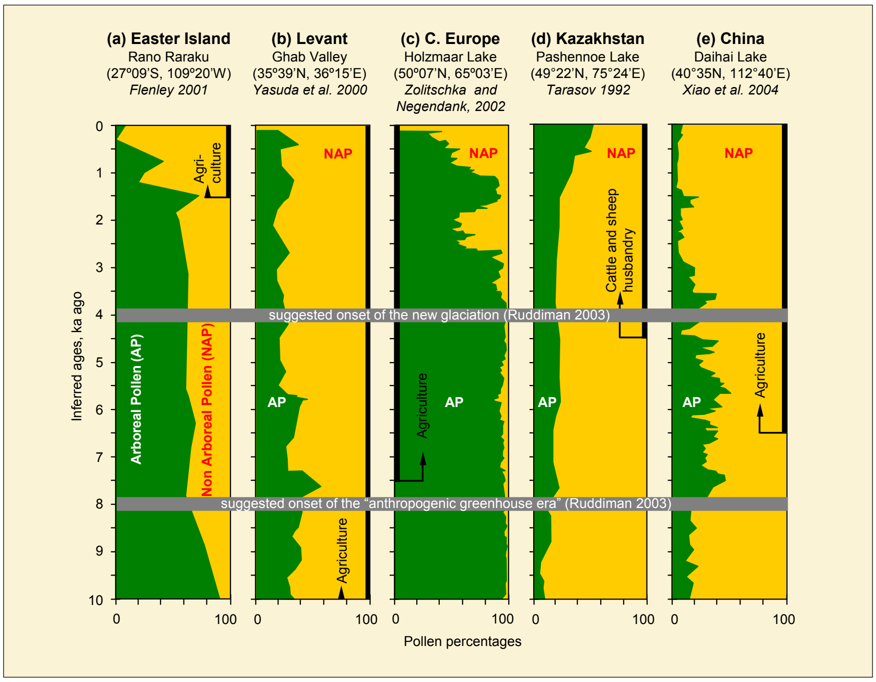

*Fig. 1: Changes in arboreal (AP) and non-arboreal (NAP) pollen percentages since 10 ka ago and the occurrence of agriculture (**a-c**, **e**) or cattle and sheep husbandry (**d**).*

Case 2: The Levant
Large-scale man-made deforestation can be assumed in Syria accompanying the inception of agriculture (Zohary and Hopf, 2000). In the Ghab record (Fig. 1b) AP varied from 55% to 30% during 10 ka to 5.6 ka, and from 25% to 15% during the later period. Yasuda (2001) reported that a decrease in pollen percentages for deciduous oak at 10 ka was accompanied by an increase in evergreen oak and olive pollen percentages and by high frequencies for charcoal particles. The Ghab record illustrates anthropogenic deforestation but the Hula record from Israel (Baruch and Bottema, 1999) fails to reproduce the same story—a reminder that any spatial extrapolation of deforestation requires careful investigation, including modeling of climate-sensitive taxa/biome distributions.

Case 3: Central & Northern Europe
In mid-latitude Europe, noticeable changes in AP exceeding natural variability occurred after 3 ka ago (Berglund, 1991; Zolitschka and Negendank, 2002: Fig. 1c), i.e. 4.5 ka after central Europe and 3 ka after northern Europe acquired agriculture (Rowley-Conwy, 2004). To link plant cultivation with deforestation poses the challenge of confronting pollen with archeological data following the spread of agriculture from the Levant across Europe. Nevertheless, the forest decline about 3 ka ago coincides with the Late Bronze Age intensification of landuse (Berglund 2003).

Case 4: Kazakhstan
By contrast to cases 1 to 3, pollen records from Kazakhstan (Tarasov,

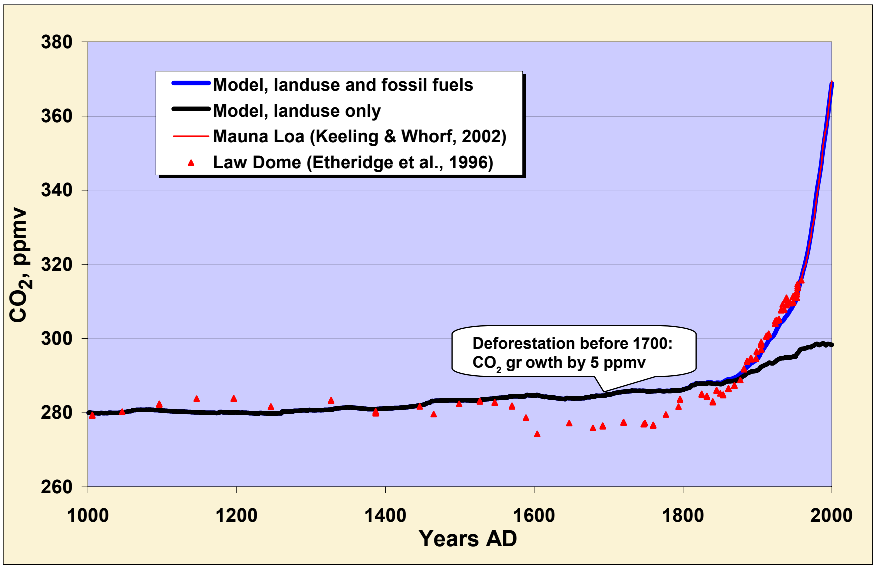

Fig. 2: Atmospheric CO_2 concentration from the CLIMBER-2 simulations for the last millennium driven by changes in landuse (Ramankutty and Foley,1999), black line, and by changes in landuse plus fossil fuel emissions (Marland et al., 2002), blue line; for details see Brovkin et al. (2004).

1992; Kremenetski et al., 1997) offer a different scenario of forest dynamics, suggesting that forestation of the steppe zone started at 6 ka and reached a maximum during the last millennium (Fig. 1d). Until the mid-Holocene, tree cover was minimal and did not experience any traceable impact of pastoralism or agriculture (Rosen et al., 2000). The remaining question is: to what extent were other parts of the Eurasian steppes free from forest clearance and did not influence the pre-industrial CO_2 rise?

Case 5: China

Forest dynamics on the Chinese landmass undoubtedly influenced the Holocene climate. At about 8 ka ago, Neolithic people subsisted mainly on cultivated millet in the northern plains (Chang, 1986) and on rice in the south (Crawford and Shen, 1998). The 2 ka time-slice saw the expansion of the Han Empire, bordered by local kingdoms in the south and the mighty confederation of Xiongnu tribes in the north. The tasks ahead of us include quantitative evaluation of settlement/population density and forest clearance; and explanations for high AP percentages in central Inner Mongolia (Fig. 1e) during early intensive settlement development (Tian, 1991a, 1991b) and for a major expansion of trees in south-eastern China at 6 or 4 ka (Ren and Beug, 2002), when the number of settlements drastically increased (Zhang, 2000).

Mapping of Holocene Forest Dynamics

Quantitative approaches facilitate the transformation of pollen records into vegetation maps (Sugita, 1993) as demonstrated by the successful reconstruction of forest and cultural landscape dynamics in southern Sweden (Berglund, 1991; Gaillard et al., 1994; Sugita et al., 1999). Surface pollen and remote sensing based vegetation datasets matched by a modern analogue technique were applied to fossil pollen records from North America (Williams, 2003) in order to map post-glacial tree-cover changes. This approach was successfully tested with data from Eurasia (Brewer et al., 2005) and can be applied on a global scale.

Modeling: Climate, Vegetation, Carbon Cycle

Previous estimates of pre-industrial emissions associated with anthropogenic land-use are limited to 60-80 PgC (House et al., 2002) which corresponds to a 3-5 ppmv increase in atmospheric CO_2 concentration (Brovkin et al. 2004, Fig. 2). However, this is a very preliminary estimate because a global-scale dataset on the timing and magnitude of anthropogenic deforestation prior to 1700 AD is not available. Since most changes in the carbon balance are associated with changes in tree cover, its global reconstruction provides a firm constraint on the land carbon balance. We suggest combining the potency of terrestrial biogeochemistry models with pollen-based reconstruction of tree cover to evaluate changes in land carbon storage, either in transient simulations or in frequent time-slice experiments. Interactive climate-vegetation simulations performed by several models can be used to evaluate the uncertainty in climate changes.

Call for a New Initiative

IGBP-PAGES BIOME 6000 Project (Prentice and Webb, 1998) involved many individuals and research groups all over the world in pollen data synthesis and quantitative reconstruction of the mid-Holocene and LGM biomes. Furthermore, it initiated close co-operation between pollen and modeling communities and produced substantial new results. Extending on BIOME 6000 and adding to ongoing Focus 5 activities on human-environment interactions, we suggest to launch a new international initiative addressing the Man-Trees-Climate System (MATRICS) that will bring together paleobotanical and archeological records with modeling results and set direct evidence of human activities against indirect signs of human impact on vegetation.

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Holocene Environmental Catastrophes in South America: From the Lowlands to the Andes

Miramar, Córdoba, Argentina, 11-17 March 2005

How can we unravel the environmental consequences of natural changes from those induced by human actions? How can we better understand the complex interaction between catastrophes and society? What is the important message and how to convey it to end-users and governments? These and other questions were at the core of our conference organized by the Research Center for Geochemical and Surficial Processes, University of Córdoba (Argentina) and the Department of Geography and Earth Sciences, Brunel University (U.K.).

We planned the meeting to bring Quaternary scientists, archeologists and end-users together to make a "bridge" between the environmental events/shifts since the beginning of the Holocene and the current situation, and to examine the state-of-the-art of paleoclimate research in South America. Eighty-five participants from 11 countries met in Miramar by the coast of Laguna Mar Chiquita in central Argentina. During the four-day meeting, participants had the unique opportunity to discuss the human dimension of paleoclimate research and to observe the vulnerability and reaction of Miramar inhabitants facing recent and dramatic lake water-level rises (8 m in 10 years, Fig. 1).

Fig. 1: Upper panel - Present-day scenario in Laguna Mar Chiquita. A highstand has dominated since 1977, producing drastic economic and social consequences. Lower panel - The program included an excursion to flood-affected areas of Miramar and the abandoned "Hotel Viena", a relict of past-flourishing times during low lake-levels. The last highstand of Laguna Mar Chiquita strongly disrupted the tourism-based local economy.

Invited lecturers and conference sessions addressed:

1. Natural system responses to environmental change and sustainability
2. Catastrophes and the archeological record. Holocene events and cultural consequences
3. Holocene fire history records
4. Rapid geological change
5. High resolution and co
al changes
7. Holocene climate changes

The program included an excursion to the flood-affected areas of Miramar. A video documenting the demolition of the flooded portion of the village documented the psychological impact. A post-meeting field trip was focused on the evaluation of positive/negative feedbacks of comparatively higher precipitation on erosive processes and agricultural activities in the Pampas, the consequences of a catastrophic flood event, and a general view of Quaternary fluvial deposits and loess.

Several presentations showed that the 20th century climatic variability in a wide and very productive region of SE South America is represented by contrasting hydrological scenarios. Dry intervals characterize the first 75 years, while a rise in precipitation has occurred after the 1970s. The wet phase now affecting Argentine Pampas has increased the provision of services with a market value (i.e., food and fibre) but has also seriously impacted on the quality of other non-marketable natural services and resources (i.e., erosion control, fresh water supply, biodiversity, biogeochemical cycles). Paleoclimate reconstructions show that the present positive P-E balance has had no equivalent since the Early Holocene when there was probably no human influence in the area.

Results point towards the necessity to reinforce paleoclimate research to fully appreciate natural climate variability beyond the instrumental record and to plan future strategies leading to sustainable development. Efforts should concentrate on bridging the gap between geoscientists and policy-makers and government agencies, persuading the latter two groups about the significance of our research for improving long-term planning actions. Geoscientists alone cannot seal the gap. One strategy could be to involve social scientists and economists in our projects, to decode our findings to the end-users and politicians.

This conference successfully established new contacts between scientists from Latin America, North America and Europe. The scientific outcome will take the form of a special issue in the journal "Quaternary International" edited by E. Piovano, R. Villalba and S. Leroy. The meeting was sponsored by IGCP-490 (The role of Holocene environmental catastrophes in human history), ICSU/IUGS (Dark Nature) and a number of Argentinean agencies including CONICET and FONCyT. The International Association of Sedimentologists, the Inter-American Institute for Global Change Research, the IUGS-Geoindicators Initiative and ICSU project provided funding to 26 participants from Argentina, Brazil and Chile.

The volume of abstracts is available at: http://www.efn.uncor.edu/investigacion/ciges/Meeting/index%20mar%20chiquita%20meeting.htm.

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Sub-aerially Exposed Continental Shelves Since the Middle Pleistocene Climatic Transition

INQUA International Workshop, Hong Kong SAR, China, 9-13 May 2005

This workshop, held at the University of Hong Kong, forms part of a 3-year project aimed at the study of sub-aerially exposed continental shelves since the Middle Pleistocene climatic transition. It was attended by 47 participants from 15 countries over 4 days with an additional full-day excursion to Lantau Island. There were 8 keynote addresses covering topics ranging from exposed carbonate shelves (L. Collins), speleothems (F. Antonioli), luminescence dating (A. Wintle), climate change and human migration (A. Montenegro), sea-level studies (Y. Yokoyama), Wanganui Basin (B. Pillans), cosmogenic radionuclides (D. Fink), and geochemical evidence (A. Chivas). A special address was also given to review the results obtained through coastal infrastructural developments in Hong Kong, where 5 interglacial-glacial cycles similar to those in the Vostok ice core have been identified (W. Yim).

Fig. 1: Field excursion stop to examine offshore cores in a shallow bay showing evidence of 4 interglacial-glacial cycles. Photo taken by Dr S. Yang.'

Sub-aerially exposed continental shelves provide evidence of climate and sea-level change. Because of the marginal location, continental shelves show features unique to both truly terrestrial and truly marine environments, and are therefore important for high resolution land-sea correlation. Other topics discussed included paleosol development, greenhouse gas production, landslide deposits, fluvial deposits, eolian deposits, geotechnical properties of sea-floor sediments, and the applicability of a range of dating methods for future investigations.

Current plans are to hold the 2006 field meeting either in Western Australia, eastern India, or southern Italy. Finalized details will be announced at a later date. In 2007, a symposium is planned for the 17th INQUA Congress in Cairns, Australia.

Acknowledgements
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7th International Conference on Dendrochronology: Cultural Diversity, Environmental Variability

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Tales from the Field

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