Reconstruction of climate and vegetation changes of Lake Bayanchagan (Inner Mongolia): Holocene variability of the East Asian monsoon

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In this study, we report a high-resolution pollen and *Pediastrum* record from sediments obtained from the bed of the Lake Bayanchagan, southern Inner Mongolia. Vegetation reconstruction is based on the objective assignment of pollen taxa to the Plant Functional Type (PFT) (Prentice et al., 1996), based on broad classes of plants defined by stature, leaf form, phenology and climatic thresholds. We used the standard modern analogues technique (PT-MAT, Guiot, 1990) and the new PFT modern analogues technique (PFT-MAT, Davis et al., 2003), which have been applied successfully to Holocene climate reconstruction in Europe (Guiot et al., 1993; Magny et al., 2001; Davis et al., 2003), to constrain a quantitative estimation of climate changes in southern Inner Mongolia.

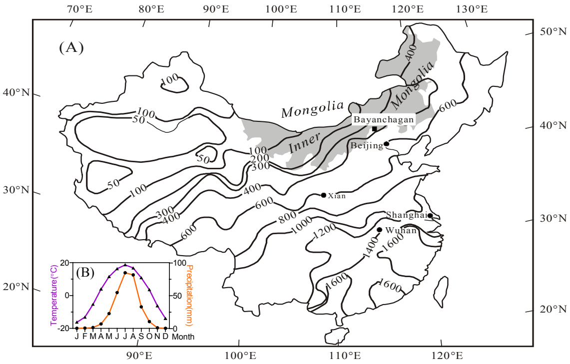

Fig. 1 Map showing the location of Lake Bayanchagan (115.21°E, 41.65°N, and 1355 m a.s.l) and Inner Mongolia (shaded area, situated at the limit of the present East Asian monsoon).

(A) Distribution of mean annual precipitation (mm) in China (modified after Domrös and Peng, 1988). The monsoon rainfall decreases dramatically on a southeast to northwest transect;

(B) Monthly average temperature (triangles) and precipitation (dots) for Huade weather station (114.00°E, 41.54°N) during 1952-1990. Data from the National Meteorological Center of China. About 70% of the precipitation occurs during the summer, a characteristic typical of the East Asian monsoon climate.

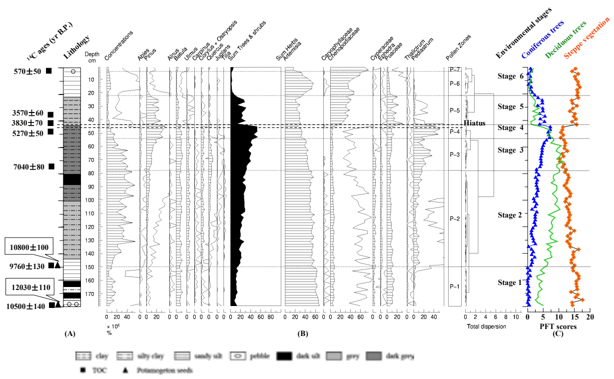

Fig. 2 (A) Lithology, (B) Simplified pollen diagram of core BY, Lake Bayanchagan, and (C) Affinity scores of dominant PFTs (the orange line, steppe vegetation; the green line, deciduous trees; the blue line, coniferous trees). Throughout the Holocene, Southern Inner Mongolia was dominated by steppe vegetation, except between 9200-6700 cal yr B.P., when woodland becomes an important factor in the vegetation.

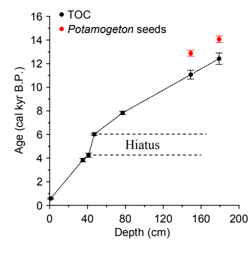

Fig. 3 The time-depth curve from the BY core. Ranges of calibrated dates are shown for Total Organic Carbon and *Potamogeton* seeds. Age-model is based on TOC dating.

Table 1 Statistical comparisons for climate reconstruction using PT-MAT and PFT-MAT. RMSE is the root mean square of errors. The meaning of the abbreviations of the climate variables is given in Figure 4.

Climate variable	Correlation (R^2)		RMSE	
	PT-MAT	PFT-MAT	PT-MAT	PFT-MAT
MTCO	0.84	0.76	5.1	6.2
MTWA	0.71	0.60	2.4	2.7
TANN	0.84	0.77	3.2	3.7
GDD5	0.68	0.58	571	667
PANN	0.55	0.37	193	223
E/PE	0.62	0.45	13.4	15.6

As shown in Table 1, for each climatic variable, correlations are higher, and RMSE is lower for PT-MAT than PFT-MAT. This can be partly explained by the range of the analogues (pollen taxa or PFT) used by two techniques. A set of pollen taxa links to vegetation type, while PFT groups can be directly related to climate. The best modern analogues selected by PT-MAT are more constrained to come from geographically close localities, e.g. northern China, Mongolia and Russia with the same taxonomical composition. For PFT-MAT, this constraint is more relaxed, with the consequence that the best modern analogues come from a wider range of climate.

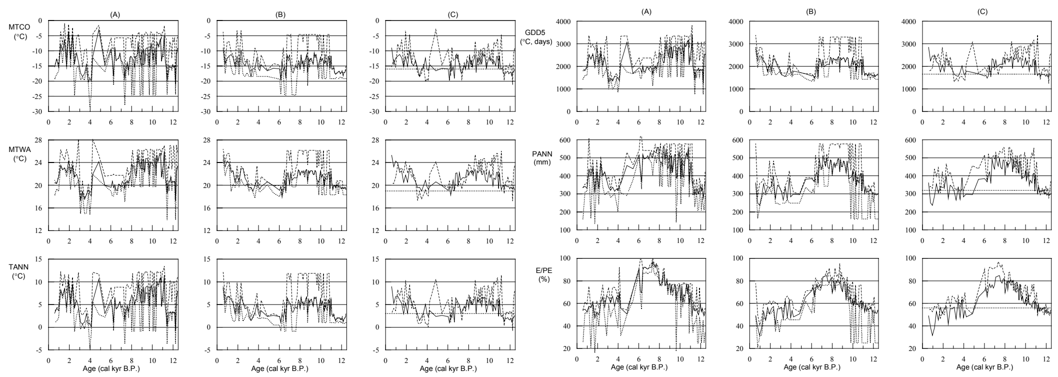

Fig. 4 Climatic parameters reconstructed from pollen data using PFT-MAT (A), PT-MAT (B). MTCO, mean temperature of the coldest month; MTWA, mean temperature of the warmest month; TANN, mean annual temperature; GDD5, growing degrees day above 5°C; PANN, annual precipitation; E/PE, actual evapotranspiration/ potential evapotranspiration. Each reconstructed curve shows the mean estimates (solid lines), the lower limit of estimates (dotted lines) and the upper limit of estimates (dashed lines). (C), Comparison of the mean estimates between two techniques (dashed line, values obtained from the PFT-MAT; solid line, values obtained from the PT-MAT technique; dotted horizontal line, present day climate).

As seen in figure 4, the six parameters variations, estimated respectively by PFT-MAT and PT-MAT, have generally consistent pattern. Both PFT-MAT and PT-MAT show that a cold and dry climate prevailed during the period between 12,500 and 11,000 cal yr B.P., and a rapid rise in both temperature and precipitation occurred at ~10,500 cal yr B.P. Around 8000 B.P., temperature decreased, followed by a rapid reduction in precipitation at 6500 cal yr B.P., about 1500 years later than the cooling event. A major difference in the averaged temperature and precipitation obtained by PFT-MAT is that both are slightly higher than those calculated by PT-MAT.

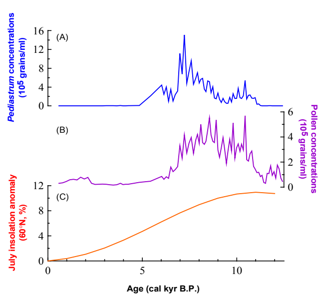

Fig. 5 (A) *Pediastrum* concentrations interpreted as a rough indicator of water depth, (B) Pollen concentrations being an indicator of vegetation density, and (C) July insolation anomalies at latitude 60°N (Berger and Loutre, 1991)

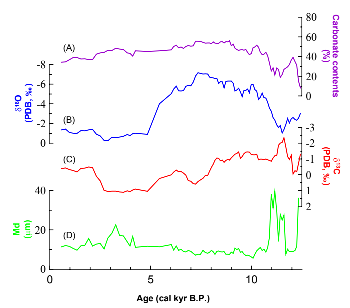

Fig. 6 (A)Variations in contents of carbonate, (B) δ^{18}O values of carbonate, (C) δ^{13}C values of carbonate, and (D) the Md, median grain size.

References:

1. Berger, A., Loutre, M.F., 1991. Insolation values for the last 10 million years. Quaternary Science Reviews 10, 297-317.
2. Davis, B.A.S., Brewer, S., Stevenson, A.C., Guiot, J., data contributors, 2003. The temperature of Europe during the Holocene reconstructed from pollen data. Quaternary Science Reviews 22, 1701-1716.
3. Domrös, M., Peng, G., 1988. The Climate of China. Springer-Verlag, Berlin.
4. Guiot, J., 1990. Methodology of the last climatic cycle reconstruction from pollen data. Palaeogeography, Palaeoclimatology, Palaeoecology 80, 49-69.
5. Guiot, J., Harrison, S.P., Prentice, T.C., 1993. Reconstruction of Holocene patterns of moisture in Europe using pollen and lake-level data. Quaternary Research 40, 139-149.
6. Magny, M., Guiot, J., Schoellammer, P., 2001. Quantitative reconstruction of Younger Dryas to Mid-Holocene paleoclimates at Le Locle, Swiss Jura, using pollen and lake-level data. Quaternary Research 56, 170-180.
7. Prentice, I.C., Guiot, J., Huntley, B., Jolly, D., Cheddadi, R., 1996. Reconstructing biomes from palaeoecological data: a general method and its application to European pollen data at 0 and 6 ka. Climate Dynamics 12, 185-194.

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