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Molecular Signals of Climatic Change over the Last 30,000 Years in Zabuye Salt Lake Sediments, Tibet

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The utility of alkenone temperature proxies in assessment of oceanic palaeoclimates prompts efforts to explore their veracity in lake environments. Interpretation of changes in lacustrine temperatures based on alkenones would represent a significant addition to the armory of proxies currently employed in the reconstruction of continental palaeoclimates, affording the possibility for comparisons with marine records. Investigation of sediments from Zabuye Salt Lake (ZSL) in western Tibet illustrates that alkenone signals can record the frequency and magnitude of abrupt climate fluctuations in lacustrine settings.

Alkenones occur in sediments from temperate and high altitude freshwater lakes (L. Titicaca), saline lakes (L. Qinghai, China), and alkaline lakes (L. Van, Turkey; Hotong Qagan Nur, Inner Mongolia) (Brassell, 1993; Li *et al.*, 1996; Thiel *et al.*, 1997; Sheng *et al.*, 1999; Theissen *et al.*, 1999). However, attempts to apply alkenone palaeothermometry in lacustrine settings are not straightforward, requiring consideration of: (i) Differences in distributions compared with marine environments, notably the abundance of tetraunsaturated alkenones. (ii) Ignorance of biological origins despite concerted efforts to identify and isolate source organisms (e.g. Li *et al.*, 1996). (iii) Prospects that factors other than temperature (e.g. salinity, nutrients) may influence alkenone unsaturation. (iv) Concerns that the robust, first-order relationship between alkenone unsaturation ($U^{K'}_{37}$) and surface ocean temperatures does not extend to lake environments. (v) Absence of an established calibration for the $U^{K'}_{37}$/temperature relationship in lakes. Irrespective of these considerations temporal changes in alkenone unsaturation ($U^{K'}_{37}$ and U^{K}_{37}) in sediment cores from both Lake Van and Hotong Qagan Nur demonstrate that variations in alkenone distributions reflect climatic events. The alkenone data from ZSL confirms this view.

ZSL is the lowest lake of the Taro-ZSL lake chain. Lakes at higher elevations act as evaporative basins and their effluent contributes to the accumulation of dissolved salts in ZSL, which has become increasingly saline. Reconstruction of lake levels (Zheng *et al.*, 1989) from a series of sand spits show that ZSL has evolved from a freshwater lake within the Lunngar basin to a shallow salt lake. This 30ka history is recorded by a 20m core (ZK2), which contains a mixed sequence of carbonates and clastics. Several lithological units are recognizable lake-wide and their boundaries often correspond with changes in water level, thereby enabling stratigraphic correlation, aided by ^{14}C ages.

Alkenone distributions in core ZK2 from ZSL resemble those of sediments from Qinghai Lake (Li *et al.*, 1986) and Lake Van, Turkey (Thiel *et al.*, 1997). They differ from marine environments in terms of their high relative abundance of alkatetrenones, and the absence of C_{38} methyl alkenones. C_{37} methyl and C_{38} ethyl alkenones occur in low concentrations (often <0.5 ng/g; Figure 1) that are consistent with an environment containing low nutrients levels where the growth season is limited by ice formation and cold temperatures. Alkenones disappear in the uppermost core section when salinities reach ~19.2%, perhaps reflecting a catastrophic decline in algal production. Values for $U^{K'}_{37}$ and U^{K}_{37} calculated from alkenone distributions (Figure 1) show no systematic depth trends, which precludes a sequential diagenetic trend or a response to the progressive increase in salinity. The most widely accepted calibrations suggest temperature ranges for ZSL of 1.6 to 10.3ºC and 5.1 to -13.5ºC based on U^{K}_{37} and $U^{K'}_{37}$, respectively. They correspond to a warming of ~13ºC and ~7ºC from the last glacial maximum to the mid-Holocene optimum, values that bracket most global estimates. The relative temperature records for both indices seem reasonable, but the presumption that alkenone production is limited to summer months suggests that only the temperatures based on $U^{K'}_{37}$ values are viable. The more plausible temperatures are therefore based on the index that excludes the alkenone ($C_{37:4}$) which shows the greatest variation among the samples.

The temperature trends of the alkenone indices (Figure 1) appear to record climatic events, irrespective of complications associated with assessment of influences governing production of alkatetrenones and differences between the alkenone indices. There is evidence of the mid-Holocene climatic optimum, the Younger Dryas event and the last glacial maximum. These alkenone trends compares favorably with the climate variations proposed on the basis of pollen assemblages (Figure 1) and indicates abrupt climate changes in Tibet, based on marked differences between samples at sub-millennial scales.

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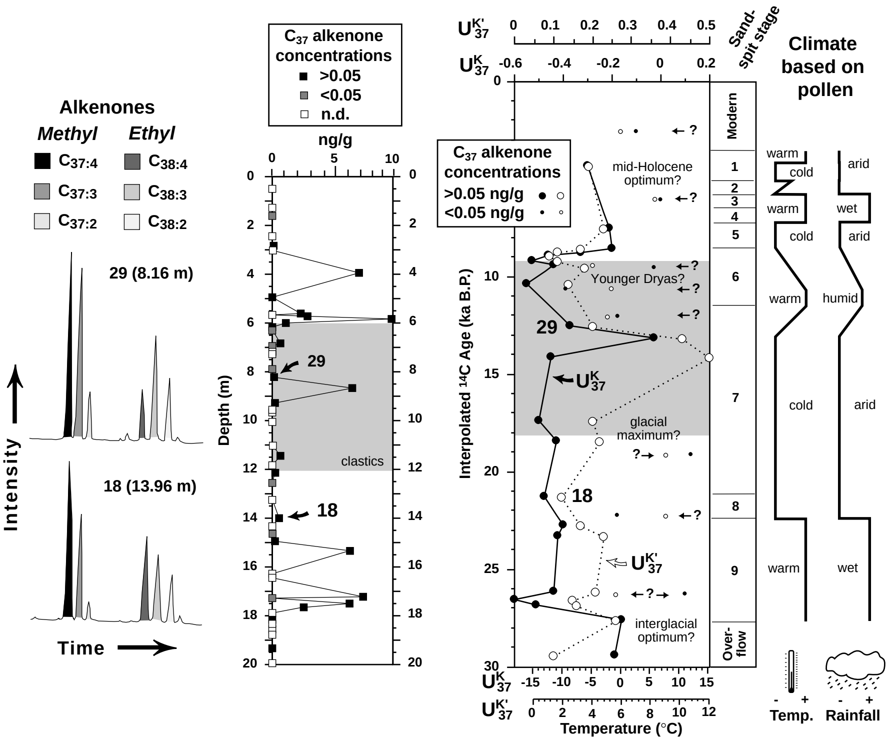

Figure 1: Representative distributions of alkenones in ZSL sediments, depth profiles of alkenone concentrations in ZSL, temporal changes in unsaturation indices and alkenone-derived temperatures coupled with climatic variations inferred from pollen data.

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