Palaeoenvironmental events and cycles at the southern front of the Tibetan Plateau during the Pleistocene: A record from lake sediments

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Lake sediments provide high resolution palaeoenviromental archives. In and around the Himalayan region there are numerous lacustrine deposits formed during the last ca. 40 ka. However, there are only few such basins covering almost the complete Pleistocene. These are the Karewa basin (Kashmir, India), Kathmandu basin (central Nepal) and Heqing basin (Yunnan, China). They span over a distance of about 2000 km and are therefore suitable targets to search for synchronous climatic or tectonic events significant for a large region south of the Tibetan Plateau. Karewa sediments cover the Pleistocene until to about 200 ka. They were studied mainly during the eighties of the last century, but due to political instability of the Kashmir region research stopped since then. In the Kathmandu basin early work was done by Yoshida and Igarashi (1984). During recent years drill-cores from the center of the basin were studied (Sakai et al. 2001 and this volume) providing a far more continuous record. Our own work focuses on a continuous succession of fine-grained almost uniform lacustrine sediments from a 168 m-drill-core in the Heqing basin and a 120 m long section of the Lukundol Fm in the Kathmandu basin (**Figure 1**). This core spans a period of 0.05 to 1.00 ka.

The most remarkable feature of the Heqing core is the record of both, orbital cyclicities and regional events. Cyclicities are observed along the entire succession in the carbonate content as well as in the carbonate-free concentration of magnetic minerals. Spectral analysis reveal dominant power in a cycle, which according to dating results (radiocarbon, magnetostratigraphy) is about 100 ka and thus seems to be controlled by eccentricity. Despite solar radiation is only weakly influenced by eccentricity a 100 ka variation is also dominating the marine oxygen isotope curve of the Late Pleistocene. The carbonate content of the Heqing sediments is extremely high (between 20-80%) and most likely stems from erosion of limestones in the catchment area. However, the mechanism of carbonate variation is not clear in detail. Probably it is related to climatically driven changes in the catchment area, i.e. conditions of weathering, erosion and transport. Changes of mineral magnetic concentration are likely due to low temperature oxidation (LTO) of magnetite resulting in maghemite formation. With increasing degree of weathering more maghemite is formed, which further converts to hematite under more extreme conditions. The magnetic concentration signal decreases with progressing degree of maghemite formation. Time series of carbonate content and magnetic concentration show a non-linear phase shift varying between in-phase and anticorrelated, which indicates that the control mechanism of the magnetic concentration signal is non-unique. This could explain why the precession cycle is well represented in the carbonate spectrum but insignificant in the spectra of magnetic concentration parameters.

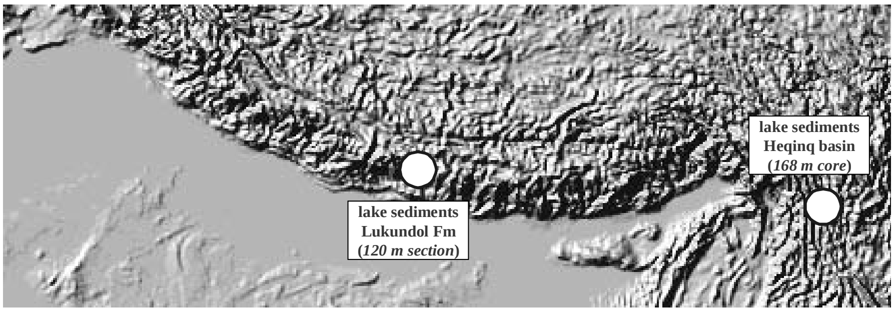

FIGURE 1. Locations of the studied lacustrine sequences in Heqing basin and Kathmandu basin

The pollen record of Heqing shows no cyclic behaviour. However, it indicates the prevalence of strong temperate-humid and cold-dry periods documented by increased *Tsuga* and reduced total tree pollen, respectively. Magnetic mineralogy also provides indications for climatic events. The highest degree of alteration by LTO can be expected during extreme temperate-humid conditions. It results in a tendency towards an increased ratio of ARM/SIRM (due to a decrease of the effective magnetic grain size by maghemite formation) and a lower S-ratio (due to formation of hematite). Temperate-humid phases in the Heqing core (based on *Tsuga* and supported by ARM/SIRM and S-ratio) can be identified at 990-960 ka (strong indication), 800-780 ka (moderate), 690-670 ka (strong), 630-620 ka (moderate), 580-570 (moderate), 530-520 ka (weak), 450-420 (strong), 360-340 (strong), 215-200 (weak) and 65-35 ka (strong). Especially the event at 450-420 ka is interesting as it could provide a high-resolution record of oxygen isotope stage 11. The transition of glacial stage 12 to interglacial stage 11 represents the highest-amplitude deglacial warming within the past 5 Myr, it cannot be solely explained by Milankovitch forcing mechanisms, and is considered to be of particular importance in terms of understanding present global warming (Droxler et al. 1999). In the lower and middle part of the Heqing core the temperate-humid events seem to be related to the global oxygen isotope curve. In contrary, this is not the case in the upper part (above the event at 360-340 ka, which probably represents stage 9). Data show no indication for the last interglacial stage 5. Furthermore, a strong cold-dry period indicated at 160-110 ka and the temperate-humid period at 65-35 ka do not match with the global climate evolution. They probably reflect regionally controlled climatic features. The later phase of the 65-35 temperate-humid period coincides with the formation of many lakes in the Himalayan and Tibetan region at 40-30 ka, which is attributed to neotectonic activity in the Himalaya (Kotlia et al. 2000) and intensification of Indian monsoon with distinctly higher temperatures and higher precipitation on the Tibetan Plateau (Shi et al. 2001). The most dramatic event seen in the sedimentary record of Heqing is the found at about 65 m (420 ka) where several properties (sedimentation rate, grain size, magnetic mineralogy) reflect a distinct transition of environmental conditions in the region. This fits with the observation that in the lower and middle part the pollen record can be related to the global oxgen isotope curve whereas this is not the case in the upper part. It is interesting that this transition occurred during the time after high-amplitude warming of stage 11 followed by a period without significant temperate-humid phases. We may speculate that changes in the realm of the Tibetan Plateau caused or at least influenced the transition at 65 m. It should be also mentioned that there is a slight indication for a further earlier but less clear transition in the sedimentation regime at around 700 ka (change of sedimentation rate and wavelet power spectrum).

A further study section (ca. 120 m) on outcrops of the Lukundol Formation in the southern Kathmandu basin comprises an age of probably 0.7 to 1.8 Ma overlapping in part with the Heqing core. Observed characteristic features are far less significant than for the Heqing core due to non-uniform and discontinuous sedimentation. The topmost 10 m interval shows a clearly different pattern of anisotropy of magnetic susceptibility than in the succession below. This indicates a change in the sedimentation regime contemporaneous with the temperate-humid period at 800-780 ka of the Heqing core. Thick gravel beds were deposited during the preceding ca. 200 kyr and a dry period is evident at these times. Before 1.0 Ma humid climate prevailed with changes of warm and cool conditions.

The Heqing core has revealed interesting new aspects about the palaeoenvironmental evolution in the Indian monsoon region southeast of the Tibetan Plateau (**Figure 2**). It still bears a large potential for further high resolution analyses. On the other hand the results from Kathmandu basin has clearly shown the limited use of outcrop studies. A more suitable database to compare with the Heqing core can be expected from the Japanese drilling project in the center of the Kathmandu basin. Availability of drillhole-based Pleistocene records from these two areas should stimulate our Indian collegues to initiate a lake sediment drilling project in the Karewa basin of Kashmir.

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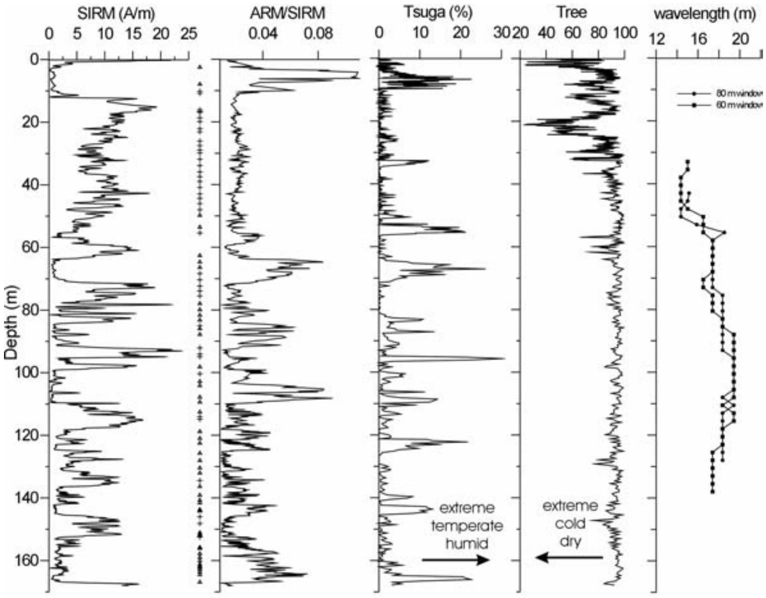

FIGURE 2. Results of Heqing core. Saturation isothermal magnetization (SIRM), ratio of anhysteretic remanent magnetization (ARM) to SIRM, pollen data (*Tsuga* and total tree) and wavelength of main spectral peak of carbonate variation. Crosses and triangles along ARM/SIRM column denotes magnetic mineralogy (crosses: magnetite + maghemite, triangles: maghemite only)