Geographisches Institut der Universität zu Köln

Reconstruction of aeolian and fluvial interaction in the Gobi Desert

D. Hülle[1], A. Hilgers[1], C. Stolz[2], J. Grunert[2]

1 Institute for Geography, University of Cologne   2 Department of Geography, Johannes Gutenberg-University of Mainz

Introduction

Mongolia belongs to one of the driest regions in the world due to its pronounced continentality. Thus, its sparse water resources and fragile ecosystems make it vulnerable to climatic changes in the past and future. Nevertheless, compared with east and south Asia, the knowledge about Pleistocene, Late Glacial and Holocene climatic fluctuations in "central arid Asia" (Chen et al. 2008) is still sparse and inconsistent. In this study, we present new data about past climate and landscape evolution in Mongolia by dating sediments with optically stimulated luminescence. The focus is placed on the chronological relation between dune sand and silty lacustrine and/or fluvial sediments in the two Mongolian dune fields Khongoryn Els and Mongol Els.

Regional Setting

The study areas are situated in the Gobi Desert in southern and western Mongolia.
The first site is located in the dune field Khongoryn Els in a basin (1000-1500 m a.s.l. on average) near the Gobi-Altai Mountains. The 20m high section results from the interaction between the construction of a natural dam by west-east moving sand dunes and frequent fluvial inundation by an episodic river system from the mountain ranges in the South.
The second site is the dune field "Mongol Els" in western Mongolia, where the river Shurgiyn Gol is dammed by seasonally active transversal dunes and thus forming a flood plain.

In the past, the present balance between fluvial and aeolian processes could have been disturbed by both, more arid or more humid climatic conditions. The dunes could have been moving eastward by increasing aridity and dam the rivers resulting in lake formation. With increasing humidity, however, dunes would have been fixed by vegetation and eroded by the rivers (Grunert et al. 2009).

Fig.1: Map of the study area in southern Mongolia.

Methods

By combining OSL age results with sedimentological and geochemical analysis, the sediments can be characterized concerning the timing and type of transport and sedimentation processes, and consequently conclusions on environmental conditions in the past may be drawn.

For the samples from Mongolia, OSL dating is complicated by feldspar-contamination of the quartz samples. As X-ray-diffractometry and mineralogical analysis showed, all samples in this region are affected by this due to their geological provenance (Hülle et al. 2010). Therefore, the feldspar fraction was used for OSL-dating. For this fraction, a pheneomenon called „fading", a luminescence signal loss over geological time scales, is known. Methods to correct for fading were applied (Auclair et al. 2003, Lamothe et al. 2003).

Results

Fig. 2: The dune field Khongoryn Els.

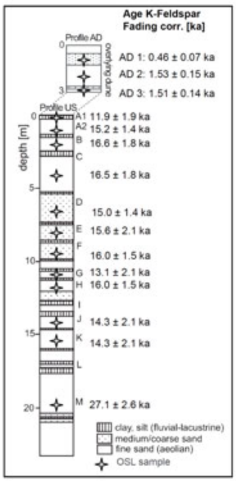

Fig. 3: OSL dating results for coarse-grain potassium-rich feldspars. Note that the dune AD was sampled some hundred meters away from US.

The fading-corrected feldspar results (Fig. 3) imply that the basal aeolian sand sample US-M (20 m depth) was deposited around 27 ka.
Samples between 20 and 15 m depth could not be taken, but it is assumed that this segment represents a time period that includes the LGM.
The ages of the samples US-K to US-A1 (15 to 0.2 m depth) indicate sedimentation of several fluvial-lacustrine and aeolian layers between 18 and 11 ka (the error weighted mean of these ages is 15.1 ± 1.5 ka, n = 11). It can be deduced that massive dune sand accumulation in an overall arid environment repeatedly blocked most likely episodical runoff water from the mountain ranges
Much younger events are represented by a dune (AD) overlying the profile. Here, two samples in a depth of 1.90 and 2.80 m yield ages of 1.5 ± 0.2 ka and thus reflect rapid dune accumulation. The uppermost layer was deposited 0.46 ± 0.07 ka ago.

Fig. 4: Photo of the section US. The episodic river Khongoryn Gol has cut through the dunes, but an active barchan is already migrating into the drainage channel.

Four profiles are investigated across a 700m transect at the dune front (Fig. 5). The sequences were trenched a) in the desiccated flood plain, b) at a semi-active dune at the rim of the dune field, c) in a lake sediment at flood plain level, but inside the dune field and d) at an older lake level 17 metres above the floodplain.

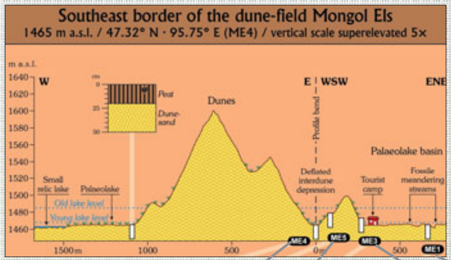

Fig. 5: Transect of the dune field Mongol Els.

Fig.6: The flood plain and the front of the dune field.

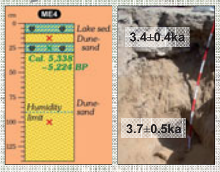

Fig. 7: Section ME4.

Section ME4 shows a discrepancy between the two OSL age results of 3.4 and 3.7 ka and the higher ^{14}C age of an interjacent mollusc. Furthermore, the chronological relation to the sediments at the same altitude in the recent flood plain has to be investigated.

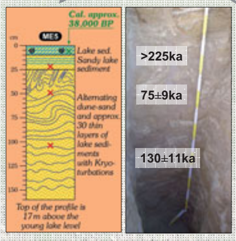

Fig. 8: Section ME5.

The profile **ME5** (17 m above recent flood plain level) represents a huge palaeolake. The lowest sample has a model age of 130 ± 11ka, the sample in 55 cm depth has an age of 75 ± 9ka. Taking the ^{14}C minimum age of the mollusc shells and the position of the profile into account, the approximate ages are considered to be plausible (Lehmkuhl et al. 2001: high lake levels around 75 ka in the Valley of the Gobi Lakes). The uppermost sample, taken from a fluvial-lacustrine layer in a depth of 30 cm, has a surprisingly high model age of >225 ka, which is probably caused by incomplete bleaching during high-energy floods.

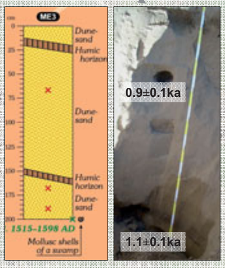

Fig. 9: Section ME3.

Section **ME3** was taken from a small and partly active dune bordering the flood plain. Ages around 1ka correspond to the ages of ME 1 and to the dune overlying the profile US. This corroborates several authors postulating increasing aridity during the last 2ka (e.g. Chen et al. 2008, Walter et al. 2003).

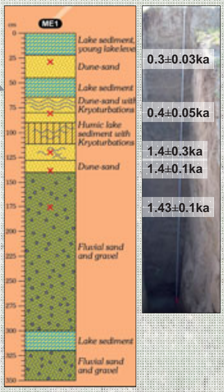

Fig. 10: Section ME1.

Similar to the profile US, the age results of the profile **ME1** represent lake sediments as a paradoxical indicator for more or less dry conditions (but during a different time period): Due to increasing aridity, the dunes formed a barrier for the river Shurgiyn Gol so that a flood plain could develop. This happened at least three times during the last 1.5 ka.

Conclusion

Both areas show a comparable regional setting with dunes serving as a natural dam for frequent fluvial inundation from the mountain ranges nearby. Contrary to the apparent interpretation in the field, the temporal differentiation of the sediments with OSL dating reveals that the stratification of aeolian and fluvial sediments is not caused by long term climatic variations. It rather represents arid conditions with episodical fluvial activity. For the profile US, a strong geomorphic activity lead to the accumulation of 15 m stacked fluvial-lacustrine and aeolian sediments during a rather short time period around 15 ka. The ages in the study area Mongol Els corroborate increasing aridity during the last 2ka. Further studies in this area will be carried out to complement this valuable contribution for the interpretation of geomorphological processes in arid central Asia.

References

Auclair, M., Lamothe, M., Huot, S., 2003. Measurement of anomalous fading for feldspar IRSL using SAR. Radiation Measurements 37, 487-492.
Chen, F., Yu, Z., Yang, M., Ito, E., Wang, S., Madsen, D.B., Huang, Y., Zhao, Y., sato, T., Birks, J. B., Boomer, I., Chen, J., An, C. & Wünnemann, B., 2008. Holocene moisture evolution in arid central Asia and its out-of-phase relationship with Asian monsoon history. Quaternary Science Reviews 27, 351-364.
Grunert, J., Stolz, C., Hempelmann, N., Hilgers, A., Hülle, D., Lehmkuhl, F. Felauer, T., Dasch, D., 2009. The evolution of small lake basins in the Gobi desert in Mongolia. Quaternary Sciences (China), 29.
Huelle, D., Hilgers, A., Radtke, U., Stolz, C., Hempelmann, N., Grunert, J., Felauer, T., Lehmkuhl, F. (accepted). OSL dating of sediments from the Gobi desert, Southern Mongolia. Quaternary Geochronology XX, 1-7.
Lamothe, M., Auclair, M., Hamzaoui, C., Huot, S., 2003. Towards a prediction of long-term anomalous fading of feldspar IRSL. Radiation Measurements 37, 493-498.
Walther, M., Wünnemann, B., Tschimeksaichan, A., 2003. Seen und Paläoseen in der Mongolei und Nordwestchina. Petermanns Geographische Mitteilungen 147/5, 40-47.