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Paleo-Environmental Changes in the Uvs Nuur basin (Northwest-Mongolia)

M. Walther

Abstract

Geomorphological, geochemical, sedimentological and palynological results are presented against the background of palaeoclimatic changes during the past 15 000 years, yielding a chrono-, bio- and morphostratigraphical model of landscape evolution in the region of northern Central Asia. Holocene and Late-Glacial climatic fluctuations there are shown to correlate well with conditions in central Europe. Particular attention is given to the importance of the palaeoclimatic interpretation of lake Basin sediments when reconstructing the palaeoenvironment.

Keywords: Holocene, climate change, lake deposits, Northwest-Mongolia

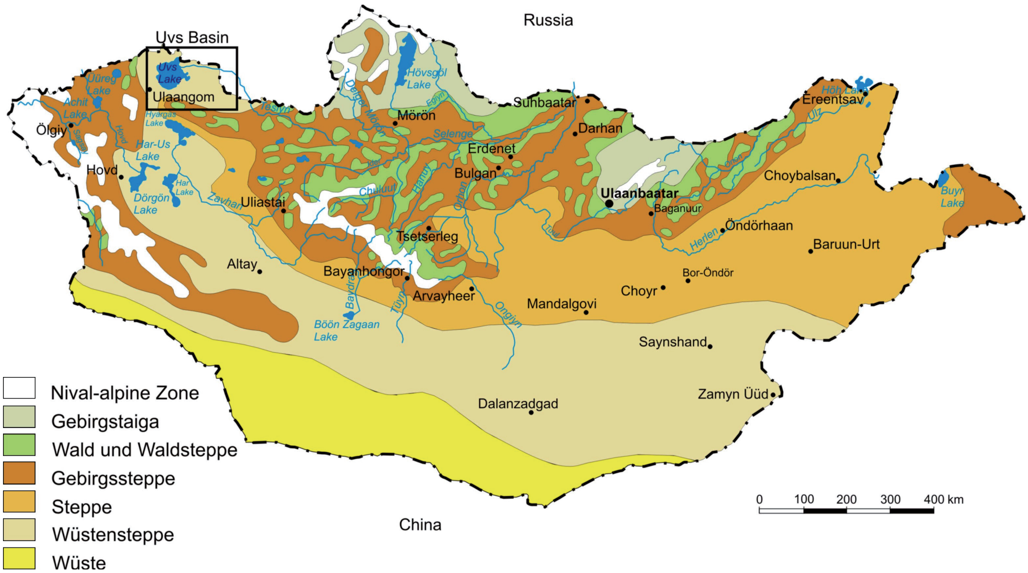

Fig. 1: Planetary and hypsometric change of vegetation and position of the study area.

1. Introduction

In the landscapes of the Earth, various agents transport geogenic and biogenic information over longer or shorter distances, and - under certain conditions - this evidence is preserved. The aim of the limnological studies presented here was to investigate material transport over short and long distances and to analyse the palaeoclimatic information contained in the lake sediments. Because the Uvs Nuur basin is virtually a closed system, an endorheic basic with no outflow, it is particularly appropriate for studying such material balances and climate conditions. However, it should be remembered that the basin probably also underwent deflation and weathering, i.e. information was also destroyed.

2. Palaeoclimate and geomorphology of the lower and middle basin zones of Uvs Nuur basin

Uvs Nuur basin is located in NW Mongolia (see. fig. 1) and represent s the northern most part of Gobi desert. Several drilling cores were taken near the lake and in Bayan Nuur east of Uvs Nuur. In all, four geomorphological units contributed to forming the lake shore and its hinterland: lacustrine sediments and landforms, aeolian forms, pediments and river deltas, alluvial fans and estuaries. Each of these units (see fig. 4) took a different period of time to form. Furthermore, the four may overlap and combine in different ways. For example, lake deposits overlie the alluvial fans and river deltas in the area surrounding Uvs Nuur in the north (WALTHER 1999: 135, fig.2); lake sediments occur on the pediments in the south (WALTHER 1999: 139, fig. 4); lake-induced erosional landforms are visible on the entire eastern side - the side that is strongly exposed to the westerly winds. These include the ingression shore on the western side of the dunefield, immediately to the north, the embayed, sand-bar shoreline of the eastern bay and the *Fabrikbucht,* and the cliffs and abrasion platforms of the eastern shoreline of Uvs Nuur (WALTHER 1999: 141, fig. 6).

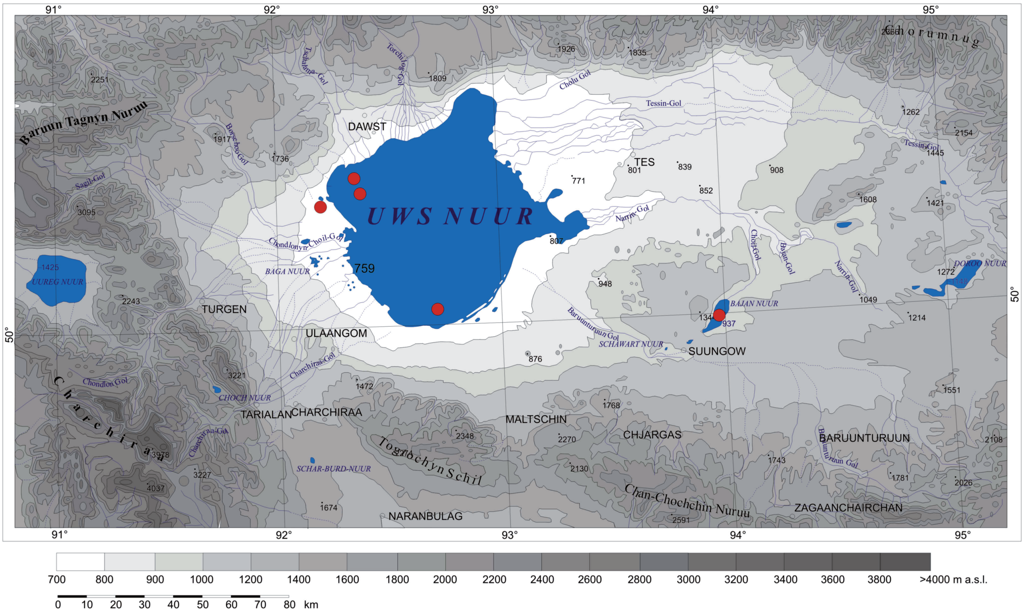

Fig. 2: Location of the drilling sites inside the Uvs Nuur basin.

2.1. Lacustrine sediments and landforms:

- recent and fossil sand bars
- stretches of dead/fossil cliff
- carbonate limnopsammites

In all geological eras the formation of sand bars in open and closed systems in direct proximity to the lake shores has supplied clear evidence of lake water levels. Often clastic, minerogenic bars, generated by drifting at the lake shore, interlock with organogenic deposits in the lagoon lakes of the landward side. Both formation processes occur synchronously and are a measure of the rise or fall of lake levels. At the present-day lake level of 759 m asl. there is now no active cliff along the entire shoreline of Uvs Nuur, apart from small sand cliffs forming at the start of the dune belt on the eastern side of Uvs Nuur. However, if the water level were to rise by 5 to 8 m, pediments on the southern side would be undercut and the fossil cliff on the eastern side would be reactivated. If the present strong trend towards higher lake levels continues, in 50 to 80 years time considerable flooding is likely to occur, even up to the high levels of the middle and late Holocene.

Carbonate limnopsammites were found only rarely in the southern shoreline area, on the pediment and in the dunes of the eastern bay (see fig. 3). Authigenic carbonate lake sands are visible up to an elevation of 30 to 35 m above the present lake level; they were radiocarbon-dated to the Late Glacial. On this basis a maximum highstand of 800 m asl. was calculated. In the entire basin, biogenic carbonate is the only source of carbonate enrichment in the dune sands and soil formations. On the eastern shore of Uvs Nuur on the western anterior side of the dunefield, a higher lake level occurring synchronously with a higher water table in direct proximity to the lake, was shown to lead to strong summer biomass production (algae), to colonization by submerged macrophytes and also emersed species, and to the presence of gastropods and molluscs in the interdune valleys as a result of increased moisture or even total flooding, leading to lake formation. The Late-Glacial lake carbonates of the eastern bay (WALTHER 1999: 141, fig. 6) still contain hollow stem fragments of *Phragmites*, which in conjunction with the molluscs signal a littoral palaeoenvironment.

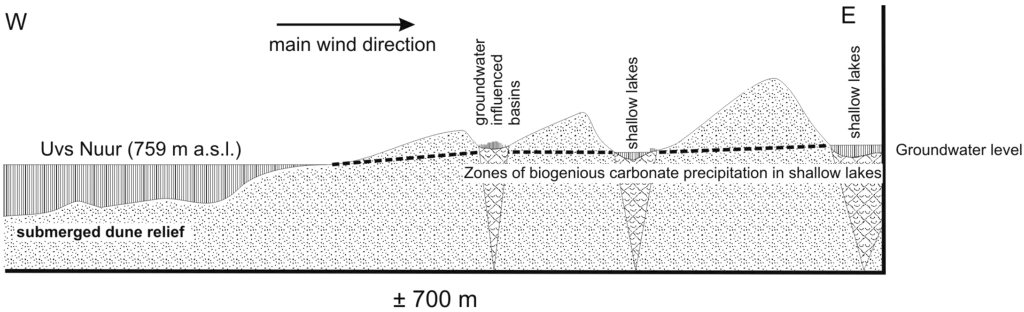

Fig. 3: Cross-section of the western side of the dune field on the eastern shore of Uvs Nuur.

2.2. Aeolian dynamics (dunes and loesses)

The dunes in the Uvs Nuur basin were the subject of several detailed studies by GRUNERT (2000) on their distribution, genesis and chronostratigraphy. In palaeoclimatic terms they belong to phases of the dry and cold "kataglacial" period *sensu* HÖVERMANN & SÜSSENBERGER (1986) and WALTHER (1999). Sparse or no vegetation and exposed sandy surfaces supplying material are the palaeoecological conditions required for dune formation. At different locations in the dunefields GRUNERT et al. (1999) distinguished three generations of dune development: a) active dunes (barchans and barchanoid landforms) with little or no plant cover and no soil formation; b) partially active dunes with a plant cover of up to 50 %; these were parabolic in shape and in places incorporated remains of ancient dunes, and c) inactive dunes with fully developed soils (kastanozems) and a plant cover in excess of 70 %. Hence the dunes are major palaeoclimatic indicators, especially in view of the fact that they interlock with lake sediments and with fossil and relict soils. The TL dates reported by GRUNERT et al. (1999) undoubtedly support the conclusion that the youngest phase of distinct dune migration probably occurred during the Younger Dryas. More recent OSL dates by GRUNERT (pers. comm. and this volume) clearly confirm this phase of dune formation. However, further OSL dates from the Bayan Nuur area show that the main phase of dune formation was considerably older than the Würm, probably middle or even early Pleistocene. Accordingly, it is beyond doubt that at Bayan Nuur an "old" dune relief was flooded by higher lake levels in the same way as is happening today on the eastern shore of Uvs Nuur (fig. 3). This provides confirmation of the evidence reported by WALTHER (1999), NAUMANN (1999), NAUMANN & WALTHER (2000) and GRUNERT et al. (2000) that lake sediments had been deposited in an older dune relief.

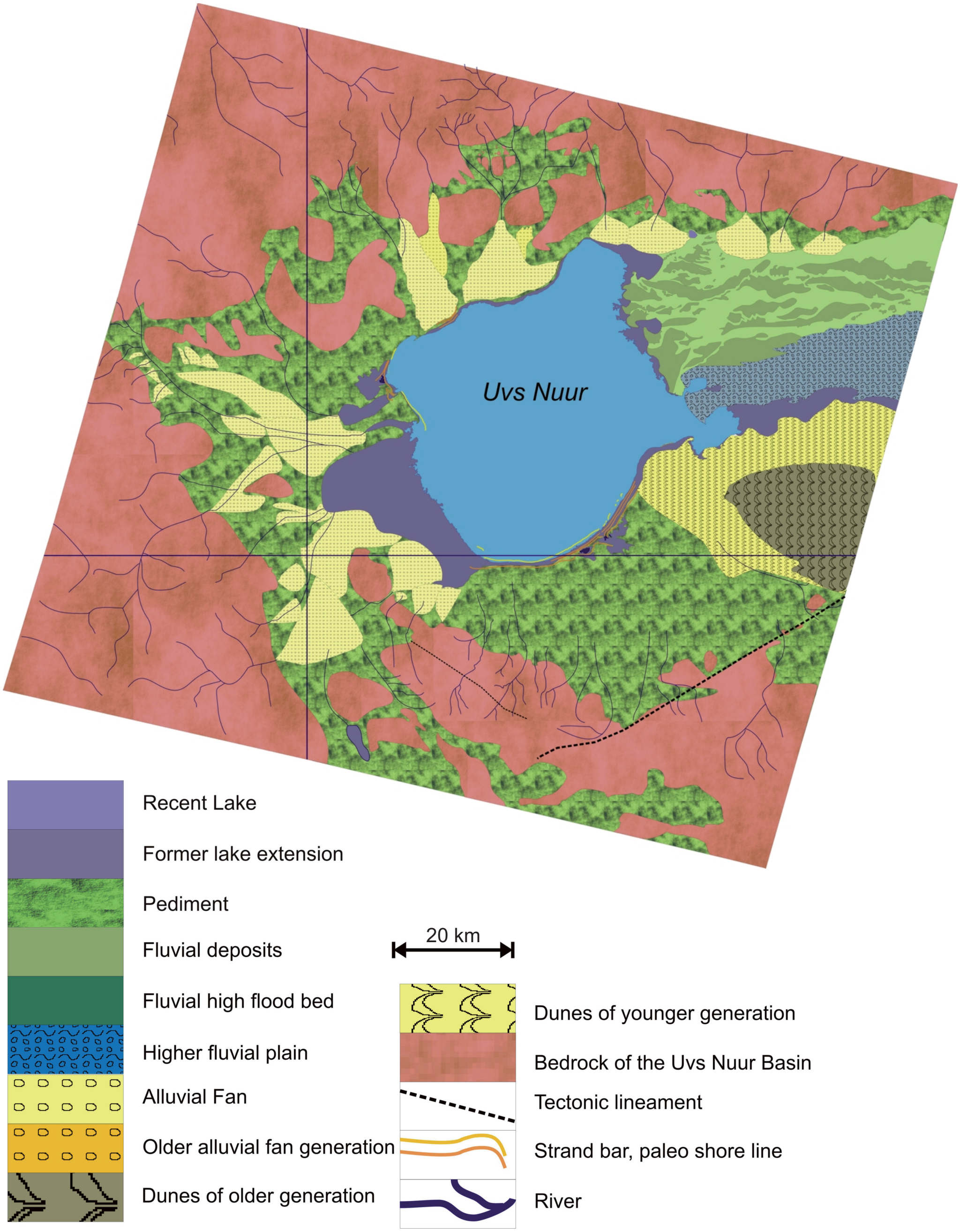

Fig. 4: Recent landscape units of the Uvs Nuur based on satellite image.

Older, very probably middle or even early Pleistocene loesses that may be stratified by fossil soils have been deposited on top of blue-grey limnopelitic sediments in the cliff profile on the eastern side of Uvs Nuur (WALTHER 1999: 141, fig. 6). However, more recent episodes of sand transport or reactivation also occurred throughout the entire Holocene.

2.3. Pediments

Pediments in the sense of pediments with alluvial covers belong to the cold semihumid till semi-arid phases of the last ice age. Older landforms are also known, but the pediments directly adjacent to the present-day Uvs Nuur are relatively young (Würm age). They have been described, partly mapped, and dated by WALTHER & NAUMANN (1997), WALTHER (1998), LEHMKUHL (1999, 2000) and GRUNERT et al. (2000). Periglacial features – also pointing to permafrost – clearly show that the pediments had built up according to an episodic to rhythmic pattern, the inactive intervals being characterized by cold-dry periods with little accumulation, sufficient residual soil moisture and increased cryogenic dynamics. The extensive pediments to the south and west of Uvs Nuur received their modern shape during the Würm stage, yet they represent a polygenetic chronosequence. Older and generally higher-lying units (P2 and P3 pediments - described by WALTHER & NAUMANN 1997) - occur here and there, sometimes over larger continuous areas. (see also GRUNERT et al. 2000).

To date, field studies indicate that the Late-Glacial (late Würm) highstand at most covered the bottom quarter of the Uvs Nuur basin to about 30 m above the present-day water level of Uvs Nuur. As WALTHER (1998: 215) has already shown for other, more southerly parts of Mongolia (valley of the Gobi Lakes), it undercut the youngest Würm pediment or cut cliff edges into it.

2.4. River estuaries and inland deltas

Long stretches of the littoral zone consist in the fluviatile shore configuration of the deltas of Tessin Gol in the east and northeast, and of tributaries from the Tannu Ola area in the north and from the Turgen Kharkhiraa catchment in the northwest. Near the shore of the northwest bay Holocene sand bars have accumulated up to 10 m above the present lake level and fossil cliff stretches with a height of up to 10 m have formed in unconsolidated sediment (WALTHER 1999: 135, fig. 2). From this, it is concluded that the lake level was 10 m higher after the delta or alluvial fan had formed. Therefore the final major phase of delta deposition in the Tessin Gol, Tannu Ola and Turgen Kharkhiraa catchments probably occurred during the transitional phases between the Last Glacial Maximum and the Late Glacial or early Holocene. However, their formation is assumed to have been polygenetic with later modifications, similar to the evolution of the pediments.

3. Palaeoclimate and sediment records (see fig. 5 and 6)

3.1. Lacustrine sediments (limnocalcites, limnohumites)

During our field studies, lacustrine sediments were found above the present water level in the eastern bay and to the south of Uvs Nuur. Their elevation varies, but does not exceed 35 m above the present lake level in the immediate Uvs Nuur area, whereas such deposits were found up to 80 m above the modern lake level in the Bayan Nuur area (Chusutuin Gol being Bayan Nuur's main tributary from the dunefield).

The highest sedimentation rate is 3,75 mm/year during Lateglacial times due to high erosion amounts in the mountains and on the pediments (see. fig. 6).

The following finds of large mammals also belong in this context: horse (carpus, *Metacarpus* proximal end, *Metatarsus* distal end, *Calcaneus*), camel (*Metapodium* distal end, humerus fragment, vertebrate fragment, pelvis fragment), Bos spec. (*Phalanx* 1 proximal end, phalanx 3 fragments, tooth fragment), *Palaeoloxodonta* spec. (fragments of a tusk), lion (tarsal bone) and hyaena (tarsal bone)[1]. The sediments comprise carbonate sands (psammitic limnocalcites), peats (the result of Holocene organic sedimentation in the Bayan Nuur area) and carbonatized lake sands (limnopsammites). The sediment series below the present water levels of Uvs Nuur and Bayan Nuur were sampled in 10 piston corer drilling operations (4 at Uvs Nuur, 2 at Baga Nuur and 4 at Bayan Nuur). The series comprises limnocalcites (calcareous muds), limnopelites (clay muds), limnopsammites (lake sand) and limnohumites (fine detrital muds, peat muds)

[1] I wish to thank Prof. van den DRIESCH for identifying these bones during and after a joint expedition in 1997.

(NAUMANN 1999, NAUMANN & WALTHER 2000, WALTHER 1999). Studies on the evolution and occurrence of organic content (ignition loss) reveal clear differences in the individual curves of the soil profiles of Baga Nuur, Uvs Nuur and Bayan Nuur (WALTHER 1999: 137, fig. 3).

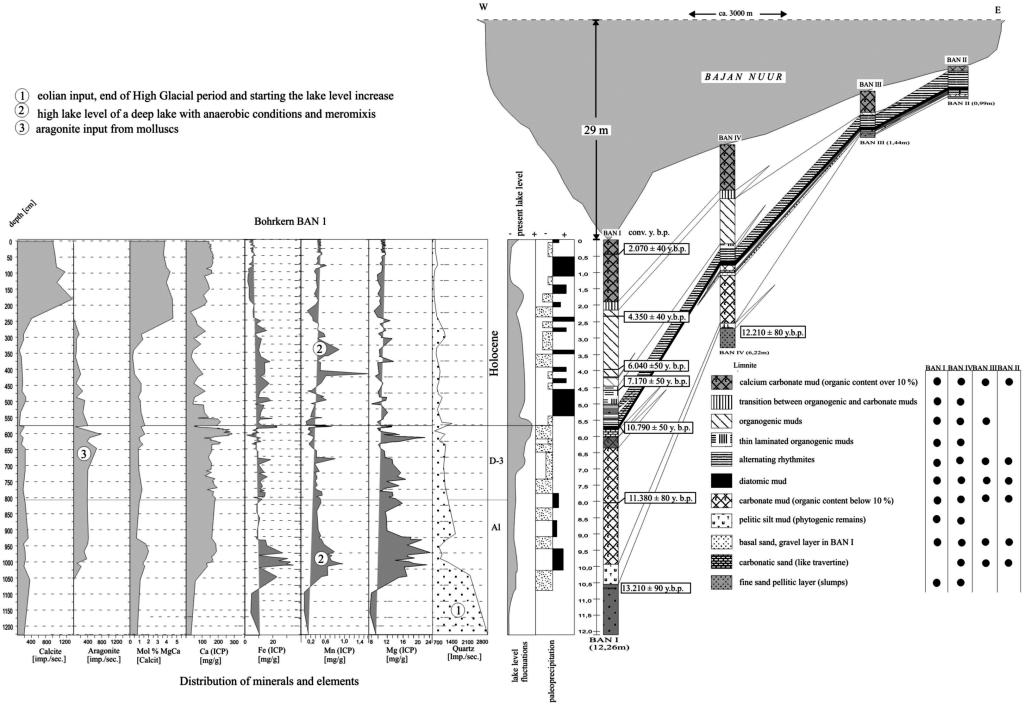

Fig. 5: Crossection of Bajan Nuur with four cores of the central Basin.

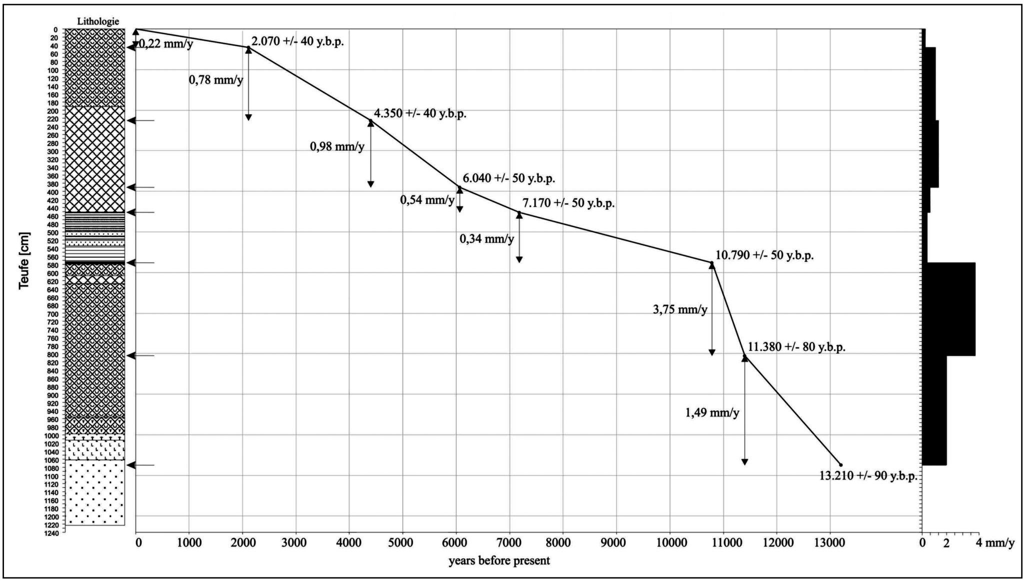

Fig. 6: Sedimentation rates of the drilling core Bayan Nuur 1.

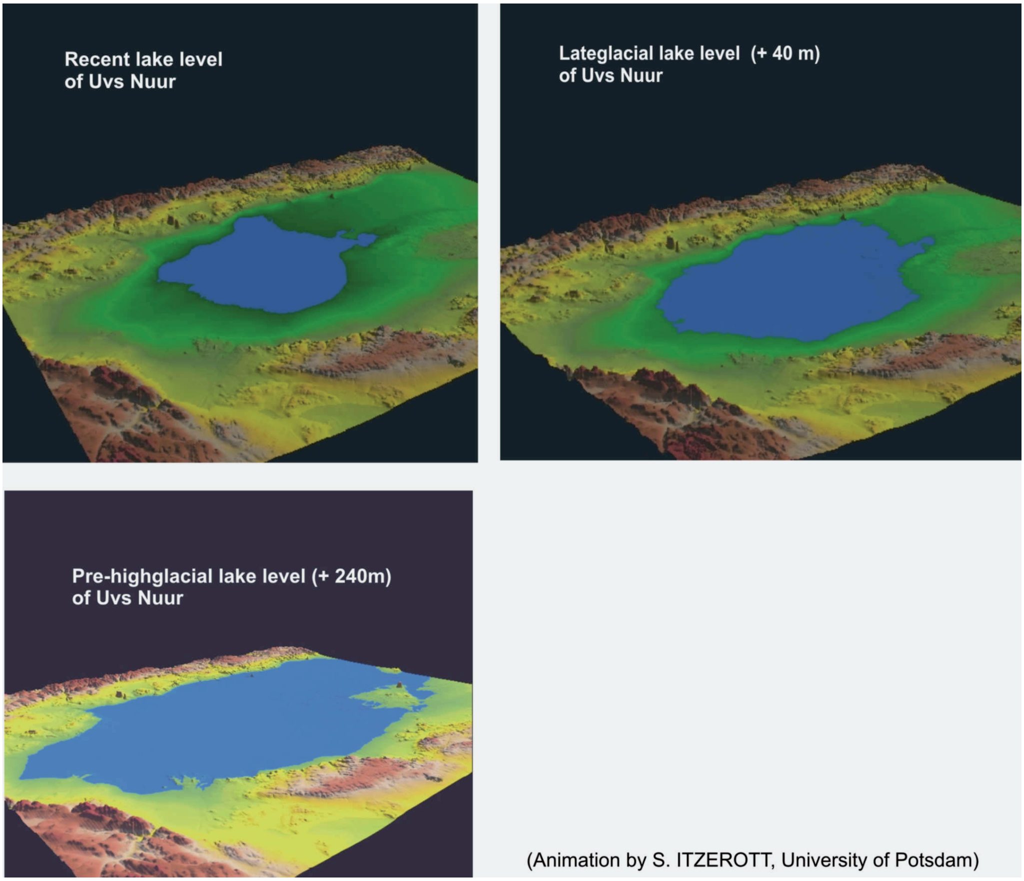

Fig. 7: DEM of Uvs Nuur basin based of geo-morphological data.

3.2. Geochemical records (fig. 5)

The curves shown in fig. 5 depict the net intensities obtained from dried and ground extracts of each total sample related to the respective main reflex (calcite, aragonite, quartz). The other curves give the element distribution (selection) in the core, measured in a 10 % HCl solution in an ICP mass spectrometer. The sodium and potassium contents were also measured, but are not given here; they are in the normal distribution range without any significant sections of concentration or depletion.

The aragonite, manganese and iron distributions in the lower half of the figure 5 show the lake must have developed and deepened very rapidly. The iron and manganese values indicate that anaerobic conditions prevailed at the lake bottom and that the lake was highly meromictic. This is supported by the presence of ostracods in this section and by the overall geomorphological setting. Geomorphological mapping revealed that at the NE-facing outlet of the Bayan Nuur lake basin (Choid Gol) the dune field formed a barrier blocking outflow to the northeast. This damming must have led to a rapid rise in lake level due to heavy inflow from the melting glaciers. Sand mobility was apparently even stronger than the rise in lake level (quartz curve in fig. 5), which was counterbalanced only towards the end of the Late Glacial, at the onset of the Pre-Boreal, when plant cover increasingly stabilized the dunes and slowed down sand transport.

Owing to continued inflow into the lake basin via a palaeo-drainage system of Baruunturuun Gol, however, the lake level continued to rise until (aided by leaching effects) the dune barrier was breached and the lake level fell rapidly.

4. Palaeoclimate and Vegetation Record

The pollen profile of the Bajan Nuur 1 core was studied in high-resolution time slices and showed a highly differentiated vegetation record over the past 15 000 years (KRENGEL 2000). A total of 9 local pollen zones were classified and assigned to a chronostratigraphic frame corroborated by 7 radiocarbon dates. They were also matched with the biostratigraphy of central Europe, showing that these radiocarbon dates are some 600 years too old for the time span of the Late Glacial and the Late Glacial/ Holocene boundary owing to the reservoir effect.

The Late-Glacial pollen zones BN 1-4 are characterized by a shrub-rich (*Salix*) formation (BN 1) also with slightly higher percentages of *Alnus* at the onset of the Late Glacial. The proportion of arboreal pollen (AP) drops only insignificantly in pollen zone BN 2. *Betula* attains values of 5 – 6 %. The following pollen zone BN 3 shows a clear increase of *Pinus*, pointing to warmer conditions. In pollen zone BN 4 tree and shrub pollen drop sharply. *Ephedra* reaches fairly high values (7-18 %). This pollen zone corresponds to the Younger Dryas.

In the following pollen zones BN 5-9 AP values no longer fall below Late-Glacial levels. Pollen zone BN 5 displays a distinct rise with a subsequent peak for *Betula* and a second section with a *Pinus* peak. This may represent the Preboreal and Boreal in chronostratigraphic terms. The highest AP percentages are found in pollen zone 6, where the wettest conditions of the Holocene are to be expected. The proportion of AP decreases again distinctly in pollen zone 7, although the values remain constant and the only sign of decreasing precipitation is the increase in steppe elements. The relative increase in steppe and desert elements and herbs suggest that in the upper pollen zones 8 and 9 prevailing palaeoecological conditions were dry and already anthropogenically influenced. The almost continuous occurrence of *Plantago* may point in this direction.

4.1. Evolution of steppe and desert formation as an indicator of Holocene dry phases (fig. 8 and 9)

In subdividing the pollen profile, the steppe elements *Artemisia*, Chenopodiaceae and - to a lesser degree - Poaceae and the *Ephedra dist*. type serve to designate arid to semi-arid phases of climate. Considering the bioclimatic index according to EL-MOSLIMANY (1990) as described by KRENGEL (2000), 10 sections of varying duration and intensity can be distinguished during the Holocene, on the basis of the *Artemisia*/Chenopodiaceae ratio; these palaeoclimatic phases count as relatively dry. Subsequently, dry phases occur at the transition between Pleistocene and Holocene (1st Holocene phase of low intensity), and then with short dry fluctuations of lesser magnitude (2nd and 3rd Holocene phases) between 6000[2] and 5000 conv. years BP. The first "great" dry phase occurred between 5000 and 4500 conv. years BP (4th Holocene phase), closely followed by two further dry phases (5th and 6th phases of medium intensity) lasting up to about 3700 conv. years BP, which should be counted as belonging to the Sub-Boreal or even the early Sub-Atlantic. The most distinct Holocene dry phase (7th phase) follows in the early Sub-Atlantic shortly after 3700 conv. years BP, and was immediately followed by a further dry phase (8th phase of medium intensity). Much more humid conditions presumably prevailed again after about 3000 conv. years BP, although weaker dry phases occurred here too (9th and 10th phases of lower intensity).

[2] All the following conventional ages are extrapolated dates on the basis of conventional radiocarbon dates corrected by about 600 years to allow for the hardwater effect.

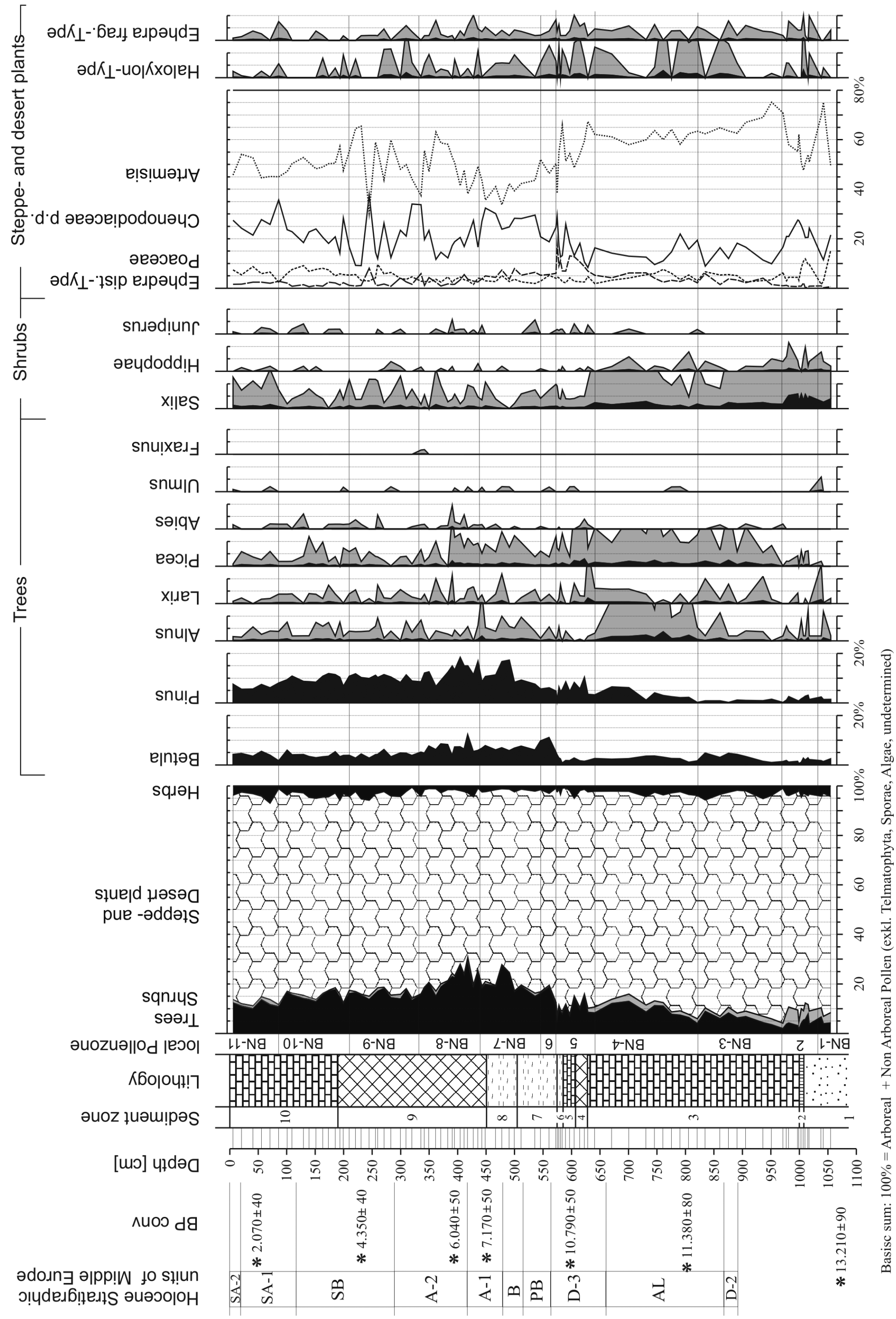

Fig. 8: Tree-, shrub-, steppe- and desert-pollen of drilling core Bayan Nuur 1.

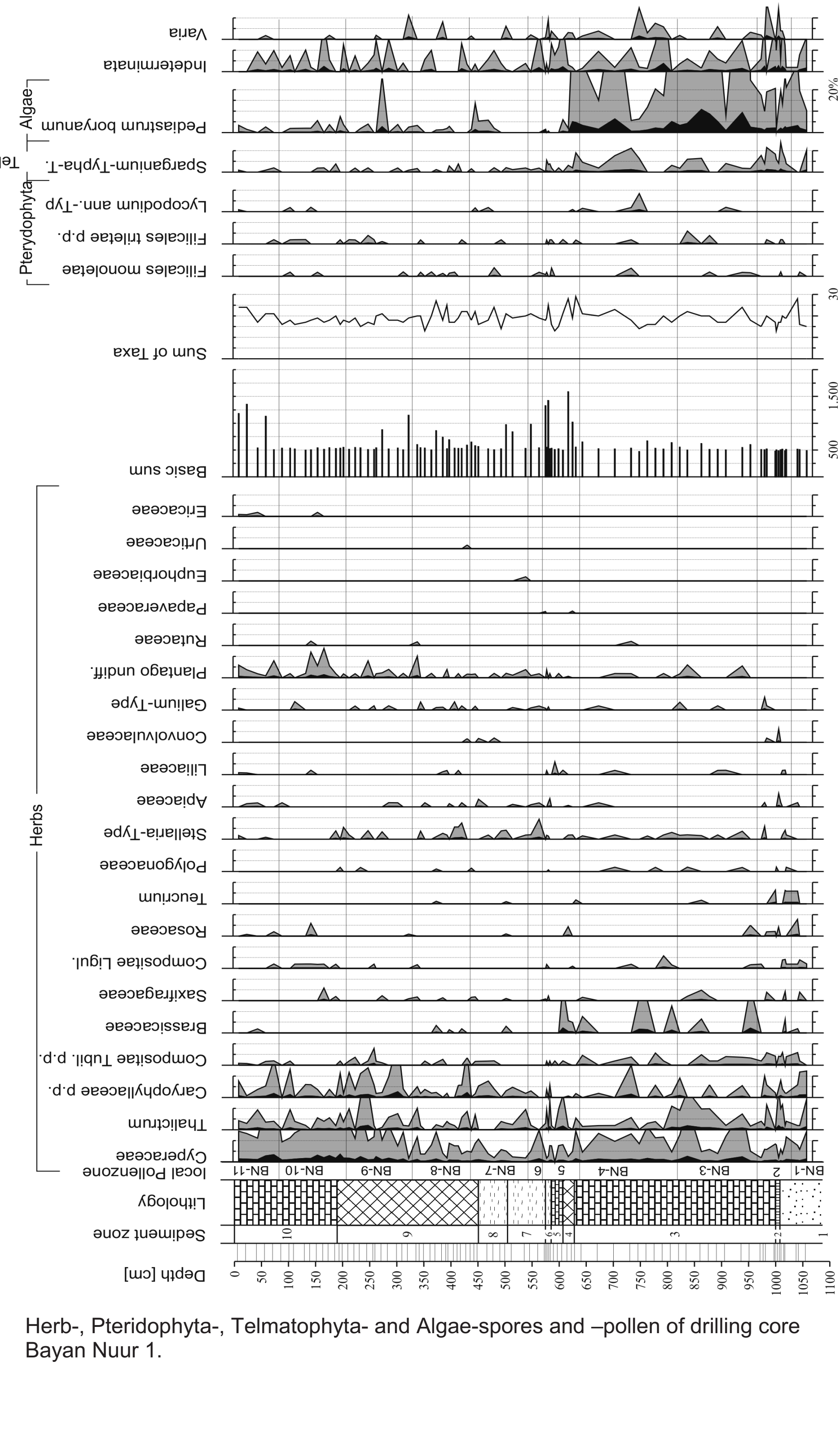

Fig. 9: Herb-, Pteridophyta-, Telmatophyta- and Algae-spores and –pollen of drilling core Bayan Nuur 1.

4.2. Evolution of woodland formation indicating Holocene and Late Glacial humid phases (see fig. 8 and 9)

Arboreal pollen occurs throughout the entire profile but the distribution patterns of the different taxa vary. Groundwater-dependent species such as *Alnus* and *Salix* illustrate the rapid lake-level rise during the Late Glacial. The distinct increase of *Betula* marks the boundary between the Holocene and Pleistocene, whereas *Pinus* has relatively high percentages in the Late Glacial already but reaches its peak at the Preboreal/Boreal boundary. However, the last two species did not necessarily grow near Bayan Nuur. It is more likely that these taxa came from the slopes of Khan Khökhiyn and Züün Tagnyn. Arboreal pollen is generally strongly underrepresented, which is probably largely due to the fact that steppe elements are strong pollen producers and trees mainly grew on sites well supplied with groundwater, near lakes and rivers, during the most favourable climatic periods of the Holocene and Late Glacial. The AP curve displays a double peak during the Atlantic period. Furthermore, lower percentages are recognizable in a Late-Glacial section that may correspond to the Alleröd interstadial alone or perhaps to an older temporarily warmer episode. The continuous curve of *Larix* - a species that may have stood near the site or whose pollen may also have been transported by streams - marks the warmer Late Glacial section of pollen zone BN 3. In the AP curve, the Younger Dryas is also visible as a section with a clear decrease in arboreal pollen.

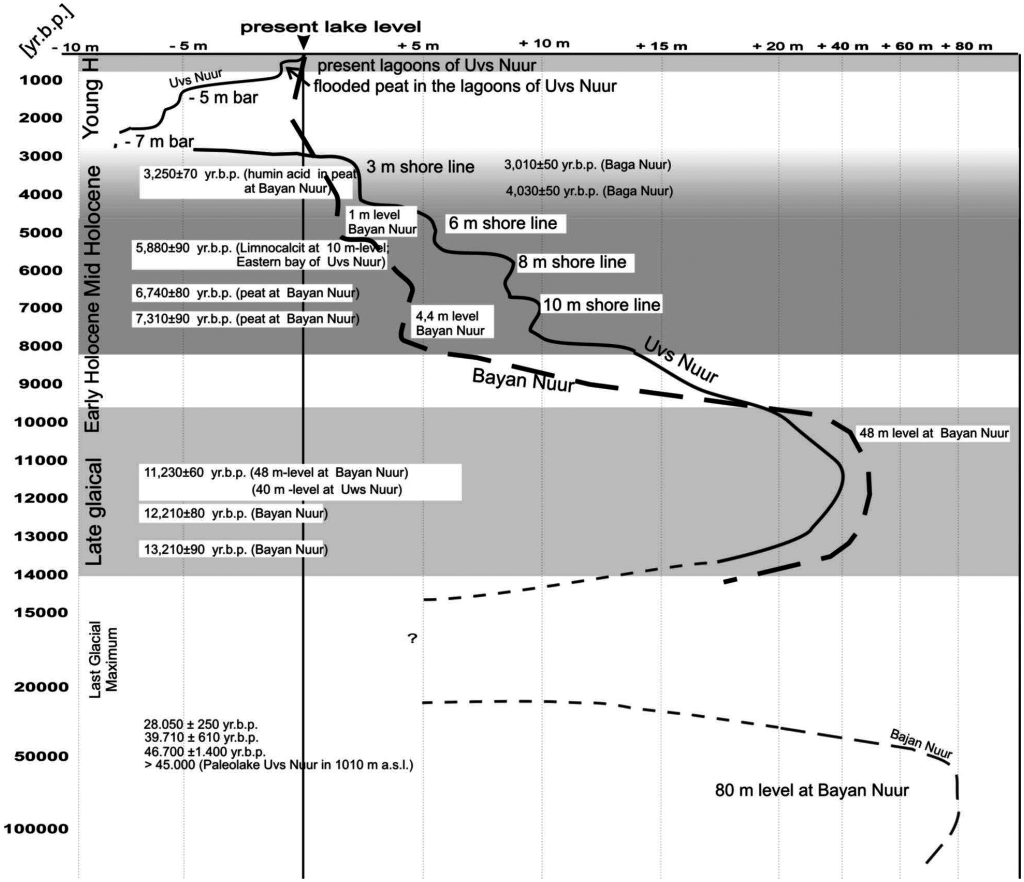

Fig. 10: Lake level fluctuations of Uvs Nuur and Bayan Nuur 1 based on geomorphological data.

5. Palaeoclimate Changes

The studies in the Uvs Nuur basin have shown that a distinction should be made between lake-level fluctuations due to climatic change and those induced by orographic factors (fig. 10). Both the vegetation record and sedimentological and geomorphological finds clearly show that Late-Glacial highstands in the Uvs Nuur basin are mainly due to the rapid melting of the valley glaciers of the surrounding mountains and to local effects such as the blockage of rivers by dunes or even tectonic faulting. In the lowest parts of the basin it even appears that a dry phase of higher magnitude occurred during the Younger Dryas, although there is evidence that lake levels were then substantially higher than they are today (by as much as 30 m in Uvs Nuur and 48 m Bayan Nuur). This means that the lake level curve is not synchronous with the aridity/humidity curve but can even develop conversely (fig. 5). A more humid Late-Glacial phase may be recognized between 13 000 conv. years BP and 10 700 conv. years BP, which, however, was interrupted by two first-order dry phases. A relatively lengthy humid phase, which was probably also milder, lasted from 9000 conv. years BP to 5440 conv. years BP From about 5000 conv. years BP dry and humid phases alternated rapidly until about 2800 years BP Only between about 2800 and 1400 conv. years BP did conditions become more humid. Pollen analysis and geochemical analyses of sediment profiles provide confirmation of dry phases of varying length and magnitude characterized by stagnating or falling lake levels during the later Holocene (from the Sub-Boreal onwards and then in the early Sub-Atlantic).

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