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The Mineralogy and Geochemistry of Core Sediments from Lake Hovsgol, Monolia and Its Paleoclimatic Implications

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1. Introduction

The Lake Hovsgol in Northern Mongolia is one of the biggest fresh water lake occupying the depression of half graben morphology in southern continuation Baikal Rift system. It is an important site for paleoclimatic studies because of its continental-interior location far from any direct influence from oceans and its continuous stratigrapfic record. The thickness of lake sediments is about 250-300 m in accordance with seismic data and consequently the sediment can be expected to record of paleoenvironmental changes in the Asian continent for the last 3-4 Myr (Fedotov et al., 2004).

This paper makes an attempt to reconstruct the paleoclimate and paleoenvironmental changes in Late Pleistocene and Holocene based on the lithological, mineralogical and geochemical data on three gravity cores (Hub02-1, Hub02-5 and Hub02-6), obtained from the southern and southeastern basins of the Lake Hovsgol during the Mongolian-Russian joint expedition in summer of 2002.

2. Materials and methods

The southernmost core Hub02-1 with length of 173.5 cm was taken at coordinates of 50°41'N, 100°21'E, from water depth of 241m. The cores Hub02-5 (133.5 cm) and Hub02-6 (62.5 cm) were collected at coordinates of 50°48'N, 100°21'E and 50°59'N, 100°37'E respectively. Water depth is 222 m and 114 m correspondingly. The cores were cut lengthwise and after lithological description and some physical properties measurements have been sub-sampled in 1-cm intervals. The sub-samples of all cores were subjected to smear slide observation in order to identify details of lithological composition of sediments. The mineralogical and geochemical analyses of all samples were made at the Korean Polar Research Institute.

Total inorganic carbon (TIC) contents were analyzed using UIC CO_2 Coulometer. Total carbon (TC), nitrogen (TN) and sulfur (TS) were analyzed using Elemental Analyzer (FlashEA 1112). Total organic carbon (TOC) contents were determined by obtaining the difference between TC and TIC. Clay and non clay minerals were identified by X-ray diffraction and semi-quantified using the method of Biscaye (1965). Additionally, the illite 5Å/10Å peak-height ratio and 10Å peak width at half height were analyzed to elucidate the weathering processes of the catchments area.

3. Chronology

The cores samples not subjected to age dating, specially. In order to tie the lithologic, physicial, mineralogical and chemical variations to the age, we used lithologic correlation to the cores, which have AMS ^{14}C data (Tomurhuu et al., 2003; Kashiwaya et al., 2003; Fedotov et al., 2004, Prokopenko et al., 2005). According to the correlation of the previously studied cores with AMS ^{14}C data, the cores (Hub02-1, Hub02-6) demonstrate a lake history for more than 20 ka years (diatomaceous silt for Holocene, silty clay for Late Pleistocene). Exception is Hub02-5 core that reveals only one lithologic type which consists of diatomaceous silt of the Holocene.

4. Results and Discussion

A. Lithology of sediments and sedimentation rates

According to the observation of smear slide, Hub02-1 and Hub02-6 cores consist of two main lithological units: dense greenish-gray to dark-greenish-gray silty clay in the lower part (unit 'B'); massive yellowish brown to grayish olive diatomaceous clayey silt in the upper part (unit 'A'). Transition zone between unit A and unit B is composed of fine laminated greenish gray silty clay, and has been distinguished between units A and B. Sediment of core Hub02-5 consists of only unit A (Fig 1.). The upper 8-12 cm of the unit A consists of oxidized sediments, indicating oligotrophic character of the Lake Hővsgől during deposition of the sedimentary unit. Thickness of unit A varies (20.5-133.5 cm) in different cores.

The liner sedimentation rates in unit A are different in cores varying from 2 cm/kyr to 12.7 cm/kyr. Consequently, the resolutions of the sub-samples in the cores are changeable from 100 (Hub02-5) to 500 (Hub02-6) years.

Lithology of unit B is different from that of previously studied cores taken from deep water central part of the lake in terms of grain size distribution (Tomurhuu et al., 2003a, 2003b; Fedotov et al., 2004). As units B contains more coarse sediments with land plant remains, these parts of the cores in present study have been considered to be accumulated in peripheral area of the lake. These circumstances also clearly support our previously published data of low stand of Lake Hővsgől during the Late Pleistocene (Fedotov at al., 2004).

The concentration of the planktonic diatom frustules (*Cyclotella ocellata, Stephanodiscus aff alpinus* and *Cyclotella bodanica)* is high (10-85%) for unit A and is absent for unit B. In contrast, unit B contains numerous shells of ostracods.

B. Magnetic susceptibility (MS)

Vertical distribution of magnetic susceptibility of the cores is close to the previous studied cores of HB105-2 (Tomurhuu et al., 2003). Magnetic susceptibility varies 5-15 cgu for diatomaceous clayey silt and 20-75 cgu for silty clay. High values of magnetic susceptibility (to 75-240 cgu) were determined in the lower part of the core Hub02-6 for sandy clayey silt.

C. Mineralogy

The clay fraction of sediments of Lake Hovsgol consists of clay minerals such as illite, chlorite, kaolinite and illite-smectite and non clay minerals such as quartz, feldspar, amphibole, opal and calcite (Fig 1). For unit A, the mean mineral composition comprises illite 15-20%, chlorite 15-20%, kaolinite 5-8%, illite-smectite 8-12%, quartz 10-15%, feldspar 25-30%, and opal 8-16%. The mineral composition of units A-B and B is quite similar to the upper diatom-rich intervals, excepting calcite. But unit B is characterized by a higher content of illite, chlorite (35%) and lower content of opal (4-5%), quartz, feldspar (5% and 10-15% respectively). Calcite is much greater in unit A-B (mean to 40-45%) than unit B. Amphibole though ubiquitous is only present in trace quantities. The semiquantitative estimate of calcite from X-ray pattern is relatively close to the geochemical measurements.

In cores, the illite crystallinity is below $0.4^{o}2\theta$, that suggests prevalence of the physical weathering around the lake Hővsgől. The illite 5Å/10Å peak ratio is more than 0.5 for unit A of cores Hub02-1 and Hub02-5, indicating presence of Al-rich illites derived from moderate chemical weathering of granite rocks. Values of the ratio are below 0.5 for unit B and for core Hub02-6, that is characteristics of Fe-Mg-rich illites derived from physical weathering of metamorphic parent rocks.

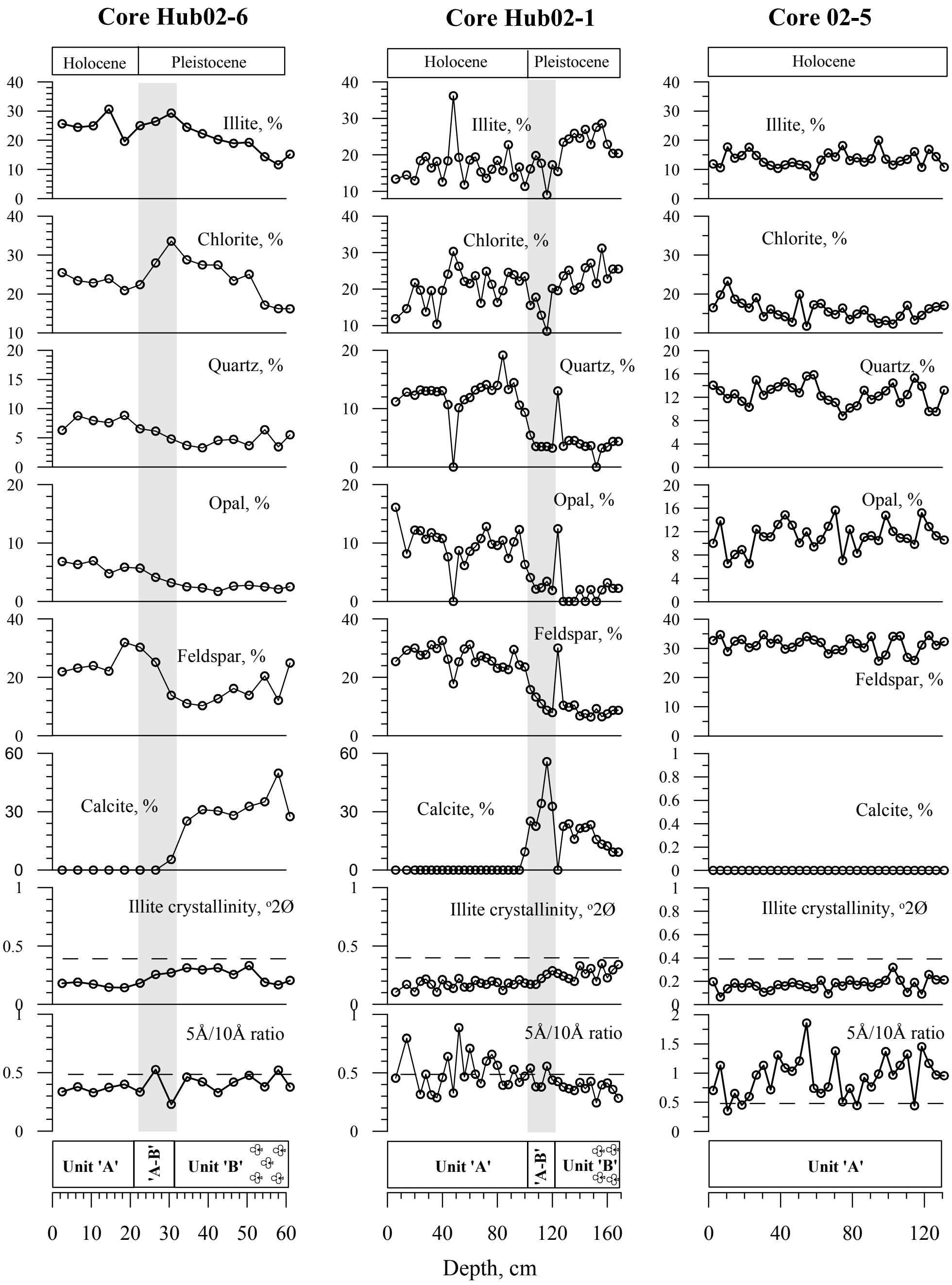

Fig. 1. Lithology and down-core variations of the relative abundances (%) of main minerals in cores of Hub02-1, Hub02-5, Hub02-6.

D. Geochemistry

TOC and TN concentration in the Hub02-1, Hub02-6 cores ranges from 1% to 12% and from 0.1% to 0.8%, respectively. High TOC and TN values (averages are 4.2-9.3% and 0.4-0.87% correspondingly) were recorded for unit A, low values of TOC (1%) and TN (0.1%) for unit B (Fig. 2). Thus, the rapid increase in TOC and TN contents from unit B to unit A in cores of Hub02-1 and Hub02-6 (Fig. 2) reflect significant environmental changes at the interval. Although organic carbon and nitrogen depletion in sediments may be result of either low productivity of the surface water or greater dilution by high terrigenous input, the low TOC, TN contents in unit B in investigating cores have been attributed to the lower natural productivity of the water as lithological correlation of these cores to the dated ones did not revealed remarkable differences in sedimentation rates between units A and B.

The down core variation of TOC and TN contents in Hub02-5 core is different from two other cores in this study (Fig 2). Consequently, we do not observe tendency revealed in previous cores. Instead of that we observe quite amplified changes in many characteristics, namely in TOC, TN and TS, in lower part of the core, suggesting existence of at least two different sedimentary environments during the Holocene. In upper part (65-0 cm) of the core, the TOC and TN contents are relatively unique with a small fluctuation and varied within 6%-7% and 0.6-8% respectively. In contrast, the TOC and TN contents fluctuate largely (4-8% and 0.5-0.9%) in the lower part (133-65cm), possibly reflecting short-term environmental changes associated with high accumulation rate (Fig. 2).

The average TOC/TN ratios of the unit A of all cores are 9.31; 9.43; 9.05 respectively, indicating prevalence contribution of autochthonous sources of organic matter. On the other hand, high TOC/TN ratios of 24.3 and 17.6 in silty clay indicate contributions of both autochthonous and allochthonous sources of organic matter. Moreover, a high ratio of TOC/TN in low part of the cores is considered to indicate prevalence of the allochthonous (terrestrial and/or coastal plants) organic matter delivered by water discharges when the glacier margin was more advanced..

The contents of TIC (Total inorganic carbon) and $CaCO_3$ is high in late Pleistocene sediments and low in Holocene sediments (Fig. 2). In other word their down-core profiles are completely reverse from those TOC and TN. Therefore, TIC and $CaCO_3$ in sediments is assumed to be contributed mainly by terrigenous input and in situ formed minerals.

The down core variation of TS contents and TS/TOS ratio in investigating cores show relatively low values (0.1% and 0.01-0.02% respectively) for unit A and higher values for unit B. Moreover, their values are highly changeable in unit B. Especially, high TS contents of 0.6% and 0.95% occurred in lower part of Hub02-1 and Hub02-6, correspondingly. The variations in TS contents in cores are assumed to be derived from fluctuations of lake water salinity, which in turn indicate prevailed process controlling the lake water state.

Thus, the Holocene sediments in studied cores are characterized by high TOC and TN, while late Pleistocene sandy clayey silt is by high TIC, $CaCO_3$, TS and by high ratios of TOC/TN and TS/TOC, indicating completely different sedimentation environments. That means past changes in primary productivity in response to glacial and interglacial climate changes affect not only physical and rock-magnetic properties of the sediments but also geochemistry. So TOC and TN paleoproductivity index can be be successfully used for reconstruction of the paleoclimate and for exploring regularities of changes.

5. Conclusion

Silty clay and sandy clayey silt with remains of the land plants in the lower part of the cores Hub02-1 and Hub02-6 contains relatively high TIC and TS contents, indicating low stand of lake level and high mineralization of the lake water. The high calcite contents determined in this part is also an evidence for high mineralization of the lake water. Mineralogical data support this point

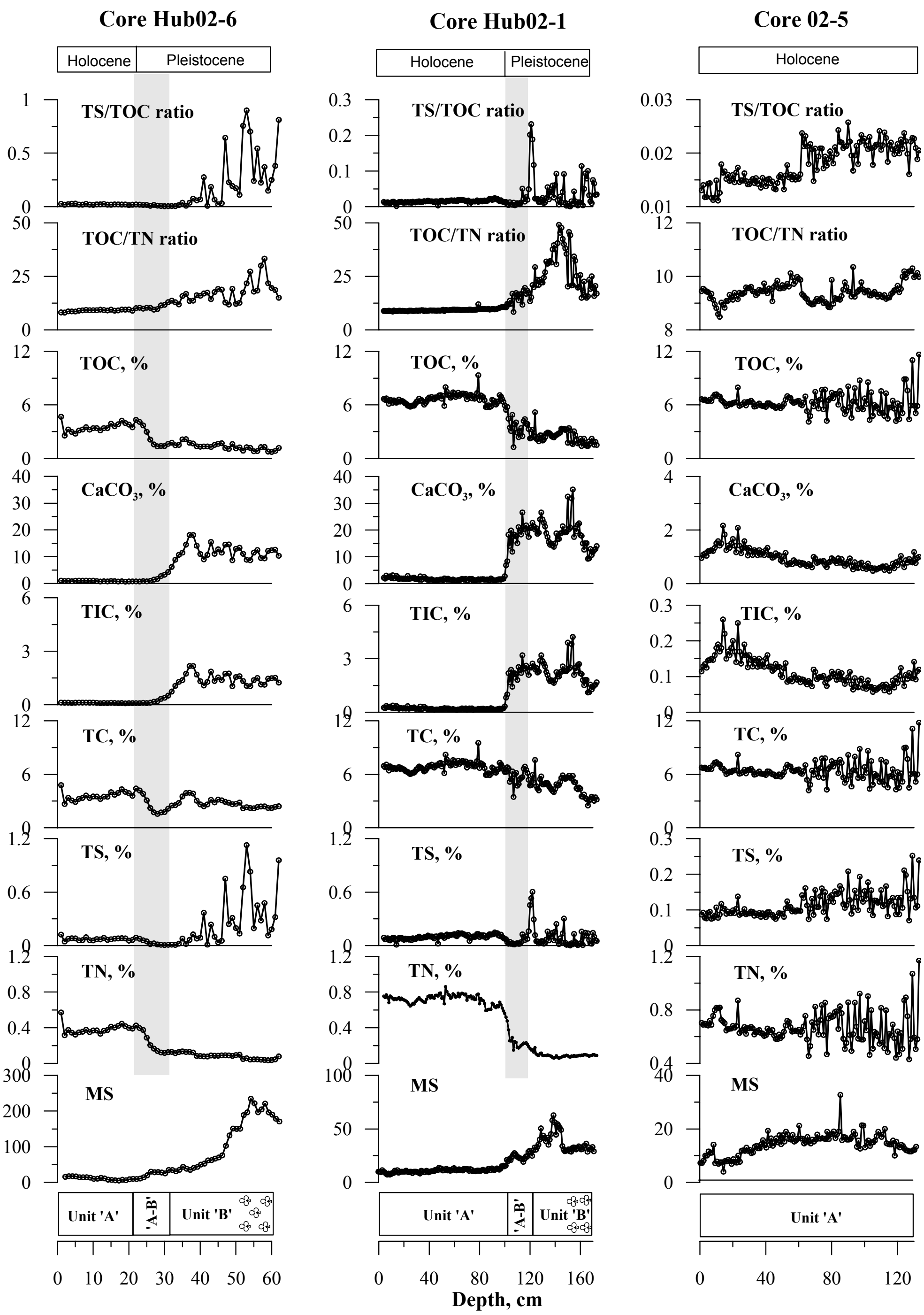

Fig 2. Down-core variations for MS, TN, TS, TC, TIC, $CaCO_3$, TOC and TOC/TN ratio and TS/TOC ratio from sediments of cores Hub02-1, Hub02-5, Hub02-6

of view, as the sandy clay contains high contents of illite and chlorite derived from physical weathering of metamorphic rocks.

Upper clayey silt deposited during the Holocene interglacial is characterized by high TOC, TN and low TC, TS and MS contents, indicating high natural surface water productivity and low salinity or mineralization of the lake water.

The TOC, TN and TS in clayey silt of the Hub02-5 core show at least two different sedimentary environments that prevailed during the Holocene in North Mongolia. Due to the lack of the age dating, exact time coverage of the distinguished sedimentary environments could not be determined. However, it may be expected that the sediments, from the 130-650 cm intervals of Hub02-5 core with high amplitude of changes of the TOC, TN and TS contents, were probably deposited for the quite short time in the beginning of Holocene. This point has been supported by diatom analysis as the isolated interval (130-650cm) of the core contains much higher diatom frustules than upper part of the core. That means the beginning of Holocene (11-8 kyr) in North Mongolia possessed quite favorable climate and humidity condition to develop high natural surface water productivity.

The C/N ratios are high (>15) in silty clay and sandy clayey silt and low (<9) in diatomaceous silt of the cores. This observation gives possibility to talk that the autochthonous primary production is dominant source of organic matter in Holocene sedimentation, whereas the organic matter in sandy clay were mainly contributed by allochthonous sourses.

High TS together with high TIC and abundant calcite phase in unit B of the cores allows speculating that the lake Hovsgol was small in size and had brackish water during the deposition of the lower part of the cores.

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