Laminated Sediments from Levinson-Lessing Lake, Northern Central Siberia - A 30,000 Year Record of Environmental History?

T. Ebel[1], M. Melles[1] and F. Niessen[2]

(1) Alfred-Wegener-Institut für Polar- und Meeresforschung, Forschungsstelle Potsdam, Telegrafenberg A 43, D 14473 Potsdam, Germany

(2) Alfred-Wegener-Institut für Polar- und Meeresforschung, Postfach 120161, D 27568 Bremerhaven, Germany

Revised 5 May 1997 and accepted in revised form 15 March 1998

Abstract - Sediment description and initial stratigraphical, geochemical, and physical analyses were carried out on a 22.4 m long sediment core from the arctic Levinson-Lessing Lake, Taymyr Peninsula (northern Central Siberia). The results reveal a continuous sedimentary history of the lake and its dependence on climatic variations since the late Middle Weichselian. The core consists of two major sediment types, clastic varves and sandy layers, which are linked to seasonal sediment supply related to meltwater runoff and episodic events related to turbidity currents, respectively. Higher frequencies of the event deposits during the Weichselian were presumably initiated by a lower lake level. Climatic warming at the Pleistocene-Holocene transition led to increased biogenic accumulation, originating from both aquatic production and terrestrial supply, but to no significant change in sedimentation rates. From the available data, a glaciation in the lake´s catchment area can be excluded during the period since the late Middle Weichselian.

Introduction

Over the last few years there has been an ongoing debate concerning the extent of the Eurasian glaciation during the Last Glacial Maximum (20 - 18 ka BP). Different opinions range from a minimal ice sheet centered in the Barents Sea (Figure 1) with an isolated small glaciation covering the Putorana Plateau (Velichko et al., 1984) to the assumption of a large ice sheet (maximal variation as shown in Figure 1) spreading from the Kara Sea towards the south, southwest and southeast (Grosswald 1980, 1988; Grosswald and Hughes, 1995). This would have affected large areas of northern Central Siberia, including most of the Taymyr Peninsula. Investigations of potential records of environmental development with respect to the influence of glaciation are therefore of special interest for the studies carried out within the scope of the Taymyr Project.

Levinson-Lessing Lake, with 110 m water depth the deepest lake of the northern Taymyr Peninsula, is situated in the southern part of the Paleozoic fold system of the Byrranga Mountains, 50 km northwest of Taymyr Lake (Figure 2). The lake basin is 15 km long and 1 to 2 km wide. It covers an area of approximately 25 km^2, stretching from the main inflow in the north, the Krasnaya River, to the Protochnaya outflow in the south. Numerous small streams drain into the lake from the adjacent eastern and western slopes. The Levinson-Lessing catchment reaches from 47 m up to 570 m a.s.l., covering an area of roughly 515 km^2.

The geomorphological setting of the basin and its catchment reflects a tectonic origin, reshaped by glacial abrasion during Early Weichselian time (Niessen et al., this volume). Today, large solifluction lobes and - along the lake's northwestern shore - tors with a relative elevation of up to 400 m characterize a typical permafrost climatic regime within the catchment.

Levinson-Lessing Lake can be described as a cold, monomictic and apparently holomictic lake, with its single annual turnover occurring just after complete melting of the more than 2 m thick winter ice cover. In Figure 3 (taken from Hagedorn et al., 1996), the waterbody's basic

---

In: Kassens, H., H.A. Bauch, I. Dmitrenko, H. Eicken, H.-W. Hubberten, M. Melles, J. Thiede and L. Timokhov (eds.) Land-Ocean Systems in the Siberian Arctic: Dynamics and History. Springer-Verlag, Berlin, 1999, 425-435.

characteristics during spring and summer are shown. The lower pH values in the upper 10 meters observed in the beginning of July are caused by acidic meltwater from snow seeping through the ice cover and from melting of the lake ice itself at the ice/water-interface. Oxygen supersaturation occurs in the still stagnant waterbody when phytoplancton production, initiated by increasing light availability due to higher solar radiation and the improving transparency of the exposed ice cover, starts at the end of June. The minor inverse thermal gradient observed in spring time is due to the cooling effect of the ice cover and ceases just after melting of the lake ice is complete in August.

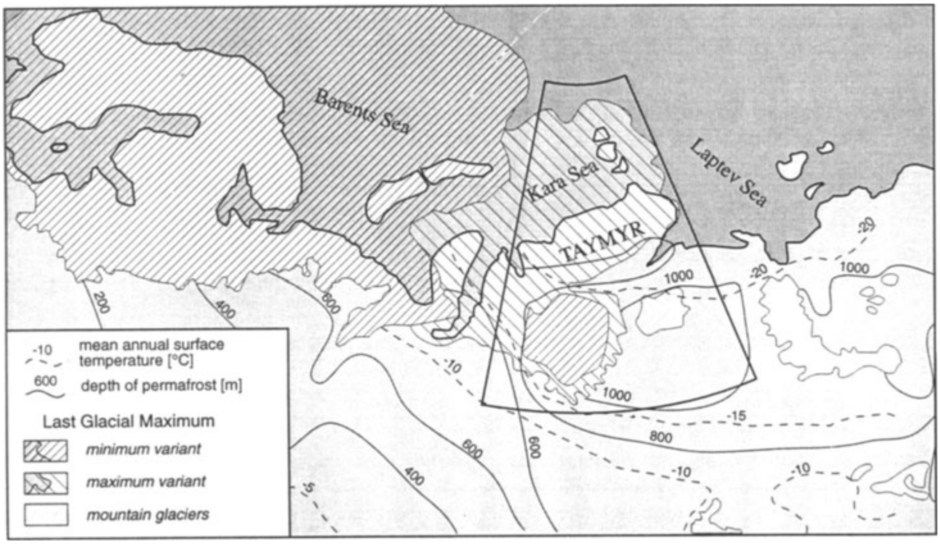

Figure 1: Map of northern Eurasia showing the Taymyr Project study area (encircled) and the extent of the Late Weichselian glaciation (minimum and maximum variants after Velichko et al., 1984)

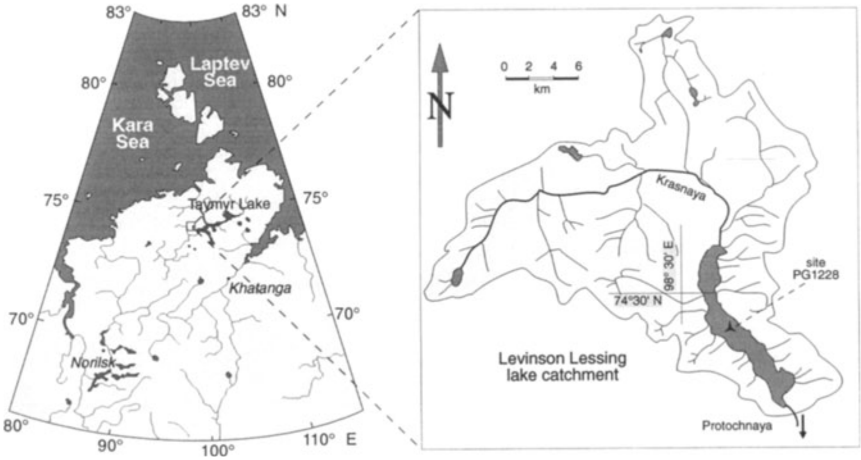

Figure 2: Levinson-Lessing Lake with the location of sediment core PG1228, and the catchment area with the major inflow Krasnaya River in the north, and the outflow, Protochnaya River, in the south. A detailed bathymetric map is published by Niessen et al. (this volume).

Long sediment cores were first recovered from Levinson-Lessing Lake during the 1995 expedition of the multi-disciplinary German-Russian *Taymyr Project* (Overduin et al., 1996). Coring in the central part of Levinson-Lessing lake resulted in a continuous sediment sequence of 22.37 m length. Based on palynological results, the core represents a complete record from the late Middle Weichselian to the present (Hahne and Melles, this volume). According to a seismic survey, it comprises only the upper third of the lacustrine sediments in Levinson-Lessing Lake, and is underlain by at least some additional 35 meters of laminated sediments (Niessen et al., this volume).

In this paper we present a description of the sediment core PG1228, along with sediment stratigraphical, geochemical and physical data. These results provide information concerning the sedimentation processes in Levinson-Lessing Lake and their dependence on climatic variations since the late Middle Weichselian.

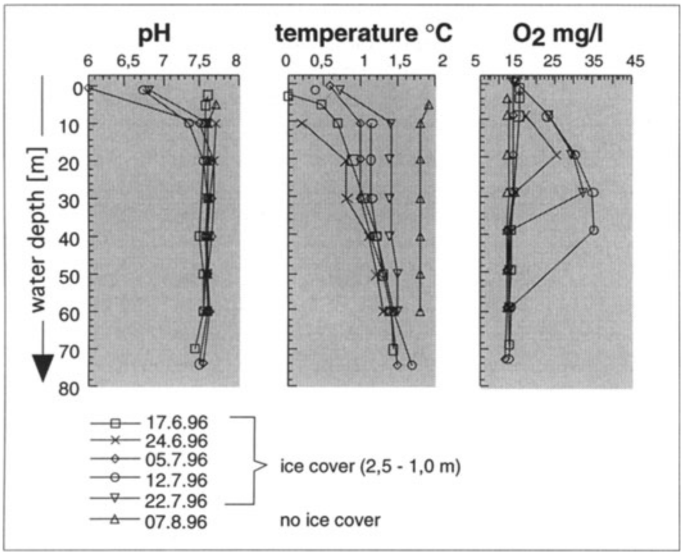

Figure 3: Distribution of pH, temperature, and oxygen content in the water column of Levinson-Lessing Lake at the transition from ice-covered winter and spring conditions to ice-free summer conditions. (Hagedorn et al., 1996).

Material and methods

Lake sediment coring in the central part of Levinson-Lessing Lake (site PG1228; Figure 2) was carried out in spring 1995 from the 2 m thick ice cover at a water depth of 108 m. The 22.37 m long sediment sequence was recovered using two different coring devices (both manufactured by UWITEC, Austria). A light gravity corer, consisting of a PVC core tube (6 cm diameter) and variable weights (4-12 kg) was employed for non-disruptive sampling of the soft near-surface sediments (0 - 27 cm). Longer sediment cores were recovered with a piston corer consisting of a 3 m long steel tube with an exchangeable inner PVC liner (6 cm diameter), equipped with a hydraulic core catcher. The entire gear is operated manually by winches mounted to the legs of a tripod, penetration momentum being supplied by a cylindrical hammer (20 or 40 kg) at the upper end of the coring device. Maximum recovery with every deployment of the piston corer is limited by the tube length to 3 m. Deeper sediments can be sampled by releasing the piston, fixed at the lower end of the corer during its way through the water column and overlying sediment, and thus starting the coring process at defined depths. Nine deployments of the piston corer, with an overlap of approx. 50 cm each, yielded a complete sediment sequence from the sediment/water interface to a depth of 22.37 m. The cores were cut into 1 m sections, sealed with plastic caps and flexible tape and stored in thermostatted boxes at positive temperatures during transport via Khatanga and St. Petersburg to Potsdam. For detailed descriptions concerning the coring technique see Melles et al. (1994).

Prior to opening the cores, physical properties of the sediment were measured using a non-destructive Multi Sensor Core Logging system (Geotek Ltd. UK) at the Alfred Wegener Institute (AWI) in Bremerhaven (described in detail in Weber et al., 1997). Wet bulk densities and porosities were calculated from γ-ray absorption at 1 cm intervals, and susceptibility values were determined correspondingly using a Bartington MS2 loop sensor.

Subsampling of the core segments and additional analyses were carried out at AWI Potsdam. The cores were halved longitudinally; one half was used for sampling and the other for the archive. Following photographic documentation and macroscopic description, subsamples (1 cm thick sediment slices) were taken from the core. They were freeze-dried and ground to < 63 μm particle size. Water content was calculated from the differences between wet and dry weights. Total carbon, sulfur, and nitrogen contents were determined using a CNS-932 Mikro analyzer (LECO Corporation). The total organic carbon content was measured with a CS 100/1000 S (ELTRA) in corresponding samples after treatment with hydrochloric acid (10%) to remove the carbonate-bound carbon. In addition, sediment slabs of 2 x 10 x 1.5 cm were used for the preparation of large-sized thin sections, which were investigated using a petrographic microscope.

Radiocarbon dating was carried out on a sample of terrestrial plant remains found in sufficient amount at a sediment depth of 467 cm in core PG1228. The measurement was conducted by ^{14}C Accelerator Mass Spectrometry (AMS) at the *Research Laboratory for Archaeology and History of Art*, Oxford. The ^{14}C age was calibrated to calendar years BP (before 1950) using the OxCal v2.18 program based on the Stuiver and Reimer (1993) ^{14}C calibration curve.

Results and discussion

Stratigraphy

The stratigraphy of sediment core PG1228, as presented in Figure 5, is based mainly on a correlation of regional pollen assemblage zones (PAZ), determined for this core with radiocarbon dated pollen records from Siberia and other areas of the northern hemisphere (Hahne and Melles, this volume). Holocene sedimentation rates of 0.7 mm/a, calculated from the pollen stratigraphy, are supported by those determined by ^{210}Pb measurements in shallow sediments (Hagedorn, pers. comm.). In addition, the agreement of PAZ LL8 with the Atlantic period is confirmed by the radiocarbon age of 5650 ± 90 ^{14}C yr BP (Lab No.: OxA-6526) of terrestrial plant remains from 467 cm sediment depth, corresponding to a calibrated age of 6670-6280 cal. yr BP.

Lithology and sedimentary structures

The sediment core PG1228 is clearly dominated by minerogenic sediment components. The organogenic components include terrestrial plant detritus, algal material and fossil coal and methane, considerable amounts of which expanded during sediment recovery from about 108 m water depth as a result of a pressure release of far more than 1000 kPa . Vivianite and pyrite accretions occur as mm-scale concretions in the upper 9 m of the sediment column. There is no evidence of postsedimentary destruction of sedimentary structures by bioturbation.

Most terrestrial material is transported into Levinson-Lessing Lake in early summer (June/July) through meltwater supplied from snow fields and the thawing active layer (Bolshiyanov et al., 1995; Gintz et al., 1996). Summer rain events result in irregularly occurring surface runoff which contribute minorly to overall sedimentation. In contrast, direct gravitational or cryogenic sediment supply to the lake (e.g. slumps, solifluction) is negligible, as indicated by the low relief at the lake shores and the absence of ice-rafted gravels in sediment core PG1228.

From the lithology and sedimentary microstructures, two main sediment types are distinguished in core PG1228, reflecting two different sedimentary facies: fine-grained laminae and sandy layers.

The fine-grained laminae (Figure 4), consisting of couplets with silt-sized basal and clay-sized top layers, comprise about 80% of the entire sediment column. Average couplet thickness is 0.7 mm, with small variations throughout the sequence. This corresponds well with the mean annual sedimentation rate of 0.72 mm/a, calculated for the uppermost 467 cm of the sediment sequence from a reliable radiocarbon age from core PG1228 (see above). Similar sedimentation rates are indicated by the pollen stratigraphy, varying between 0.46 and 0.75 mm/a for the Holocene (Hahne and Melles, this volume). ^{210}Pb measurements on a short gravity core about 4 km to the north of site PG1228, towards the Krasnaya inflow, indicate a two- to threefold higher sedimentation rate of ca. 1.5 mm/a (Hagedorn, pers. comm.) This is, however, in agreement with the sediment geometry recorded in sub-bottom profiles (Niessen et al., this volume).

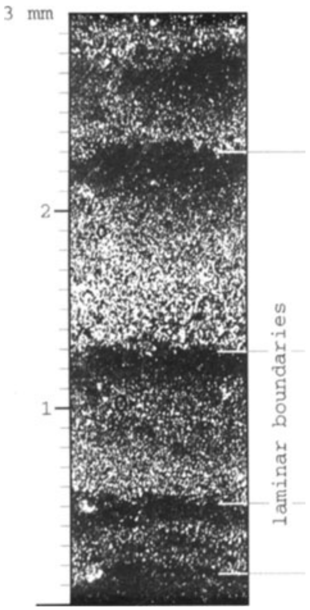

Figure 4: Microscopic photograph of clastic laminations (varves) at 19.85 m sediment depth in core PG1228 under polarized light. Note the sharp lower boundaries and graded bedding of individual laminae.

These regular fine-grained laminae very likely represent annual layers (clastic varves) as described by Sturm and Matter (1978) in alpine lakes. Varve formation in the predominantly monomictic Levinson-Lessing Lake can be explained by the summer sediment supply and winter ice coverage. From the sediment delivered during summer, coarse-grained particles are deposited in the stream channels and their deltas, while most of the fine-grained material

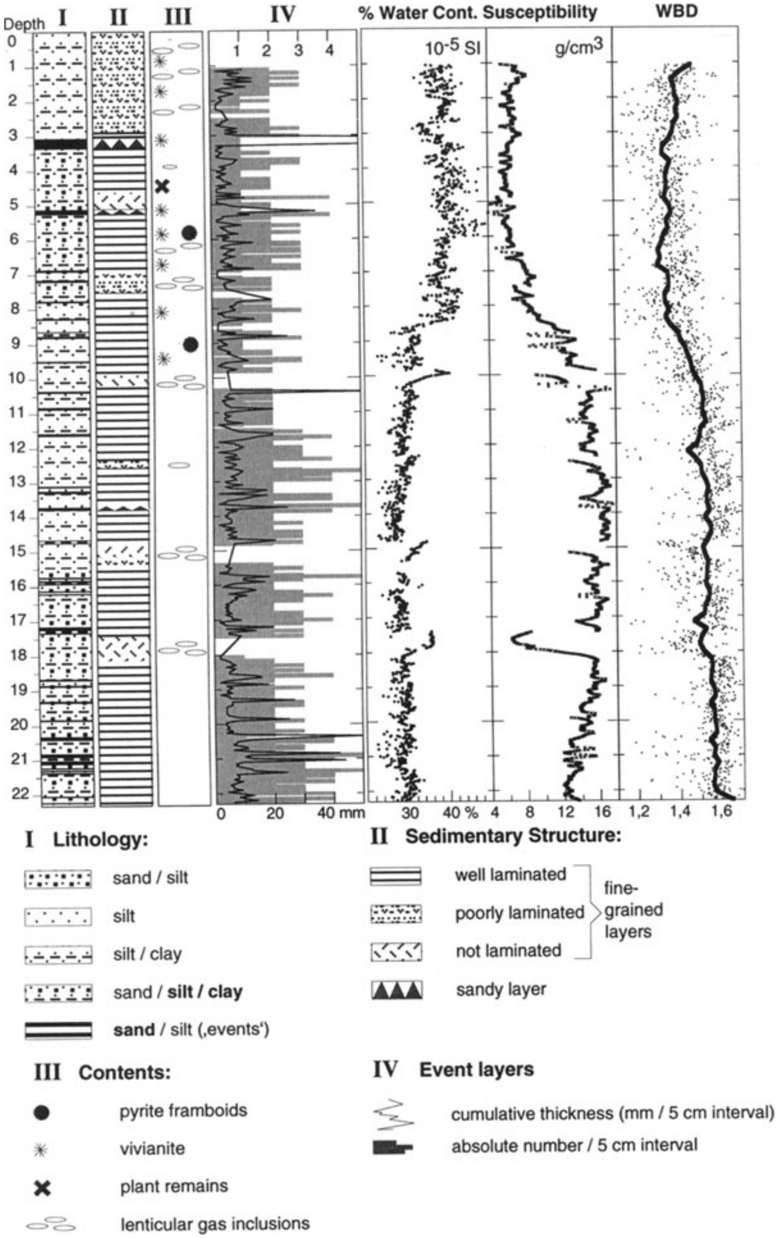

Figure 5: Log of sediment core PG1228 showing **a**) lithology, sedimentary structures, macroscopic description, sand layer frequencies and their cumulative thickness, water contents, susceptibilties, wet bulk densities (WBD) with a running mean (heavy line).

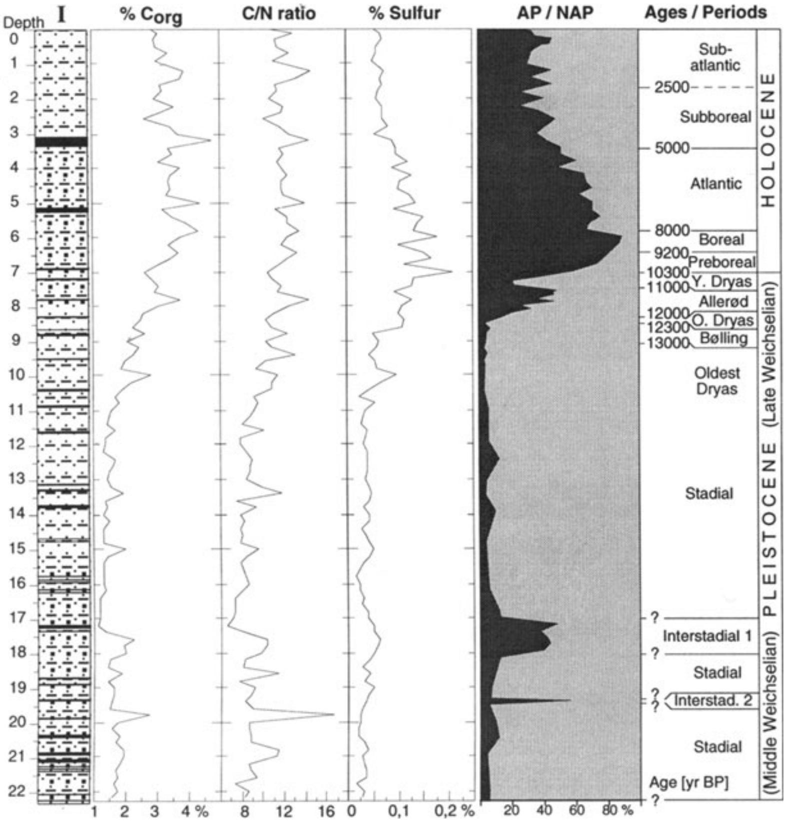

Figure 5: Log of sediment core PG1228 showing **b**) the total organic carbon (C_{org}) contents, total organic carbon to total nitrogen ratios (C/N), sulfur contents, arboreal pollen (AP) contents, and the correlation of regional pollen assemblage zones (PAZs) with corresponding chronozones as defined by Mangerud et al. (1974) and Khotinskiy (1984).

remains in suspension due to continuous circulation forced by wind, wave action and meltwater inflow during that time. In winter, as a result of the lake ice cover, turbulence in the lake water decreases, allowing the settling of finest particles according to Stokes´ Law, and thus completing the annual layer with a clay top.

The sandy layers amount to about 20 % of the sediment core PG1228 and occur irregularly throughout the sequence (Figure 5). Their thickness varies between 2 mm and 20 cm. Homogeneous layers of well sorted sand can be distinguished from layers changing from sand at the base to silty clay at the top. Both types are characterized by sharp lower boundaries. One possible process explaining the formation of these layers could be extreme meltwater freshets during very warm summers, as in 1996, when about 80% of the mean annual Krasnaya River sediment load was discharged within 2 days (Gintz and Meinel, 1997). Events like these could have caused the formation of turbid currents transporting sand-sized particles in suspension to distal areas of the lake. However, the wide range in layer thickness from 2 mm to 20 cm and their rare occurrence, about every 50 years during the Holocene, argue against this mechanism. In addition, cumulative layer thicknesses (Figure 5) show no variation in relation to major climatic changes since the Middle Weichselian.

The most likely process forming the sandy layers are turbidity currents irregularly initiated by collapsing delta front sediments and slumping of sediment material from the steep slopes of the lake bed. As indicated by the absence of erosional channels in sub-bottom profiles crossing the lake (Niessen et al., this volume), such turbidity currents did not lead to a significant resuspension of surface sediments along their flow paths. Differences in the composition of the sandy layers (massive and graded) may be due to different source areas: whilst graded layers may represent distal turbidites from the Krasnaya River, massive layers could represent proximal turbidites or slumping material from littoral areas and delta regions of small rivers entering the lake at its southwestern shore (Figure 2). Additional mineralogical and geochemical data which characterize the source area sediment compositions and allow a comparison with the composition of the sandy layers in the sediment record may support this interpretation.

Similar sediment types (fine-grained laminae and coarse-grained, „surge-type„ layers) and processes were observed in the High Arctic Lake C2, Ellesmere Island, Canada (Zolitschka, 1996; Retelle and Child, 1996). The existence of overflow, interflow, and underflow processes as described in these investigations and by Sturm and Matter (1978) is not likely in Levinson-Lessing Lake due to the very weak stratification of the lake water column.

Whilst the number of sandy layers in core PG1228 decreases slightly in the Holocene sediments, their cumulative thickness is comparable to values in Weichselian sediments (Figure 5). This indicates that turbidites were more frequent during the Weichselian, but had no stronger contribution to the total sediment accumulation, as the individual events were of lower energy than those during the Holocene. Higher turbidite frequencies together with lower current energies during the Weichselian could have been caused by a significantly lower lake level at that time. This interpretation is also supported by sub-bottom profile investigations from Levinson-Lessing Lake (Niessen et al., this volume).

Based on the largely constant contribution of sandy layers to sediment accumulation, and on the with small variations in laminae thicknesses throughout the fine-grained sediments (around 0.7 mm), rather constant long-term sedimentation rates throughout the time interval covered by the core were determined. This implies that no glaciation occurred in the Levinson-Lessing Lake area during that time period. The existence of glaciers within the catchment area would have caused significant changes in both the sedimentation rates and facies.

Moreover, relatively constant sedimentation rates allow an estimation of the ages of Interstadials 1 and 2 occurring in the lower portion of the core (Figure 5). The linear extrapolation of the post-Bølling sedimentation rate of 0.7 mm/a towards the underlying sediments results in ca. 27 and 25 ka BP for Interstadials 1 and 2, respectively. This indicates that those periods with assumed interstadial conditions could correspond with the youngest Middle Weichselian warming in Siberia, which, according to Isayeva (1984), occurred between 24 and 30 ka BP. However, since interstadial conditions in Siberia were also described for several other Middle Weichselian time periods (e.g. Grichuk, 1984; Kind, 1974; Rybakova, 1989) and since a displacement of Holocene material during the coring process cannot be completely excluded, the absolute ages of Interstadials 1 and 2 can only be determined by accurate absolute dating. As bulk sediment ^{14}C dating is regarded to provide unreliable results due to contamination by fossil coal, radiocarbon dating of defined organic fractions (such as humic acids) must be performed and is currently in progress.

Geochemical and physical properties

The geochemical and physical properties of sediments in core PG1228 show a very good correlation with the palynological results, especially with the ratio of arboreal to non-arboreal pollen, which, according to Hahne and Melles (this volume), mirrors variations in Late Pleistocene and Holocene average summer temperatures (Figure 5).

The sedimentary processes influencing both the chemical composition and the physical properties of the sediment have undergone changes dependent on natural climatic variations. The total organic carbon, nitrogen, and sulfur contents show distinct increases at the Pleistocene-Holocene transition (Figure 5). Whilst the values of organic carbon and nitrogen remain at high levels closer to the sediment surface, sulfur is clearly enriched in the Preboreal and Boreal pollen zones, which are believed to represent the Holocene climatic optimum in this area (Hahne and Melles, this volume). Varying contents of all three parameters within the Weichselian sediments are less pronounced, showing somewhat higher values in horizons which exhibit an interstadial character according to pollen data (Interstadial 1 and 2).

The increasing contents of organogenic components in warmer periods are not exclusively the result of enhanced aquatic biogenic accumulation. The total organic carbon contents comprise autochthonous aquatic plant material as well as allochthonous terrestrial plant detritus and fossil coal. Higher C/N ratios during warmer times clearly evidence increasing proportions of vascular plant detritus in the total organic fraction (Meyers and Ishiwatari, 1995). At least for the Holocene, this was probably due to both enhanced availability of plants in the lake's catchment and enhanced river supply to the lake, as indicated by a denser vegetation cover and the supposedly higher amounts of summer precipitation during that period (Hahne & Melles, this volume).

The higher amounts of organic material, starting at the Pleistocene-Holocene transition, led to chemical changes in the interstitial waters of the sediment. The occurrence of pyrite (FeS) framboids in parts of the post-Oldest Dryas deposits indicates anoxic conditions within the pore water, as well as sufficient sulfate supply for that time, whereas iron oxides are ubiquitous throughout the entire sequence. Autochthonous vivianite ($Fe_3(PO_4)_2 \cdot 8H_20$) points to a complete pyritic fixation of sulfide at these depths, allowing post-sedimentary formation of iron phosphates (Zolitschka, 1990). The anoxic pore waters and increased organic contents are related to increased biological methane formation. Horizons with highest methane contents are rendered macroscopically visible by enrichments of lenticular gas inclusions (Figure 5). Whilst methane remains dissolved and is partly consumed in surface sediments and the water column by methanotrophic bacteria at site PG1228, in the central, deepest part of the lake, in shallow waters it is released to the atmosphere in significant amounts (Samarkin, 1997).

The high gas contents in parts of sediment core PG1228 strongly affected the whole-core measurements of the sediments physical properties - i.e. wet bulk density (WBD) and susceptibility (Figure 5) - resulting in scattered values and under-estimations of both parameters. Nevertheless, their general trends, similarly to that of the water content, show good (positive or negative) correlations with geochemical data. Significant decreases in WBD and susceptibilities towards the upper, Holocene part of the sediment core can be traced back to higher water and methane contents as well as to a higher concentration of organic material with lower density, and related lower concentrations of minerogenic components, including magnetically active mineral grains.

Conclusions

From the description and first analyses of core PG1228 the following conclusions can be drawn on the sedimentation history recorded in the Levinson-Lessing Lake basin since the late Middle Weichselian:

A continuous lacustrine sediment record was recovered from Levinson-Lessing Lake covering at least the last 30,000 years. Sedimentation rates with a mean value of 0.7 mm/a were relatively constant throughout this period.

The sedimentation was dominated (ca. 80% of the whole record) by seasonal fluvial sediment supply, which caused the formation of annual laminations (clastic varves). In addition, episodic events, probably due to turbidity currents originating from littoral and delta areas, led to the accumulation of sandy layers (ca. 20% of the record).

Higher frequencies of lower energy turbidites during the Middle Weichselian can be interpreted as indicators for a lower lake level at that time.

Climate warming during Middle Weichselian interstadials and post-Oldest Dryas led to increased organogenic sedimentation, comprising both autochthonous aquatic plant material and allochthonous terrestrial plant detritus.

No evidence was found for the occurrence of any glaciation in the Levinson-Lessing Lake catchment area since the late Middle Weichselian.

In summary, core PG1228 from Levinson-Lessing Lake provides the longest, laminated sediment sequence recovered from a High Arctic environment. It may be of major importance for the understanding of Late Pleistocene climate-controlled environmental evolution in a part of the world that acts as a key region with regard to recent climatic change debates.

Acknowledgements

Thanks to the members of the 1995 Taymyr Expedition - especially the coring team - for their invaluable help and the warm atmosphere during sometimes difficult conditions. Dr. M. Sturm and Dr. B. Zolitschka are acknowledged for critically reviewing this manuscript and providing helpful commands. Special thanks are due to M. Köhler for thin section preparation at the GeoForschungsZentrum Potsdam. Financial support was provided by the German Ministry of Education, Science, Research and Technology (BMBF; Grant No. 03PL014A,B). This is contribution No. 1351 of the Alfred Wegener Institute for Polar and Marine Research, Bremerhaven and Potsdam.

References

Bolshiyanov, D.Y., D. Ginz and V.P. Zimichev (1995) Surface drainage. In: Russian-German Cooperation: The Expedition Taymyr 1994, Siegert, C. and D.Y. Bolshiyanov (eds.), Ber. Polarforsch. AWI, Bremerhaven, 175, 13-17.

Gintz, D.A. and T. Meinel (1997) Hydrology and suspension transport in the Krasnaya River. In: Russian-German Cooperation: The Expedition Taymyr/Severnaya Zemlya 1996, Melles, M., B. Hagedorn and D.Y. Bolshiyanov (eds.), Ber. Polarforsch. AWI, Bremerhaven, 237, 58-61.

Gintz, D.A., V. Mescherjakov, H. Becker, J. Boike and B. Hagedorn (1996) Hydrological Investigations at the Krasnaja River. In: Russian-German Cooperation: The Expedition Taymyr 1995 and the Expedition Kolyma 1995 of the Pushchino Group, Bolshiyanov, D.Y. and H.W. Hubberten (eds.), Ber. Polarforsch. AWI, Bremerhaven, 211, 92-95.

Grichuk, V.P. (1984) Late Pleistocene vegetation history. In: Late Quaternary environments of the Soviet Union, Velichko, A.A. (ed.). University of Minnesota Press, Minneapolis, 155-178.

Grosswald, M.G. (1980) Late Weichselian ice sheets of northern Eurasia. Quaternary Research, 13, 1-32.

Grosswald, M.G. (1988) An Antarctic-style ice sheet in the Northern Hemisphere: toward a new global glacial theory. Polar Geography and Geology, 12.

Grosswald, M.G. and T.H. Hughes (1995) Paleoglaciology's grand unsolved problem. Journal of Glaciology, 41(138), 313-332.

Hagedorn, B., J. Boike, T. Ebel, D.A. Gintz and H.-W. Hubberten (1996) Sedimentation processes, hydrology and geochemistry of the Levinson Lessing Lake (Taymyr Peninsula, Siberia). In: Third Workshop on Russian-German Cooperation: Laptev Sea System, Terra Nostra, 96/9, 21-22.

Hahne, J. and M. Melles (this volume) Climate and vegetation development on the Taymyr Peninsula since Middle Weichselian time - palynological investigations on lake sediment cores.

Isayeva, L.L. (1984) Late Pleistocene glaciation of north-central Siberia. In: Late Quaternary environments of the Soviet Union, Velichko, A.A. (ed.). Longman, London, 21-30.

Khotinskiy, N.A. (1984) Holocene Vegetation History. In: Late Quaternary Environments of the Soviet Union, Velichko, A.A. (ed.). University of Minnesota Press, Minneapolis, 179-200.

Kind, N.V. (1974) Geochronology of the late Anthropogene from isotope data [in Russian]. Nauka, Moscow.

Mangerud, J., S.T. Andersen, B.E. Berglund and J.J. Donner (1974) Quaternary Stratigraphy of Norden, a Proposal for Terminology and Classification. Boreas, 3, 109-128.

Melles, M., T. Kulbe, P.P. Overduin and S. Verkulich (1994) The Expedition Bunger Oasis 1993/94 of the AWI Research Unit Potsdam. In: The Expeditions Norilsk/Taymyr 1993 and Bunger Oasis 1993/94 of the AWI Research Unit Potsdam, Melles, M. (ed.), Ber. Polarforsch. AWI, Bremerhaven, 148, 35-38.

Meyers, P.A. and R. Ishiwatari (1995) Organic matter accumulation records in lake sediments. In: Physics and Chemistry of Lakes, Lerman, A., D.M. Imboden and J.R. Gat (eds.). Springer, 279-328.

Niessen, F., T. Ebel, C. Kopsch and G.B. Fedorov (this volume) High-resolution seismic stratigraphy of lake sediments on the Taymyr Peninsula, Central Siberia.

Overduin, P.P., D. Bolshiyanov and T. Ebel (1996) Lake sediment sampling on the Taymyr Peninsula. In: Russian-German Cooperation: The Expedition Taymyr 1995 and the Expedition Kolyma 1995 of the Pushchino Group, Bolshiyanov, D.Y. and H.-W. Hubberten (eds.), Ber. Polarforsch. AWI, Bremerhaven, 211, 111-121.

Retelle, M.J. and J.K. Child (1996) Suspended sediment transport and deposition in a high arctic meromictic lake. J. Paleolimnol., 16, 151-167.

Rybakova, N.O. (1989) Late Quaternary changes in plant cover and climate in the Kolyma Lowland [in Russian]. In: The Pleistocene in Siberia, stratigraphy and large-scale correlation [in Russian], Skabichevskaya, N.A. (ed.), Nauka, Novosibirsk, 137-142.

Samarkin, V.A. (1997) Methane Biogeochemistry in Levinson-Lessing Lake. In: Russian-German Cooperation: The Expedition Taymyr/Severnaya Zemlya 1996, Melles, M., B. Hagedorn and D.Y. Bolshiyanov (eds.). Ber. Polarforsch. AWI, Bremerhaven, 237, 67-70.

Stuiver, M.A. and P.J. Reimer (1993) Extended ^{14}C data base and revised CALIB 3.0 ^{14}C age calibration program. Radiocarbon, 35(1), 215-230.

Sturm, M. and A. Matter (1978) Turbidites and varves in Lake Brienz (Switzerland); deposition of clastic detritus by density currents. In: Modern and ancient lake sediments; proceedings of a symposium, Matter, A. and M. Tucker (eds.). Blackwell, Oxford, 147-168.

Velichko, A.A., L.L. Isayeva, V.M. Makeyev, G.G. Matishov and M.A. Faustova (1984) Late Pleistocene Glaciation of the Arctic Shelf, and the Reconstruction of Eurasian Ice Sheets. In: Late Quaternary Environments of the Soviet Union, Velichko, A.A. (ed.), University of Minnesota Press, Minneapolis, 35-41.

Weber, M.E., F. Niessen, G. Kuhn and M. Wiedicke (1997) Calibration and application of marine sedimentary physical properties using a multi-sensor core logger. Marine Geology, 136, 115-172.

Zolitschka, B. (1990) Late Quaternary annually laminated Lake Sediments from selected Eifel-Maar Lakes [in German]. Documenta Naturae, 60, München, 226 pp.

Zolitschka, B. (1996) Recent sedimentation in a high arctic lake, northern Ellesmere Island, Canada. J. Paleolimnol, 16, 169-186.