The Alleroed - duration and climate as derived from laminated lake sediments.

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Introduction

Though rapidly improving, the chronological framework of the Late Glacial is still under discussion. This is due to systematical difficulties with the radiocarbon dating during the Late Glacial and the early Holocene, and to the complete lack of buried trees for dendrochronological calibration during the Younger Dryas. Annually laminated lacustrine muds becoming increasingly available are therefore used to help to close the gap between the pleniglacial and the Holocene. The alleroedian Laacher See tephra (LST) is an important piece in the chronostratigraphic efforts in western Europe as a widespread stratigraphic marker.

Further the Late Glacial acquired even social interest because of the rapid and severe climatic oscillations which took place in short intervals and which should be better understood. The Alleroed period and the Younger Dryas constitue the last important climatic swing before the definite onset of the postglacial.

Zolitschka (1990) found about 800 varves for the duration of the Alleroed in the Holzmaar. Lotter (1991) counted 587 ± 22 calendar years and Lotter, Amman & Sturm (1992) measured ca. 600 varves for the pollenanalytically defined biozone. They also discussed the differences between the so called chronozones and the biozones. Their inadvertent use still causes much confusion. The latest comprehensive synopsis from the chronostratigraphic and the paleoclimatological point of view has been made by Kaiser 1993.

The biozone of the Alleroed is here used for the delimitation of the studied period as it is founded on the vegetation, which closely reacts on the climatic development. This is a sounder reasoning compared to that of the chronozones. The study of the microfacies shows similar features: lacustrine sediments when carefully studied are useful climatic proxies.

Sites and methods.

The presented results are almost exclusively based on sediments from the Hämelsee (TK 25, Bl. Eystrup, 3221). This lake is situated at 70 km NW of Hannover in the weichselian fluvial plain of the Weser-Aller system over the rim of a saltdome. The basin collapsed by subrosion, presumably during the older part of Late Glacial. The Hämelsee has a diameter of 370 x 420 m and its water depth is today 4 m. The central flat bottomed part of the basin contains 17,5 m of lake sediments.

The study is made on two cores retrieved by a Livingstone corer from the lake's center. The late glacial part of the cores is an uninterruptedly laminated sapropelitic mud between 19,51 and 20,23 m below lake level. The overlying clayey and sandy silt (Younger Dryas) is massive. At the basis is a 15 mm-turbidite, followed by more minor turbidites and some slumps preventing a continued investigation of details of microfabric with reliable results. The Alleroed zone, however, occupies a finely and annually laminated section between 19,69 and 20,13 m (Fig. 2).

Overlapping samples were freeze-dried, impregnated with epoxi-resin and thin sections polished down to 30-40 mikron.The lamina were counted and the sublamina, made up by different parameters (clay/silt, sand, calcite, siderite, organic matter) forming conspicouos, largely individualized bands, were measured under the microscope. Low magnification was preferred to maintain the control of the irregularities of the fabric. The thickness-"units" in the diagrams of Fig. 1 are 0,077 mm each. The thicknesses of the sublamina cannot be compared to results of chemical analyses, as an example may clarify: 6 units of siderite may mean that densely arranged siderite crystals are floating in a matrix of jelly-like organic substance. The latter can neither be excluded from the band of siderite, nor can it be added to the adjoining organic sublamina. On the other hand are sparse crystals of siderite not considered which occur in the organic sublamina outside of the siderite band.

Counting errors can be excluded where the boundaries of the indivual sublamina can clearly be identified and their thicknesses measured. This has been shown by repeated counts of different sides of the slides and of two different cores. However, there are in the lower part or the section zones with poorer preserved lamina with less distinct boundaries where counting errors of up to 10 % are possible. An overall error of 2-3 % will not be exceeded.The control counts were better than 2%.

Results

The composition of the annual layers.

The organic matter is the primary constituent of the alleroedian varves in the Hämelsee. Coarser particulate organics are deposited during fall and winter. They are structured but highly decomposed under anoxic conditions, to an extent that primary cell fabrics are destroyed and the particles cannot be identified and attributed to original organisms. The upper part of this layer may contain diatom frustules and chrysophyte cysts occurring in the lake during late winter and spring. However, opaline silica is frequently dissolved under the conditions prevailing in the Hämelsee monimolimnion during Alleroed. Faint streaks of finegrained silt may be present in the background. Extremely fine grained, jelly-like matrix, devoid of any internal fabric represents the summer. Tiny algae (bluegreens) can sometimes be found at high magnification and depending on their optical properties compared to that of the epoxi-resin. The summer layer contains sometimes pine pollen in its lower part. The occurrences of diatoms, chrysophytes and pollen and their position within the structure of the lamina constitute the biological proof of the seasonal/annual character of the lamina.

Siderite crystals floating losely in the summer layer form conspicouos bands like densely and well arranged milky ways. They are mostly made up by tiny (2-4 mikron) rhombohedra with rounded edges. They prevail in the upper half of the studied section, whereas wheat-grain siderite occurs sometimes in the lower half. Siderite is more frequent and considerably stronger in the upper half which most likely indicates more pronounced anoxia. Siderite may also precipitate as a postdepositional mineralisation. It then typically forms very fine grained undistinct cloudy sections, that may be mistaken for the above described "summer siderite". The precipitation of siderite during summer is a chemical proof of the seasonality of the lamina.

Vivianite (not displayed in Fig. 1) occurs in the lower part of the section. It is often arranged in lines of blocky crystals mixed with actinomorphic minerals and finegrained nodules. It is typically concentrated in the organic winter layer. It is now observed in recent winter layers of finnish lakes, and it seems that it is formed during the winter. Vivianite competes with siderite for the iron and indicates less severe anoxia during the older part of the Alleroed.

The calcite crystals found in the profundal zone of the lake show the typical forms of calcite precipitated in the macrophyte belt in shallow water. They are not individual crystals but aggregates. As former crusts on macrophytes some still show imprints of the plants they grew on. The typical triangular forms from chara stems can frequently be identified. They ara now deposited in the winter layer. It follows from Fig. 1 that the calcite at the onset and towards the end of the Alleroed was reworked and transported to the deep part of the basin. It is most likely that this process is due to unique events at the transition to more severe climate conditions as would be a lake level fluctuation, extinction of macrophytes or trees resulting in stronger, wind-induced wave action.

Clay, silt and sand are always associated with the winter layer. They are mostly at its end and near the summer, but sometimes they mark the begin of the winter. Some of the bigger are graded, fining upwards from silt to clay , but most of the clay/silt layers display surprisingly narrow grain spectra. Their majority are not typical turbidites departing from the slopes of the basin, but suspensions brought into the lake from the surrounding area by precipitation or snow melt. Their distribution and the thicker layers at the begin and the end of the Alleroed indicate the transition to and from more severe climate with less dense vegetation cover. The lower frenquency during the temperate part of the Alleroed may be due to normal randomly distributed meteorological fluctuation. In the middle part of the Alleroed they have a low frenquency in the scale of about one decade.

From the different distribution of the clastic silica and the calcite at the beginning and the end of the Alleroed (Fig.1) it can be concluded that they are the results of different processes.

This type of microfacies-study reveals a multitude of sedimentary parameters related to climatic conditions and environmental changes which also affect the physico-chemical system of the lake. A synopsis gives a comprehensive insight in the development of the lake, its surroundings and the climate.

Duration of the Alleroed

Due to much denser sampling than earlier we are faced to the problem where to put the boundries. Here, as in many other small lakes is the transition to the Younger Dryas less abrupt than often assumed. Both pollen analysis (Fig. 2) and microfacies show a rather soft slope of over 100 years towards the Y. Dryas. The reworking of the calcite is without doubt the first indication of a climatic change (100 years after LST). Its is almost 100 years later that Younger Dryas is fully established. Most students accepted the fully developed Y. Dryas as boundary (200 years after LST, see Kaiser 1993 and Kaiser & Merkt in prep.). For practical reasons it is inevitable to choose this way, as different systems are differently sensitive to climatic changes. Not all methods applied on sediments can detect the first faint reaction of natural systems on the begin of change.

The basal boundary against the Older Dryas is in the Hämelsee sharp with the pollen analysis as with the sediments.

The result of 625 ± 15 years is in good agreement with the other data published so far.

Laacher See Tephra

In many lakes in Central Europe which was covered by the pumice of the LST-event on recognizes a marked change after the deposition of the LST. All lake sediments which had been laminated prior to the LST, are bioturbate for several decades after its arrival. The lamination/anoxia is often restored afterwards. It cannot be understood how an ashfall of a few millimetres should influence a lake's physics over decades. There are also biochemical signals which can be attributed to the LST (Schultze 1988/89) and v. Grafenstein (oral comm.) presumes even a faint but conspicuous isotopic signal. The Gerzensee oscillation had its peak earlier. The oxigen isotope-curve is already back near its old height when the LST occurrs.

The Hämelsee is our first lake to maintain lamination, though in a poorer state, across the LST-event. The lake is outside the known ash plume and it had received only 200 mikron of tephra. Nevertheless the lake reacted evidently in the winter after the eruption, when the ash was long deposited and largely overgrown (Fig 1). Sand and calcite was transported to the center of the basin. Eight winter layers of the following ten years contained in part massive bands of clay and silt. Twenty years at latest, the lake had returned to its state prior to the LST.

The increased frequency of clay/silt lamina, the deposition of sand and especially the unique occurrence of calcite ressemble clearly to the sediment patterns at the onset of the Y. Dryas. We therefore conclude, that the above mentioned signals should have been produced by processes similar to those. Consequently, we assume that the LST-event had through aerosols a shortlived influence on meteorological system.

Apparently the lake's system had completely recovered after some twenty years. The onset of the Y. Dryas is not related to the LST.

Conclusions

The Alleroed biozone encompasses 625 calendar years. The pollenanalytically determined upper and lower boundary is in good agreement with the development of the microfacies.

The study of the macrofacies of annually laminated sediments is a useful tool. It yields not only very accurate varve counts but also paleoclimatological and environmental proxy data.

The LST-event occurred 200 years before the Younger Dryas. They exists no relationship. However, during ten to twenty years following the LST, the lake deposited sediments similar to those at the beginning of the Younger Dryas, which should be due to comparable meteorological conditions.

References

Bogaard, P. van Deen (1983): Die Eruption des Laacher See Vulkans.- 348 S.; Dissertation Bochum.

Bogaard, P. van Deen & H.-U. Schmincke (1985): Laacher See Tephra: A widespread isochronous late Quaternary tephra layer in central and northern Europe.- Geological Society of America Bulletin, 96: 1554-1571;

Kaiser, F.K. (1993): Beiträge zur Klimageschichte vom späten Hochglazial bis ins frühe Holozän.- 199 S., 97 Abb., Tabellen; Zürich (KFR).

Lotter, A. F. (1991): How long was the Younger Dryas? Preliminary evidence from annually laminated sediments of Soppensee (Switzerland).- Hydrobiologia 214: 53-57, 3 figs.; (Kluver)

Lotter; A.F. (1991): Absolute Dating of the Late-Glacial Period in Switzerland Using Annually Laminated Sediments.- Quaternary Research 35: 321-330, 4 figs.

Lotter, A.F., Ammann, B. & M. Sturm (1992): Rates of change and chronological problems during the late-glacial period.- Climate dynamics, 6: 233-239, 6 figs.; Berlin.

Schultze, E. (1988/89): Fallstudien zur Paläolimnologie.- Geologjia, 31/32: 437-516, 34 Abb.; Ljubljana 1988/89.

Zolitschka, B. (1990): Spätquartäre jahreszeitlich geschichtete Seesedimente ausgewählter Eifelmaare.- Doc. Nat., 60: 1-226.

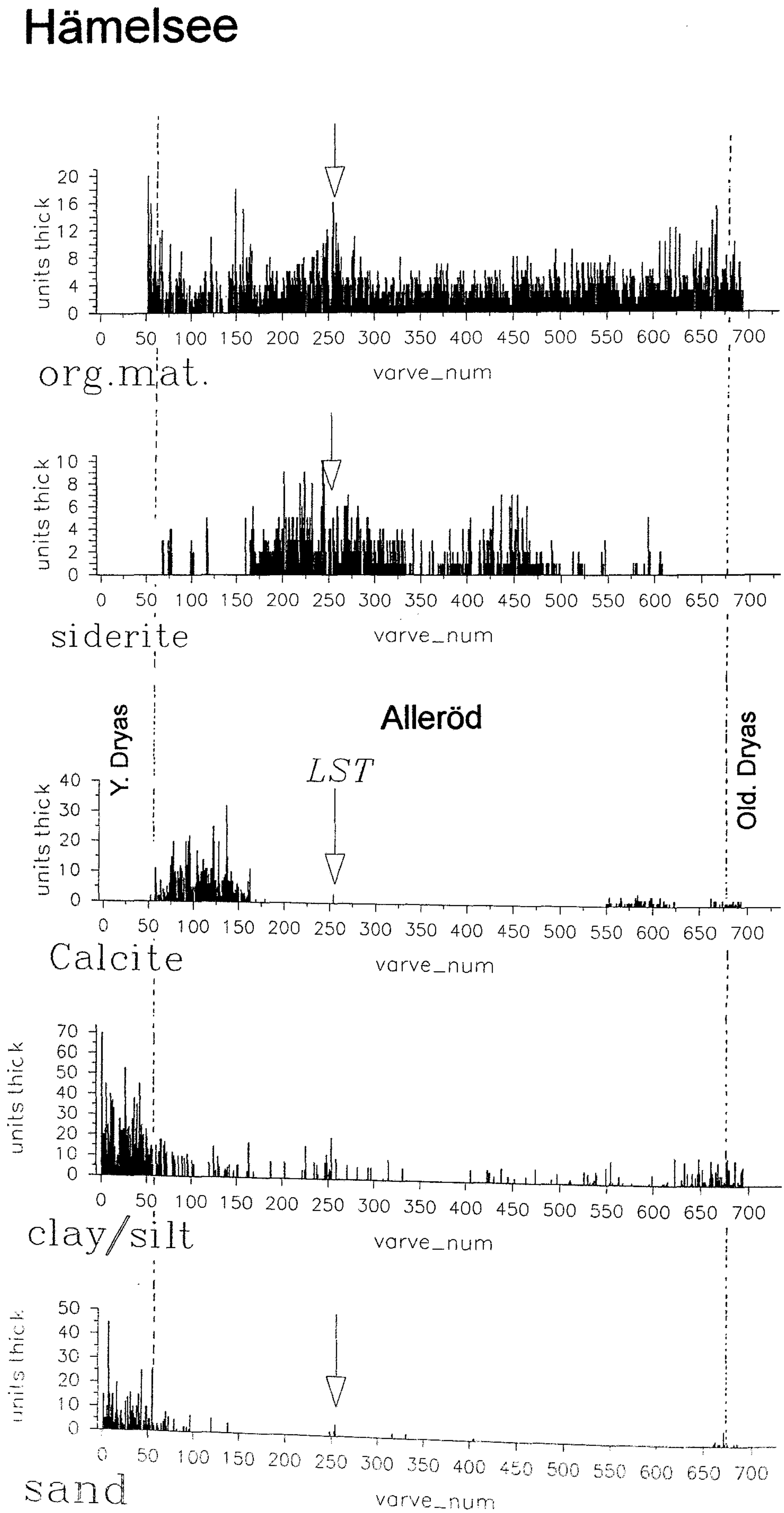
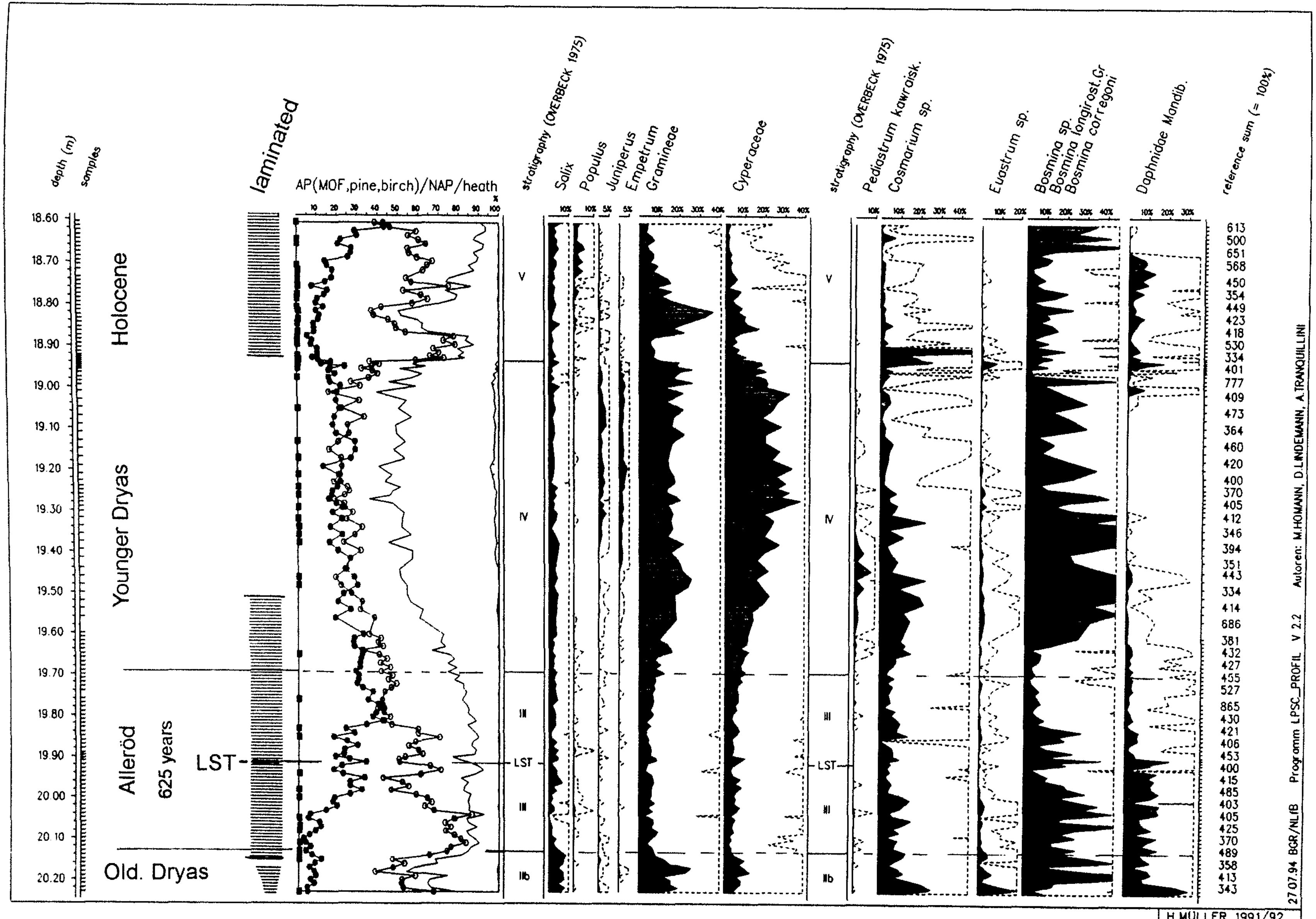

Hämelsee
org.mat.
siderite
Alleröd
Y. Dryas
Old. Dryas
LST
Calcite
clay/silt
sand
units thick
varve_num

Fig.1



Pollen diagram from HAEMELSEE (North Germany), profile HAE 6 A/B

Fig. 2