Pact 41 - II.1 : Josef Merkt and Helmut Müller

Laminated Sediments in South Germany from the Neolithic to the Hallstatt Period

Abstract

The lakes in the Southwest German Alpine Borderland contain calcareous laminated sediments dating from the Boreal period onwards. Pollen, charcoal and sediment analyses have shown that the slash-and-burn agriculture practised by early man had an impact on the sediments from the Neolithic period onwards. The calcite concentrations and the quality of the laminations change repeatedly and abruptly. These changes occur on a scale of some centuries and coincide with the *Fagus* cycles which reflect slash-and-burn agriculture.

Examination of thin sections from a core from Degersee revealed the noncalcareous parts to be massive diatomaceous mud, while the calcareous parts were almost perfectly laminated. The changes occur within one decade or less. In early times, during the Neolithic period, the calcareous lamination ends with a logical erosional input into the lake, but later on, man's presence is almost continuously visible (charcoal, silt and vivianite). More pronounced erosional input causes the lime concentration and the quality of the laminae to decrease. It is concluded that the complex response of the lacustrine systems was caused by the impact of man's activities on the lakes.

INTRODUCTION

Several small, moderately deep (10-20 m) lakes in the Southwest German Alpine Borderland contain calcareous and laminated sediments deposited under calm conditions from the Boreal period onwards. Towards the end of the Atlantic period the concentrations of lime and minerogenic matter begin to oscillate markedly, and during the Subboreal period the lime decreases or ends, so that the previously existing laminations disappear. The contemporaneous installation of neolithic and later cultures is shown palynologically (Müller, 1962 ; Rösch, 1983, 1987 ; Lotter, 1988), and it is accepted that prehistoric man influenced the systems in the lakes from the time of his arrival on their shores (Geyh *et al.*, 1974 ; Zolitschka, 1990), which he occupied periodically (Schlichtherle and Wahlster, 1986 ; Schlichtherle, 1989).

It is unknown, however, how long these periods lasted or in what way and to what intensity man's influence acted on the lakes. Above all, we do not know whether the observed changes in the lakes sediments are due exclusively to human activity or whether they partly reflect climatic changes. Furthermore, if climatic changes played a role, did man reinforce their effects by reacting to the favourable climate, or did early man's activities even have a detectable influence on the climate ? These are difficult questions which are now being tackled in a number of research projects employing high-resolution observation methods.

EARLIER WORK

In addition to their individual features, sediments obtained with a Livingstone corer from Schleinsee and the nearby Degersee displayed, an astounding similarity in their sedimentary aspect and especially in their loss on-ignition (LOI) curves (Geyh *et al.*, 1971 ; Merkt, 1975 ; Merkt *et al.*, 1979). It is therefore easy to draw connecting lines between the two profiles (see examples in Fig. 1). High- resolution pollen analysis carried out on consecutive samples covering about 15-20 years each demonstrated the reliability of these connecting lines. This means that many findings from one of the two lakes can safely be transferred to the other.

Müller (1973) found that conspicuous relationships exist between the composition of the sediments in Degersee and the vegetation history (Fig. 2) : the vegetational sequences began with grasses and herbs and continued with shrubs (e.g. *Corylus* in Fig. 2), and various deciduous trees appeared according to their time of maturity. The sequence ended with a climax beech forest. These sequences occurred repeatedly, the beech forest stage being reached after a few centuries, declining abruptly and a new cycle beginning with grass and herbs. These « *Fagus* cycles » are closely correlated with sediment changes, the peaks in grass and herb pollen coinciding with « ash » peaks, the lime peak coinciding with the development of the deciduous forest (especially *Fraxinus*) and so on. It was out of question that these repeated correlations could have been accidental. By controlling the forest vegetation early man influenced the lake systems. The coexistence of « ash » peaks, possibly indicating erosion, and forest clearing suggests a plausible explanation, although no simple models are available to explain the other parallelisms.

Clark *et al.* (1989) demonstrated the role played by fire in the deciduous forests around Schleinsee in the late Atlantic and Subboreal periods (Fig. 1), and there are undeniable relations between the clusters of peaks in charcoal counts and retrogression phases in the secondary forest. This confirms that the secondary forest successions were controlled by fires caused by human

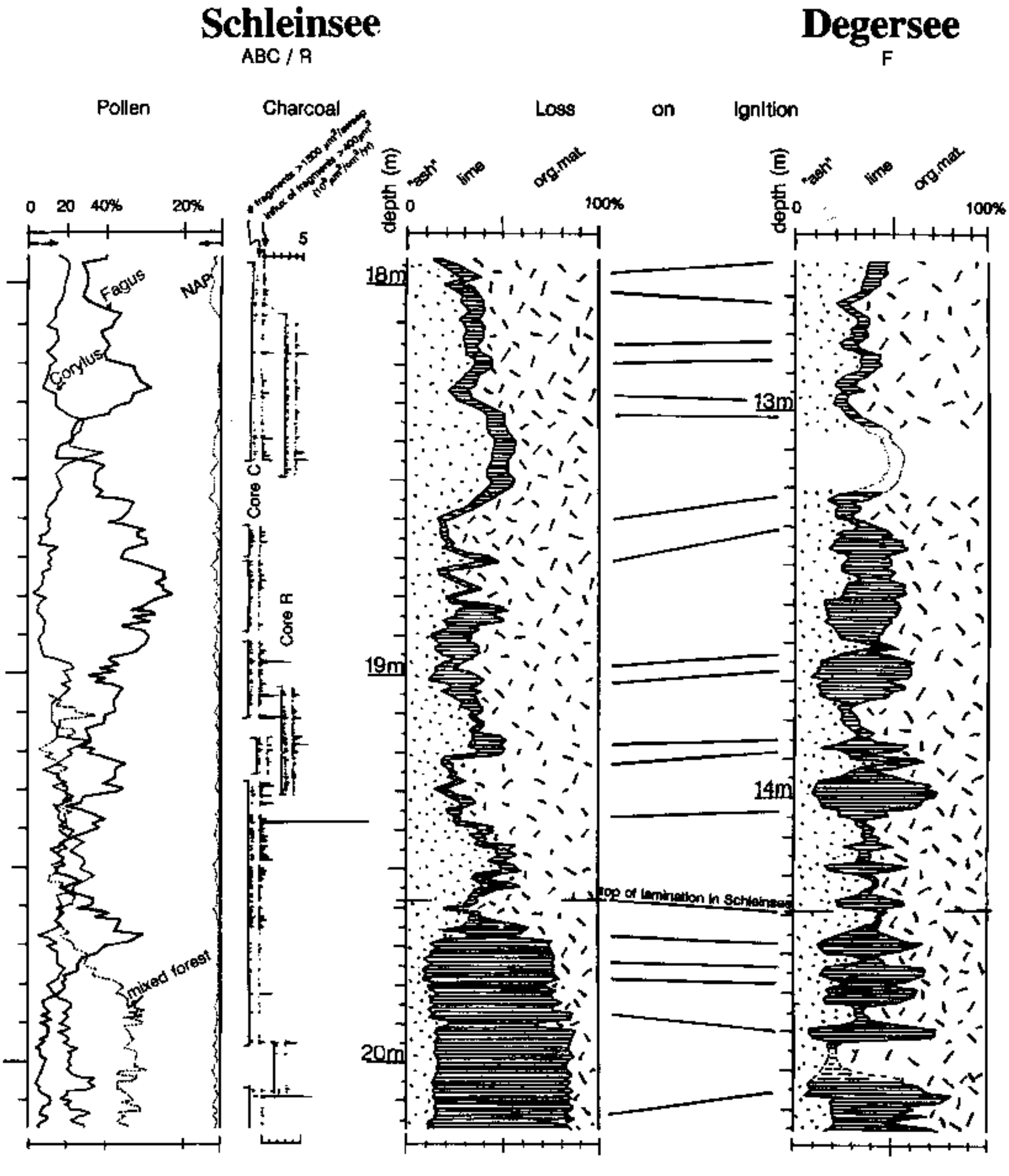

Fig. 1. Comparison of cores of upper Atlantic and Subboreal age from Schleinsee and Degersee (all depths from lake surface). Columns from left: concentration of main arboreal pollen and NAP in Schleinsee, Charcoal influx and fragments in Schleinsee (adapted from Clark et al., *1989), loss-on-ignition (LOI) profile from Schleinsee, LOI profile from Degersee (« ash » is the weight in % after 870° minus weight of the CaO fraction). The connecting lines between the cores are based on the LOI parameters, but they are palynologically verified.*

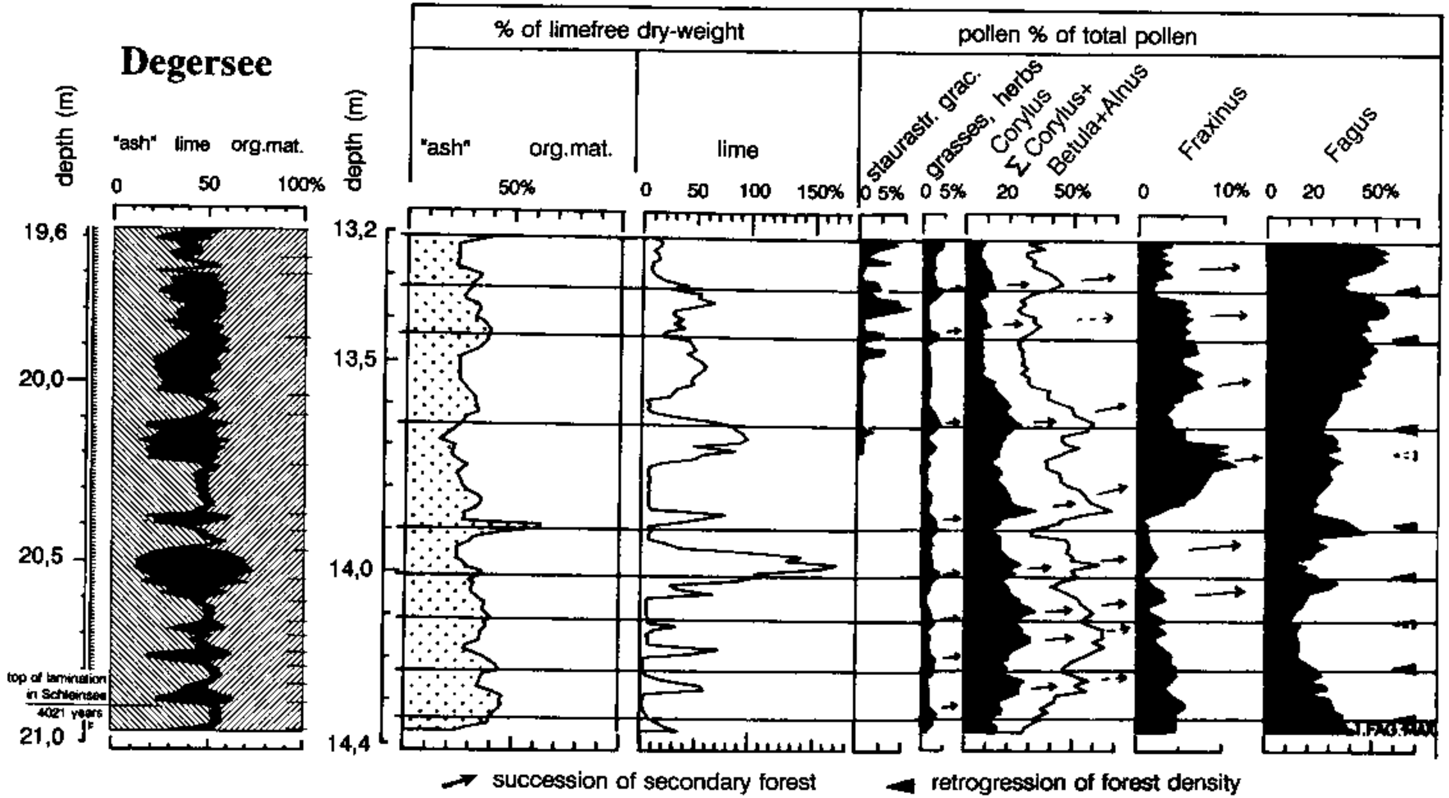

Fig. 2. Degersee, LOI curves for cores H (19.6-21.0 m) and F (13.2-14.4 m, F is identical to F in Fig. 1 but calculated on a different basis) demonstrate the lithological similarities at different depths. Note the close interrelation between lithological parameters and the stages in the succession of the secondary forest (e.g. « ash » and grasses and herbs, partly redrawn from Müller, 1973).

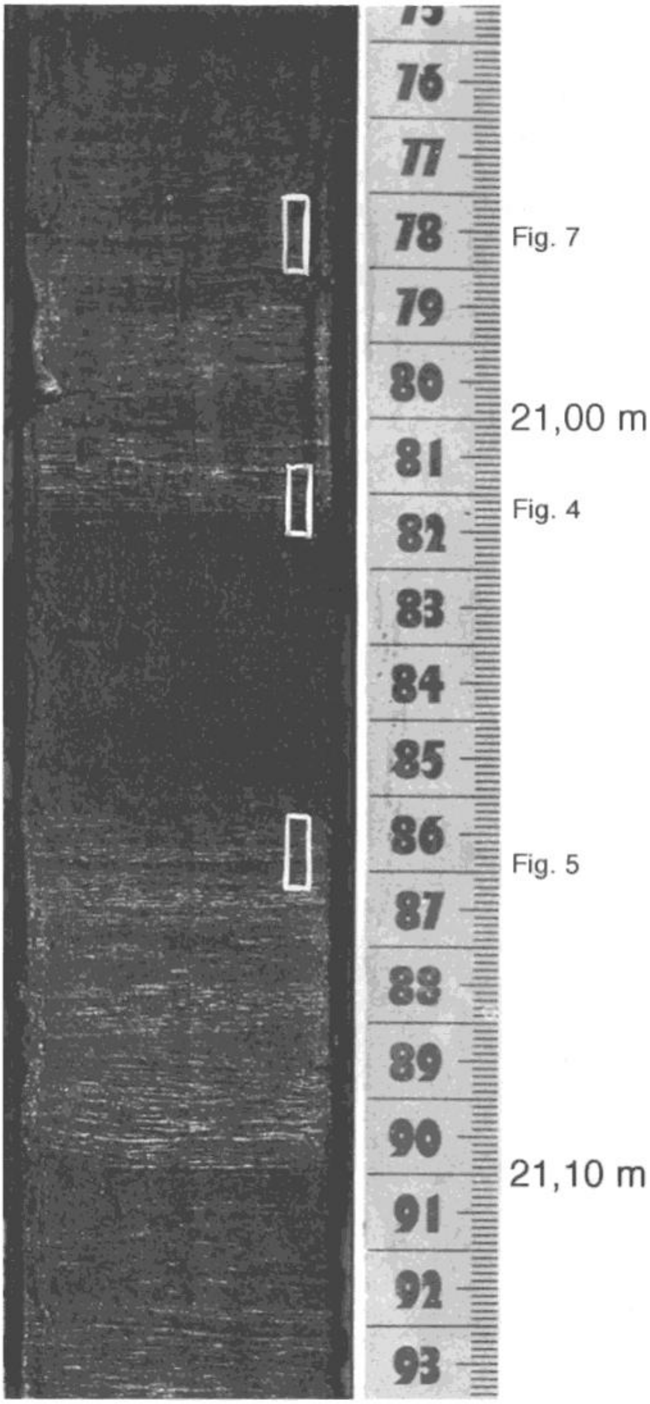

Fig. 3. Abrupt beginning and end of calcareous laminated sequences in the Degersee core H (20.94-21.13 m). Wet mud ; photographed scale : centimetres. The positions of the microphotos in Figs. 4, 5 and 7 are marked.

agency, as corroborated by the concentration of remains of the cladocer *Bosmina longirostris*, a species known to reach its peak at times of forest fires. Geochemical analysis nevertheless shows that the « ash » peaks which parallel the settlement phases do not consist of siliceous minerogenic matter but are almost entirely composed of biogenic opaline : i.e. the presence of early man mainly caused eutrophication through dissolved nutrients brought into the lake. Silica particles from erosion were less frequent in the Schleinsee from Neolithic times up to the Middle Ages, when massive clastic input began. These differences need closer observation.

Varve counts carried out on thin sections from the Schleinsee core (Merkt, 1971) cover 4021 years in an uninterruptedly laminated sequence from the early Boreal to the end of the Atlantic period. The lamination then faded out for several centuries and eventually ended at the decline in

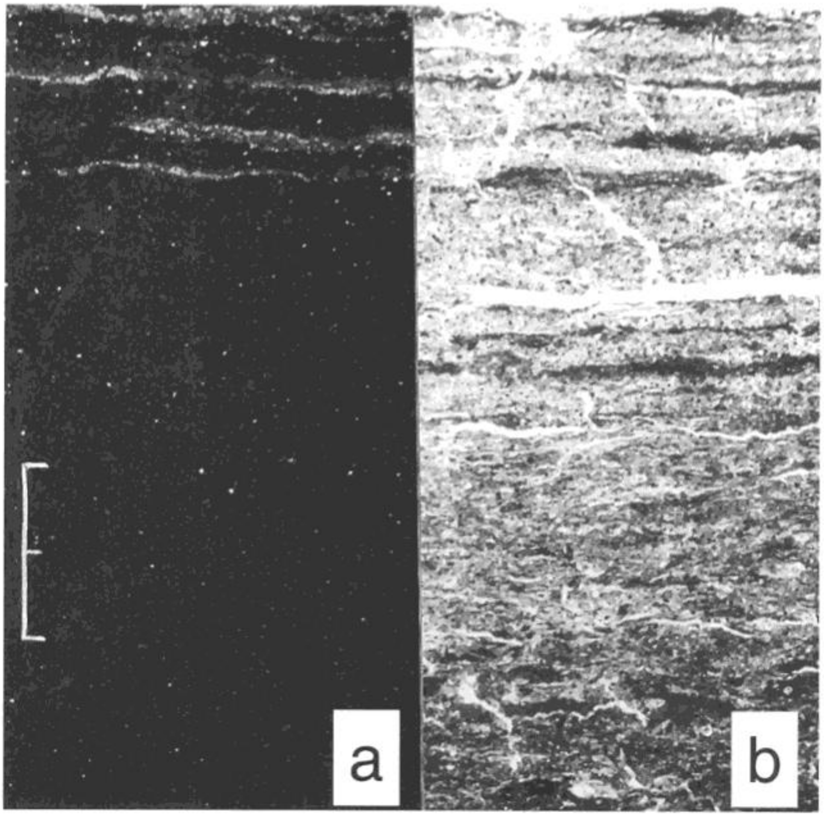

Fig. 4a-b. Distinct beginning of a laminated calcareous cycle (for position, see Fig. 3). Lamination begins first with diatom layers, with calcitic lamina following about 6 years later. a = crossed nicols : calcite is light, organic matter and biogenic silica are black (extinct), minerogenic silica grains appear as occasional light specks ; b = parallel nicols : biogenic silica forms dark bands, bar = 2 mm.

the first peak in beech pollen (« 1. *Fag*.max. » in Figs. 2, 8), with a marked rise in charcoal values (Fig. 1) indicating the presence of the late Neolithic (Hornstaad) culture. Since it became apparent that the Degersee core might contain some 3000 varves more, countable beyond the end of the Schleinsee varves, another core was obtained from the same lake. This core H was from a deeper site than F and promised to have better preserved laminae (Figs. 1 and 2), offering a chance of determining the durations of whole cycles as well as of the conspicuously laminated calcareous parts and non-calcareous parts. Furthermore, it was desirable to learn more about the complex interrelations between human activities, and possibly climate, and the vegetational and sedimentary response.

DESCRIPTION

Laminated sediment and varve counts

Fig. 3 shows a typical segment of the wet core from Degersee. Calcareous units with visible laminae are abruptly separated from massive, dark units, an aspect which perfectly reflects the course of the LOI curves.

An examination of continuous thin sections (each 10 cm long, 2 cm overlapping) showed that the calcareous subunits are seasonally laminated. The varves are of uniform composition, beginning with chrysophyte cysts, which are followed by diatoms. The overlying layer of calcite crystals is coarser at the basis and becomes finer towards the top. This « summer layer » is topped by a mainly organic layer containing the chrysophyte cysts of the next spring in its upper part (Geyh *et al.*, 1974). The calcite crystals are precipitated from the open water and differ markedly from the lake marl crystals precipitated on a marl bench in shallow water. They are mostly rather small (2-15 μm) and skeletal, and are either in a poor, corroded condition or else not fully grown. There are some rare cases, however, in which the crystals reach 20-40 μm and almost form blocks.

The calcareous segments can be counted easily, the varve numbers indicated in Fig. 8 being the means of 3 consecutive counts. The estimated error is 5 %. Surprisingly, the thin sections revealed that the lamination in the visibly massive non-calcareous parts is almost completely destroyed. The lamination is exceptionally well preserved in one sequence, 20.4-20.5 m (see quality of lamination in Fig. 8). The massive units frequently contain minor pieces of single lamina or sets of lamina which escaped complete homogenization (Fig. 6). This demonstrates that there had been a lamination previously which was extinguished by bioturbation and the preserved pieces permit an estimate to be made of the former thickness of the laminae, thus allowing rough estimates of the duration of the units concerned to be obtained by extrapolation. The error may be considerable, however. The counts/estimates for the two types of sediment are kept apart in Fig. 8.

Despite the apparent deficiencies in the counting, the data proved to fit satisfactorily into the framework of dendrochronologically calibrated dates published for prehistoric sites in the area (Billamboz, 1988). The first prominent, sharp and safely identifiable peak in *Fagus* pollen (Fig. 2) is identical to the *Fagus* peak of Rösch (1987), which is dated to 4200 BC. The « Urnenfelder » culture begins about 3140 dendro-years later (Rösch, 1987), while varve counts reach this last culture of the Bronze Age after 2900 years.

Thin section analysis of the Subboreal portion of the Degersee core

Although the sedimentary cycles appear uniform to the naked eye, the thin section analysis showed no general scheme in the succession and

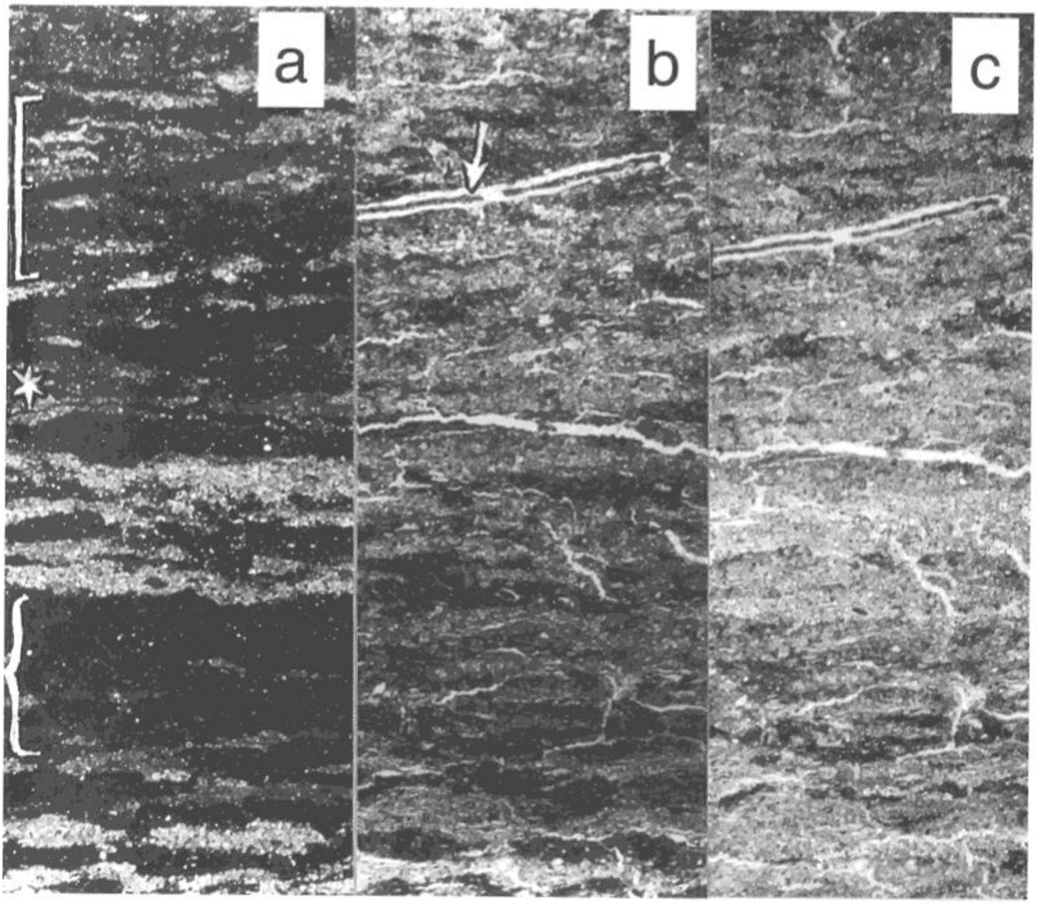

Fig. 5a-c. Indistinct end of a laminated cycle (for position, see Fig. 3). Calcite preservation continues for some years. a = crossed nicols, b = parallel nicols, c = crossed nicols and first order red (gypsum plate), bar 2 mm. Bracket = short-lived clastic input : diatom bloom (c), calcite ceases (a). Asterisk = end of lamination. Arrow = cross-section of a leaf of a deciduous tree.

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The non-laminated parts of the cycles are more or less homogenized by bioturbation throughout (Figs. 4, 5, 6).

The diversity among the siliceous frustules is considerably greater in the calcareous sections, where planktonic centric species prevail, although there are comparatively many epiphytic pennate species. The relative - and absolute quantities of biogenic silica are lower than in the non-calcareous, massive sections, however. The diatom flora in the latter is relatively monotonous. Epiphytic species occur, but planktonic forms are dominant. Chrysophyte cysts are comparatively rare. Thick layers which consist mainly of one planktonic species (*Synedra* or tiny *Cyclotella* or *Stephanodiscus*) must have been produced

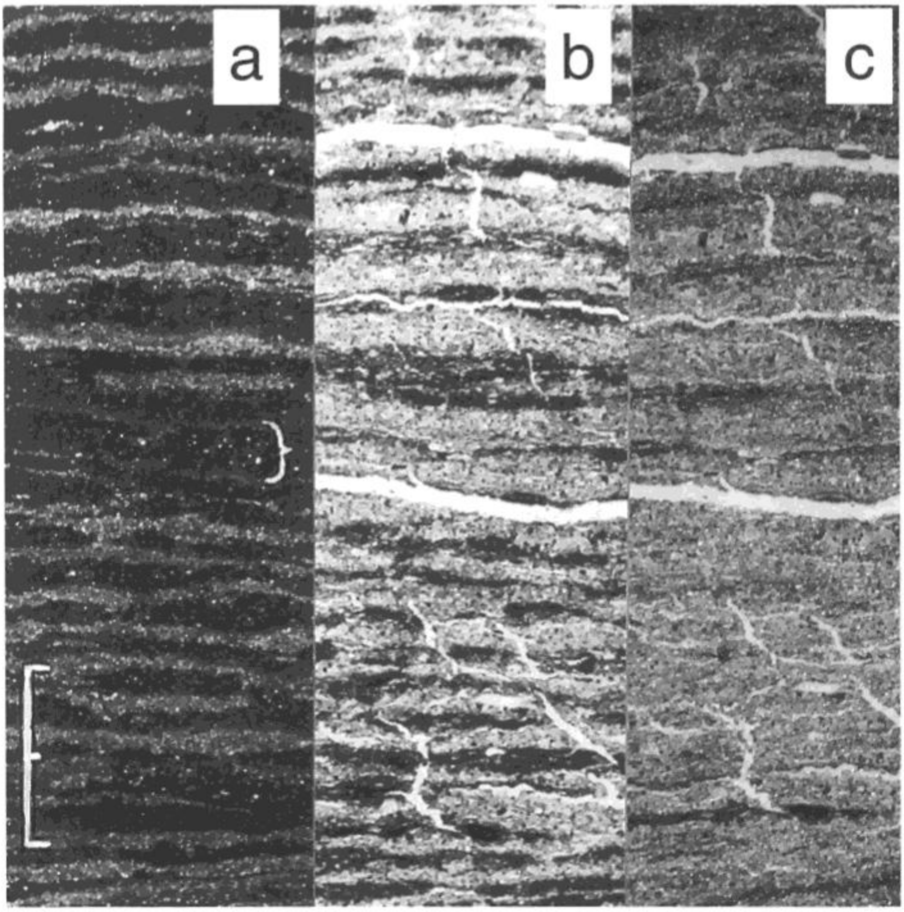

Fig. 7. Interruption of lamination and calcite preservation by short-lived allochthonous input (for position, see Fig. 3). a = crossed nicols, b = parallel nicols, c = crossed nicols and first order red (gypsum plate), bar 2 mm. Bracket = allochthonous input (clear specks) followed by poor calcite layer (a) and biogenic silica (dark bands in c).

repeatedly over a number of several years by algal blooms (the layers are visible to the naked eye).

The role of the allochthonous input in these systems is even more complex. There is practically always a siliceous « noise » at a very low level,

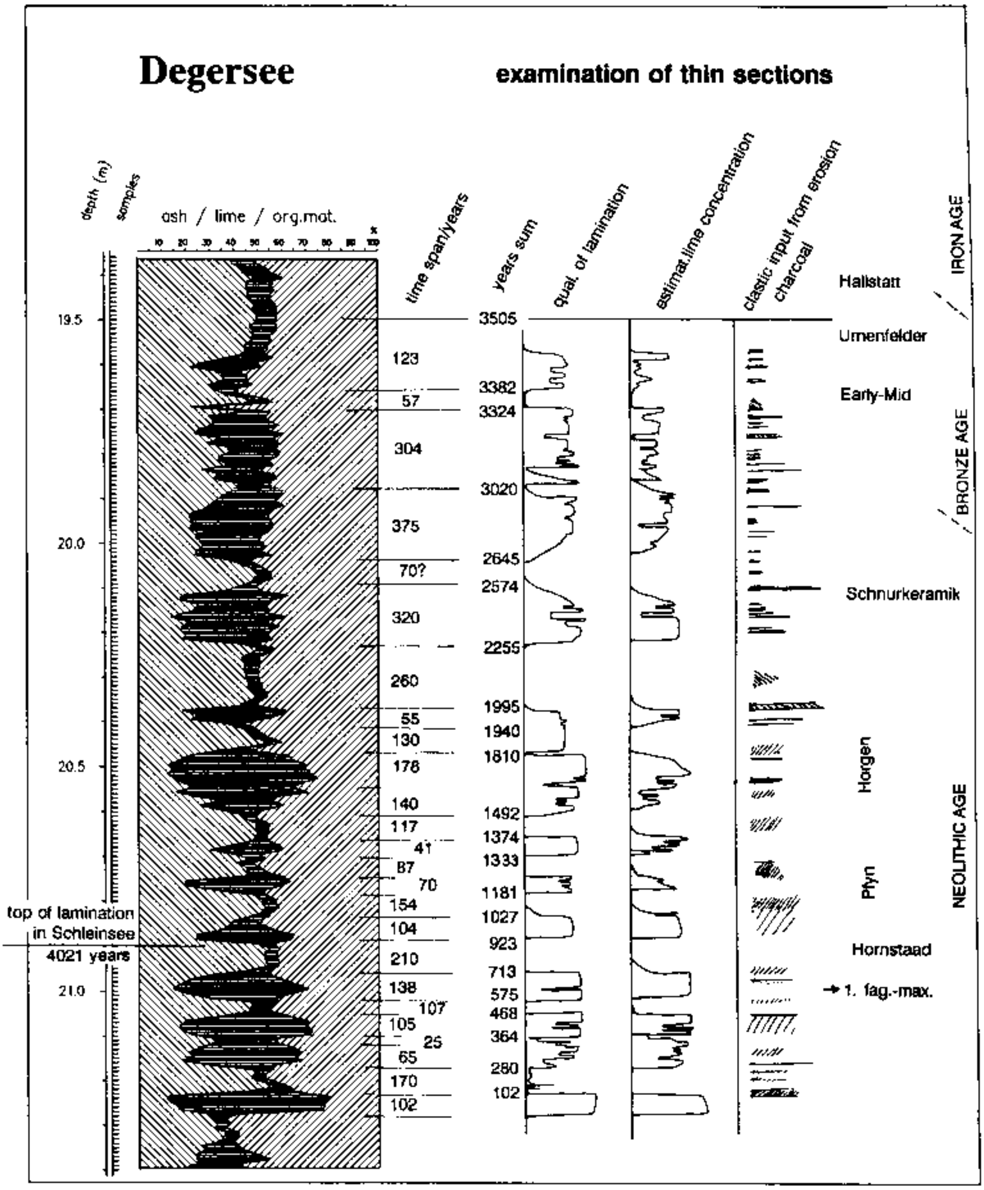

Fig. 8. Varve counts, prehistoric cultures and lithological examination of thin sections of the Degersee H core. Allochthonous input: hatched = dispersed in zones, lines = short-lived, clearly limited input.

but the upper parts of a number of the siliceous massive muds are almost devoid of silt (Fig. 6/left). Dispersed clay minerals in very low concentrations would certainly not be perceptible in thin sections. A fine-grained clastic input in low concentrations sometimes coexists with calcite at the beginning of the laminations. On the other hand, it is apparent that rising admixtures of allochthonous matter cause immediate diatom blooms (tiny centric diatoms) and a sharp decline in calcite. In some such cases a break in the lamination even occurs for a couple of years (Fig. 5, 7). The ends of the calcareous laminated series are normally associated with a marked rise in clastic input (Fig. 5, 8).

The allochthonous clastic input frequently contains tiny charcoal particles and small pieces of dark brown organic, non-structured gel matter which we interpret as being soil material. It follows that a considerable quantity of small charcoal splinters reach the lakes not by aerial transport but by being first stored in the soil and then washed across the macrophyte zone into the lake (Clark *et al.*, 1989). The allochthonous layers may also contain larger calcite aggregates similar to those precipitated in the shallow water, as parts of the marl bench have been eroded, too. The allochthonous layers give rise to pyrite framboids and sometimes to vivianite crystal aggregates.

DISCUSSION

Sedimentological data compared with the prehistoric framework

It is apparent that a simple attempt to correlate the « ash » peak and the NAP peaks with human disturbance, and lime, lamination and the recovery of the secondary forest with the absence of early man would be erroneous. From the late Neolithic period onwards the activity of man, although oscillating, is almost uninterruptedly expressed in the sediments (Fig. 8). The major prehistoric fluctuations fit well with our results. The onset of the pile dwelling settlements, the « Hornstaad » culture, approx. 4200 BC, coincides with dramatic changes in many of the observed parameters. The « Pfyn » (= « Cortaillod » in Switzerland) and « Horgen » cultures occupy several cycles. They constitute pile dwelling cultures with densely occupied lake shores in the Alpine Foreland and have a marked influence on the ecosystems of the lake. Between the « Schnurkeramik » culture and the Early/Mid Bronze Age there is a weakly disturbed period of about 7-8 centuries with recovery of the secondary forest and long laminated, calcareous series. This period is in good agreement with a large gap in the record of prehistoric lake-shore settlements. The subsequent « Urnenfelder » culture (Bronze Age) coalesces with the « Hallstatt » culture (Iron Age) in our records. This period is again characterized by major environmental disturbance in the lake sediments.

The comparison of our findings with the published prehistoric time scale is not unambiguous, because the latter is mainly based on dendrochronologically dated poles from excavated villages. The construction or reconstruction of a group of houses, using mostly oak poles, evidently has a restricted bearing on the burning of a forest for agricultural purposes. Poles from villages at slightly higher sites are decayed and not available for dating. Billamboz (1988) shows that the different cultures occupied different time spans in Western Switzerland and on Lake Constance. According to the prehistoric record, the landscape near the eastern part of Lake Constance, where our lakes are situated, was less densely settled. The reasons for this thinning out is unknown and is still being discussed among prehistorians, the pluviosity question having been raised as one possibility.

Although our data indicate that early man was practically always active in the environment of the lakes, they also support the results regarding the prehistory of the area, which point to oscillating settlement densities, allowing the forests and the lake systems time to recover during the periods of lower population density. There are many possible reasons for such population waves, including social, pedological, medical and climatic problems (famine).

Lake level fluctuations ?

Lamination and lime concentration fade out towards the shallower parts of many of the lakes in the Alpine Foreland and commonly end at a water depth of about 8-10 m. Could the oscillating disappearance of lamination and calcite be due to lake level fluctuations, which are reported to have taken place repeatedly in the Subboreal (Gaillard, 1985) ? Fluctuations of this order of magnitude are highly improbable in our lakes, however, especially since the drop of 12.3 m required to bring a layer in core H which is now at 20.3 m to a depth of 8 m would have brought the contemporaneous point at 13.8 m in core F into a nearshore position at a depth of 1.5 m, which is not possible, as the cores F and H are almost identical in their lithology (Fig. 1 and 2). The noncalcareous parts of the Degersee F core could certainly not have been deposited in such shallow water.

Minor, short-lived fluctuations may have occurred, and they could have produced some of the many discontinuous inputs of allochthonous material, but none of them seems to be sufficiently prominent as to have been responsible for a major sedimentological or vegetational shift lasting for centuries. There are no observations which could not be explained by processes less vigorous than secular lake level fluctuations.

Fagus-Cycles ?

Ammann (this volume) discusses the possibility of a natural vegetational cyclicity which might produce « *Fagus* cycles » similar to those in the period considered, but the complex system described here does not fit with such an explanation. There are several objections to this hypothesis. In the first place the durations of the *Fagus* cycles in this region are relatively irregular, and most of them were much shorter than the 600 years required by the « mosaic theory ». A climax forest dying slowly of old age will neither produce erosion, nor favour grass and herbs as markedly as is observed in these lakes. The charcoal record and its correlation with the vegetation history (Clark *et al.*, 1989) finally eliminates any assumption of a cycle of forest growth and decay. Pollen analysis assumes the « *Fagus* cycles » to be contemporaneous, but this remains to be proved for peaks identified over hundreds of kilometres. If it were the case, this would constitute an additional strong argument against the mosaic theory, which implies that the cycles travel across the land in a diachronous manner.

Can the sedimentological cycles be explained ?

Each sedimentary cycle is made up of two subsets, each characterized by a number of parameters. There is a calcareous, laminated subset, with a moderate amount of diatoms and chrysophyte cysts occurring with high diversity (epiphytic and planktonic), and possibly a certain proportion of allochthonous clastic input, which has not been homogenized by bioturbation and has consequently been deposited in a hypolimnion devoid of oxygen for a long period of the year. This part of the cycle is opposed to a non-calcareous subset whose lamination has been destroyed by bioturbation. The lakes were highly eutrophic and produced large quantities of planktonic diatoms, which often occur in monospecific blooms. The particulate allochthonous input is comparatively scarce and almost absent in the upper part. The lake bottom was mostly aerated during deposition of the sediment, as bioturbation was possible in the hypolimnion.

This line of argumentation is supported by the majority of observations, but it should be kept in mind that lamination and the presence of calcite are not tightly linked. There are laminations preceding the appearance of calcite (Fig. 4) or without calcite at all for decades, and calcareous sections which exist for several years in sediments subject to bioturbation (Fig. 5). Nevertheless it seems that they do not in general diverge.

The relation between the vegetation and the state of the lake is somewhat confusing. There is a phase difference between the vegetational and sedimentary cycles, in that the diatomaceous mud is deposited during both the rise *and* fall in the peak of beech pollen. During the « retrogression of the beech forest » (Fig. 2) we note a high concentration of biogenic material, but unexpectedly, the lowest input of minerogenic silica. The laminated sediments occur when the recovering secondary forest has not yet reached its highest wind shelter capacity. Small lakes in a drumlinized landscape should be sensitive to the influence of wind, but we should bear in mind that the time scale for such considerations is a matter of decades. The resolution of our samples is not sufficient to answer questions on time lags between forest development and pollen curves, or on the state of the soil at different forest stages etc.

The relationship between algae and submersed macrophytes constitutes another line of evidence which leaves certain questions open. Massive algal blooms are known to damage the submersed macrophyte belt which is likely to intercept particles washed into the lake and shelter its deep central part from silt, but in the present case we found a scarceness of silt accompanied by a mass development of planktonic diatoms. Calcareous lakes (clear water lakes), which are known to favour submersed macrophytes, show higher amounts of clastic silica in our cases. On the other hand there is *Staurastrum gracile* (Fig. 2), an algal species which parallels fairly well the concentration of calcite during the late Bronze and early Iron Ages. The network of our observations is again too coarse and our knowledge of the past systems of our lakes insufficient.

CONCLUSION

The repeated cycles of secondary forest in the Northern Alpine Borderland are contemporaneous, and the secondary forest successions are controlled by fire induced by human agency. The close interrelationship between the various stages of the secondary forest succession and sedimentation changes in the lakes indicates that Neolithic man had altered the natural environment and thus disturbed the systems of the lakes. No indications of discernible, significant climatic fluctuations have been found. It is still unknown whether or not the presence and activities of early man were controlled by minor fluctuations in the climate or by other mechanisms. Many questions remain open. Observations of a still higher resolution are necessary.

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