# Changing patterns of sediment accumulation in a small lake in Scania, southern Sweden

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## Abstract

Magnetic susceptibility measurements have been used to correlate synchronous depths in ca. 50 1 m. cores of recent sediment from a small lake (area ca. 55 ha) in Scania, southern Sweden. The three-dimensional picture of sediment accumulation which emerges provides a basis for studying sediment deposition patterns through time. Using a palaeomagnetic chronology, the results show that the pattern and rate of accumulation have dramatically altered during the past 350 years, thus making semiquantitative studies of downcore sediment properties in a single core problematical. Possible reasons for these phenomena are briefly discussed.

## Introduction

Palaeoecological studies often use time-consuming or costly methods of analysis, and consequently those based on lake sediments are frequently restricted to single or duplicate cores. Conventional sampling strategies in small lakes choose cores from the deepest or central zone of the lake bed, a choice not usually based on prior knowledge of accumulation patterns, but on generally accepted notions of constant and conformable accumulation in relatively deep water away from shallow margins. Recent studies of spatial variations in sediment accumulation rates (Bloemendal *et al.* 1979; Davis 1976; Dearing *et al.* 1981) do not support the universal application of the concept 'sediment focusing' (cf. Lehman 1975) and illustrate the complex nature of sedimentation in many small lakes. The present paper describes sediment accumulation patterns for two periods in the recent history of the small eutrophic kettle-hole lake Havgardssjö in Scania, S. Sweden (Fig. 1, inset) and discusses possible reasons for the observed phenomena. The study stems from a larger multi-disciplinary project aimed at reconstructing palaeoenvironments in the lake catchment, and utilises the data obtained from a network of cores correlated by magnetic susceptibility (Oldfield *et al.* 1978; Thompson *et al.* 1975; Thompson *et al.* 1980) which form the basis of ongoing total sediment influx calculations.

The lake basin is of simple form with an island, which since a water level lowering of 1.5–2.0 m during the nineteenth century has been connected to the shore. Statistics for the present lake are listed in Table 1, and it is thought that the water body does not undergo thermal stratification but remains fairly well mixed throughout the year. The catchment supports an intensive agricultural land use based on cereals and sugar beet, with some pasture and deciduous woodland. Soils are derived from thick deposits of till and glacial clay and are artificially drained over much of the catchment. Consequently, there is little surface water in the catchment and no well-defined inflow streams.

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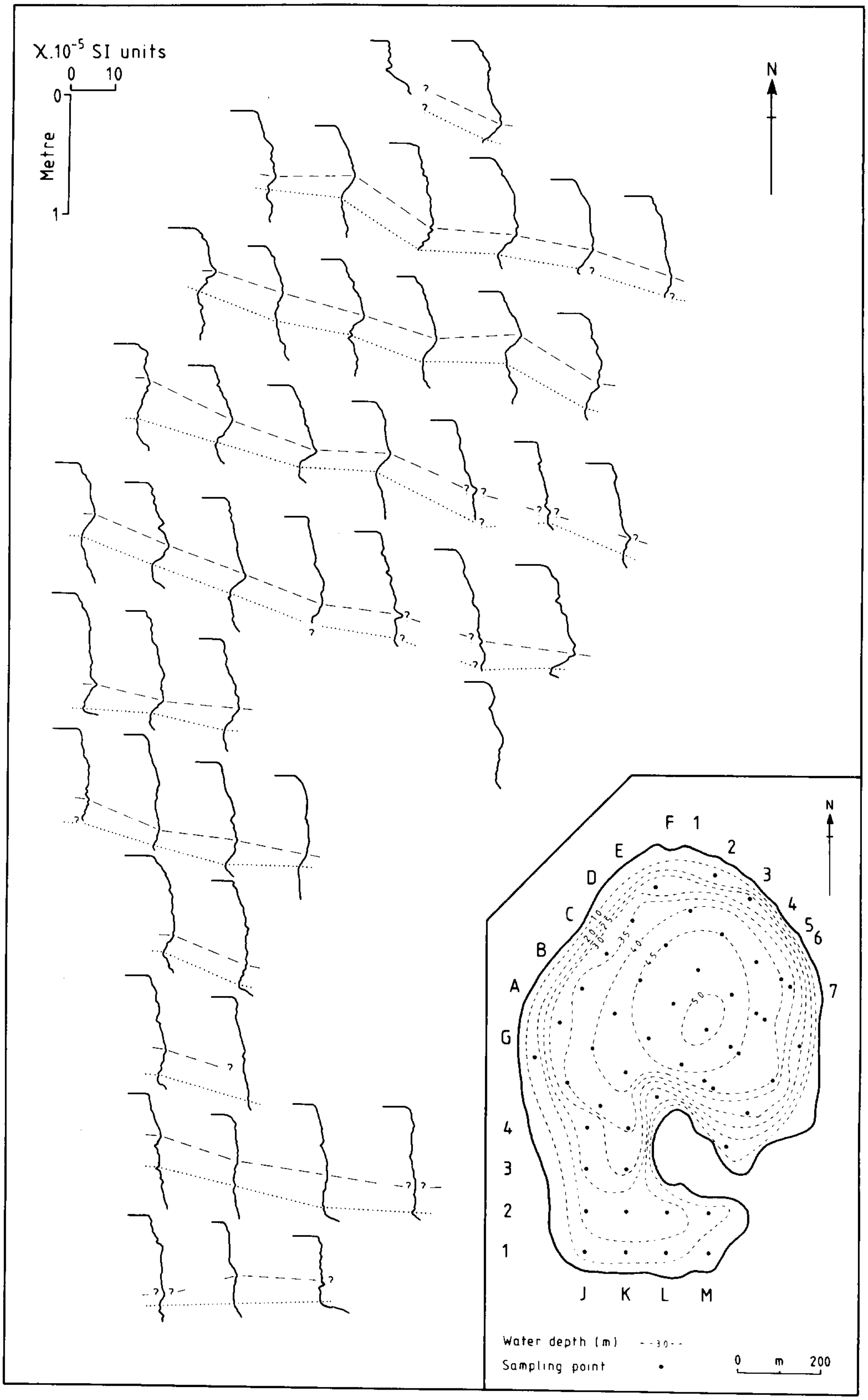


*Fig. 1.* Magnetic susceptibility profiles for 47 1 m sediment cores, showing inter-core correlations between peak values (dashed lines) and between trough values (dotted lines). Dotted lines also mark approximate position of stratigraphic boundary. Inset: underwater contours and sampling grid.

## Methods

Sediment cores were systematically sampled on a ca. 100 m × 100 m grid basis using a simple piston corer operated with rods from an anchored boat and using 1.3 m plastic core tubes. The grid was formed by stretching floating rope between the shore and the peninsular, Turestorpsö, or between the shore and temporary rafts made of polystyrene floats anchored to the lake bed, and marking 100 m intervals on each transect with small buoys or 6 m wooden poles driven into the sediment (Fig. 1, inset). Fifty per cent of the cores were sampled in clear plexiglass tubes which showed that mud-water interfaces remained intact. All cores were carefully stoppered with notched or perforated bungs at the mud-water interface to avoid mixing during transit and magnetic measurement.

Magnetic susceptibility was measured on a Digico long-core susceptibility bridge (Molyneux & Thompson 1973), at 2 cm intervals. Relative declination was measured both continuously (Molyneux & Thompson 1973) and on 5.4 $cm^3$ orientated samples extruded from a 4 m sequence of similarly orientated 1 m. Russian cores using a Digico low-speed balanced flux gate spinner (modified from Molyneux 1971). All measurements were undertaken at the Palaeomagnetic Laboratory, Department of Geology, Lund University. Calcareous bedrock excluded the possibility of using radiocarbon dating (cf Deevey *et al.* 1954).

## Results

The susceptibility profiles are of similar form (Fig. 1) with a major peak and trough in values discernible in all cores except for some near the lake margin and in the extreme shallower southern part of the lake. The synchroneity of the susceptibility peak and trough features seems certain in view of a visible stratigraphic change from dark brown gyttja to light brown clayey gyttja which coincides with the susceptibility trough in all cores which have so far been extruded and examined internally. The single sample relative declination data shows characteristic fluctuations (Fig. 2) which can be assigned ages by comparison with historical records of secular variation (Aitken 1974) and declination 'master curves' based on radiocarbon dated sedi-

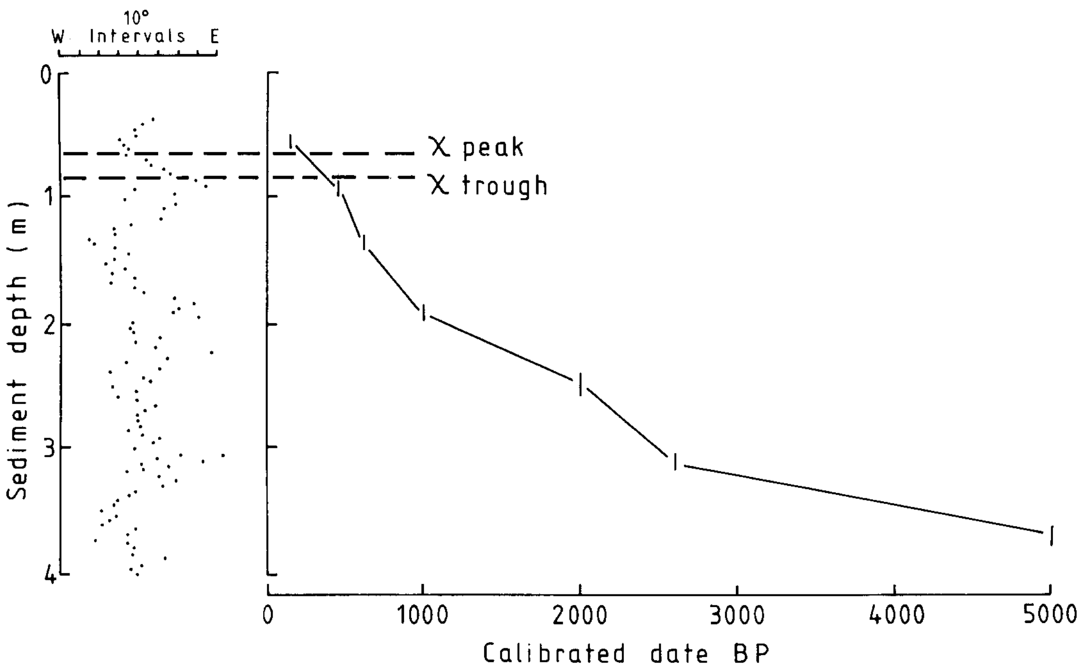


*Fig. 2.* Relative declination data for a central core, with derived depth-age curve 150–4900 BP and position of susceptibility (χ) peak and trough (cf. Fig. 2).

ment cores (Thompson & Turner 1979). The designated age of the lowest declination swing at 4 900 BP is supported by pollen analyses of sediments at 4 m which describe a spectrum characteristic of pre-*Ulmus* decline (ca. 5 000 BP) deciduous forest, with herb pollen frequencies registering ca. 20% of the total pollen sum, and *Ulmus* pollen frequencies accounting for 6–7% of total arborealpollen. From the derived depth–age curve (Fig. 2) the susceptibility peak and trough features can be dated to ca. 1712 AD and ca. 1550 AD, respectively. Using the mud-water interface as the third synchronous level, mean sedimentation rates can be calculated for the periods ca. 1550–ca. 1712 AD and ca. 1712–1979 AD at those sites which are represented by cores exhibiting common susceptibility features. These accumulation rates are shown in Fig. 3 by means of isolines. The earlier period (Fig. 3a) shows a rather uniform pattern of accumulation with maximum values occupying small areas in semi-central regions of the lake in water depths generally not exceeding 4.5 m. A finger of relatively low accumulation rates extends north-west from the tip of the peninsular. Measured accumulation rates range from ca. 0.5 mm $a^{-1}$ to ca. 2.0 mm $a^{-1}$ with a mean value of 1.23 mm $a^{-1}$. In the later period (Fig. 3b) the accumulation pattern is more complex with low isolines extending out from the margins into the central zone of the lake. Isolines of higher accumulation exist in the north-east corner and southern half of the lake, with highest isolines represented by sedimentation in single cores from water depths of 3–4.5 m. Measured accumulation rates range from ca. 1.2 mm $a^{-1}$ to ca. 3.6 mm $a^{-1}$ with a mean value of 2.25 mm $a^{-1}$.

## Discussion

The generally higher levels of accumulation rate in the later period could possibly reflect the low wet density values (g DW $ml^{-1}$) of the uppermost levels

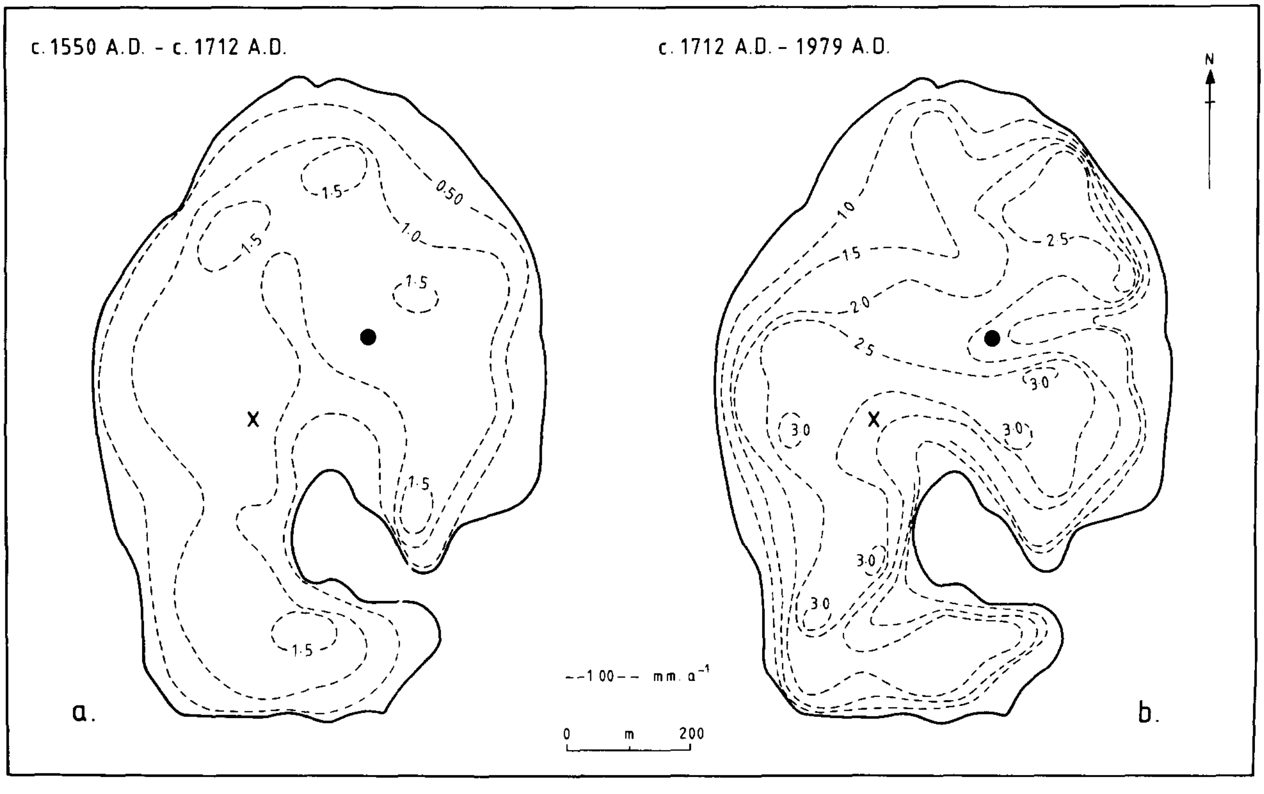


*Fig. 3.* Sediment accumulation patterns for two periods a) ca. 1550 AD–ca. 1712 AD and b) ca. 1712 AD–1979 AD. ● marks deepest zone, X marks core with mean sedimentation rate during both periods.

of sediment. There the values are 50–80% lower than the general range of values for levels in the uppermost metre of sediment. However the mean thickness of the section of sediment above the susceptibility peak is 60 cm and adjustment for the different wet density values would effectively reduce this value by only ca. 5–10 cm, a drop in the mean accumulation rate to 1.87 mm $a^{-1}$ (cf. 1.23 mm $a^{-1}$ in the lower zone). The higher accumulation rates cannot be explained by increased water content alone and seem likely to reflect increased sediment flux to the lake bed. Disucssion of the possible causes for this phenomenon lies outside the scope of the present paper, but preliminary studies of total sediment influx and the history of farming in the catchment indicate progressive soil erosion from 1600 AD to the present time (Oldfield *et al.*, in press).

Different patterns of sediment accumulation are caused by changes to the internal dynamics of the limnic system. The observed patterns could be artefacts of complex slumping-redeposition cycles where different zones of the lake are periodically subject to gain or loss of sediment as thresholds for sediment slope stability are transgressed. But the close correlation between widely spaced cores suggests that sedimentation at the majority of sampling sites is regular, and that sediment columns are not solely the product of localised mass sediment movement and deposition. The more recent pattern could be due to the varying thickness of the uppermost labile sediment caused by short term and local turbulence and currents. But, as described above, no core has more than 10 cm of labile sediment and observed differences in this thickness are not large enough to explain the range of sedimentation rates over the lake bed. A more plausible explanation lies with the changes in water movements caused by environmental factors, such as wind exposure. Progressive deforestation and hedge removal in the catchment over the last few centuries (unpublished documentary evidence) has had the effect of increasing the exposure of the lake to wind. Havgårdssjön is bounded to the south, east and north-east by wooded hills rising to ca. 30 m above the lake level, and the lake is most exposed to the west, especially the north-west. A breakdown of wind direction statistics for west Scania in the period 1931–1960 AD (Taesler 1972) for winds originating from west points and east points of the compass gives figures of 48% and 33%, respectively. Observations by Tyge Brahe who kept records for the isle of Ven (lying between Scania and Denmark) during the period 1582–1597 AD showed figures of 40% and 37%, respectively (La Cour 1876), a reduced dominance by westerlies as a result of the greater incidence of anticyclones during the 'Little Ice Age' (Lamb 1977). Conditions were cooler then and it can be assumed that there was a longer annual period of ice cover on Scanian lakes. A combination of more westerlies and greater exposure to them in more recent times is a possible explanation for the observed changes in sedimentation pattern. A wind generated current along the north-west/south-east axis of the central part of the lake may result in the periodic occurrence of a body of relatively turbulent water extending from shore to shore, and at times reaching the deepest lake bed, in which the deposition of fine material is restricted. This material remains in suspension until it drifts laterally into less turbulent areas in the sheltered southern half of the lake, and to a lesser extent the north-east corner, where it can settle out of suspension. A more sheltered and deeper (perhaps by 2.0 m) lake in the earlier period which had annual ice cover might have seen longer periods of relatively calm water in which sediments could deposit conformably over much of the lake bed. The increased depth and shelter of the lake then may have led to the development of a thermocline, with sediment moving from the margins to the centre after overturn (cf. Davis 1968, 1973).

While the results support the idea that sediment generally moves from shallower to deeper water (Davis 1968) as demonstrated by highest sediment accumulation rates away from the margins, they show that focusing of sediment to the deepest or most central area does not striclty occur. In addition, accumulation rates at sites over most of the lake bed are not constant through time, or even of constant proportions of the contemporaneous mean accumulation rate over the whole lake bed. These last observations have implications for studies aimed at interpreting downcore fluctuations in relative or absolute data. Semi-quantitative comparisons of such fluctuations could only be made with any confidence in cores which possessed mean (or some constant proportion of the mean) accumulation rates throughout the whole period since 1550 AD. Although this study is limited to the examination of just two periods it reveals that none of the cores has the mean accumulation rates for both periods. The core which comes closest to having both mean rates is A3 which was sampled 230 m away from the deepest zone of the lake (Fig. 4) in a water depth of 4.1 m. The sedimentation rate for C4, the core from the deepest zone, is very similar to the mean rate in the early period (cf. 1.1 mm $a^{-1}$ and 1.23 mm $a^{-1}$), but is only ca. 70% of the mean rate in the later period (cf. 1.6 mm $a^{-1}$ and 2.25 mm $a^{-1}$). If pollen grains sedimented in a similar manner to the rates and patterns described here, an absolute count in C4 would underestimate mean values within the later period by ca. 30%, thus giving an erroneous and misleading picture of pollen deposition over the two periods.

On the present evidence sedimentation patterns may have altered in many small to medium sized lakes during the last few centuries as a result of deforestation, accelerated erosion and infilling, climatic change or water level lowering. It seems unwise for palaeoecological studies based on recent sediments from such lakes to proceed without information about the spatiality of sedimentation as can be obtained through the correlation of widely sampled cores (cf. Dearing 1982).

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*Table 1.* Lake and catchment statistics.

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|---|---|
| Site | 55°29′N 13°22′E |
| Altitude | 50.8 m a.s.l. |
| Lake surface area | 54.7 ha |
| Catchment area | 141 ha |
| Max. water depth | c 5.5 m |
| Mean water depth | c 2.5 m |
| Annual water depth fluctuation | ±0.5 m |
| Water residence time | 4.6 y |
| Water volume | $1.4 \cdot 10^6 m^3$ |
| pH | 8.20–8.75 |
| Mean rainfall | 594 mm $a^{-1}$ |
| Mean annual temp. °C | 8 °C |

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