Land-Use Change and Lake Acidification: Iron Age De-Settlement in Northern Sweden as a Pre-Industrial Analogue

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Land-use change and lake acidification: Iron Age de-settlement in northern Sweden as a pre-industrial analogue

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Iron Age de-settlement in Hälsingland, Northern Sweden, can be regarded as a good analogue for the possible effects of land-use and vegetational changes on lake acidification without the effect of contemporary atmospheric pollution. Pollen analyses were used to identify vegetational change associated with a de-settlement period *ca.* 500 A.D. and diatom analyses to assess if there was any associated change in lake-water pH. A clear settlement horizon was found in the two lakes studied, indicating catchment disturbance associated with Iron Age agriculture. There was no change, however, in diatom reconstructed pH after de-settlement, during vegetation regeneration, when it has been postulated that the build up of raw humus and change of ion-exchange conditions would result in acidification. Importantly, one of the lakes began to acidify, before liming, under contemporary levels of acid deposition.

1. Introduction

Rosenqvist (1977, 1978) has postulated the possible importance of soil-generated acidity, by ion-exchange mechanisms, to surface-water acidification. He has argued that the demise of the Norwegian outfield system, where cows were grazed in the forest and hills during the summer, resulted in the replacement of 'grasslands' with coniferous forest and heathlands (Rosenqvist 1978, p. 48). He further suggests (Rosenqvist 1978, 1979) that the timescales of forest regeneration, humus accumulation and soil podsolization after land has been abandoned are precisely those over which the streams and lakes of Norway have acidified. Finding suitable modern analogues to evaluate Rosenqvist's hypothesis has proved difficult because of currently high levels of atmospheric pollution. Palaeolimnological approaches, however, provide a means of assessing the possible effects of land-use change in the absence of anthropogenically derived acidity, by using lake sediments that record the effects of past land-use changes, before industrial effects.

A suitable historical analogue for modern land-use changes is provided by the archaeologically well documented depopulation of Iron Age farms and villages in Hälsingland, Northern Sweden, during the Migration Period (Liedgren 1984, 1989). Iron Age settlements were systematically abandoned in the area from *ca.* 500 A.D. and re-settlement did not occur before the Middle Ages (*ca.* 1100 A.D.). Numbers of farms and settlements were high, between 750 and 1000 in Northern Hälsingland (Liedgren 1989). The area immediately east of Sjösjön has over 100 identified farms in an area of *ca.* 30 km^2. Even if all farms were not occupied simultaneously, human and cattle population levels would have been substantial. It has been estimated that some farms had up to 15 head of cattle.

2. Methods and study site

The lakes (Sjösjön and Lill Målsjön; for details see table 1 in Battarbee & Renberg, this symposium) lie inland of Hudiksvall, N. Sweden, less than 2 km from extensive documented Iron Age remains (figure 1; Liedgren 1989). Both sites have been recently limed but before liming they were of low alkalinity and susceptible to acid deposition. The lake sediments were sampled with a Russian corer in March 1987 from the ice surface. Cores were subsampled at contiguous 1 cm intervals through the period known to include the Iron Age settlement horizon. Preparation of samples for pollen and diatom analyses followed standard methodologies (Moore & Webb 1978; Battarbee 1986); pH was reconstructed by using weighted averaging (Birks *et al.*, this symposium).

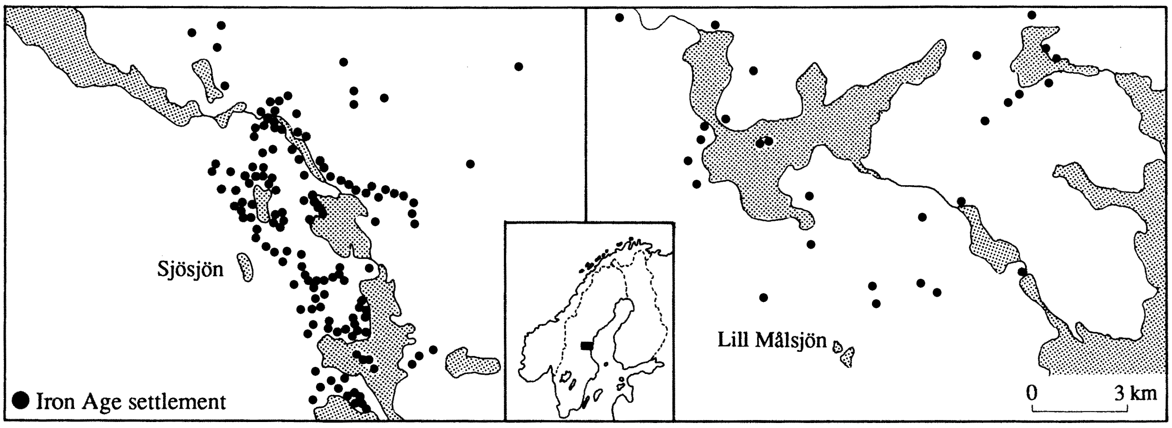

Figure 1. Location of study lakes, showing their proximity to known Iron Age farms (Liedgren 1989). Farms shown are minimum numbers; many sites will have been lost from the record by, for example, modern farming practices; the Lill Målsjön area is also currently under-researched.

3. Results and discussion

Pollen profiles (figure 2) are similar for both lakes, with a clear dominance of *Pinus*. *Picea* values increased *ca.* 500 cm depth in Lill Målsjön and at 1615 cm in Sjösjön, as a result of immigration into the area (*ca.* 2800 BP in Hälsingland). *Betula* and *Alnus* form a subsidiary component of the assemblage. The diversity of pollen types is low at both sites, with low frequencies of shrubs and herbs.

Cultural pollen indicators at Sjösjön increased above background levels at *ca.* 1600 cm, and although cereal grains are not present, the Iron Age settlement period is clear. At Lill Målsjön, there are small but significant increases in shrubs, herbs, graminids and apophytes at the same time as *Betula* increases, and *Picea* and *Pinus* decrease (450 cm depth).

At Sjösjön diatom pH preference groups show no change over the sampled period (figure 2*a*). Diatoms are dominated by pH indifferent (= circumneutral), planktonic taxa, notably *Cyclotella kuetzingiana* and *Aulacoseira subarctica* type 2, and reconstructed pH is uniform at *ca.* 6. At Lill Målsjön, acidophilous diatoms increase from the base of the core, and indifferent taxa vary around 30%. The species assemblage in Lill Målsjön reflects the shallower depth of the lake compared to Sjösjön, with benthic taxa dominant, especially a number of *Fragilaria* spp. (e.g. *Fragilaria virescens*, *F. lata*) and *Aulacoseira perglabra* var. *floriniae*. The planktonic species

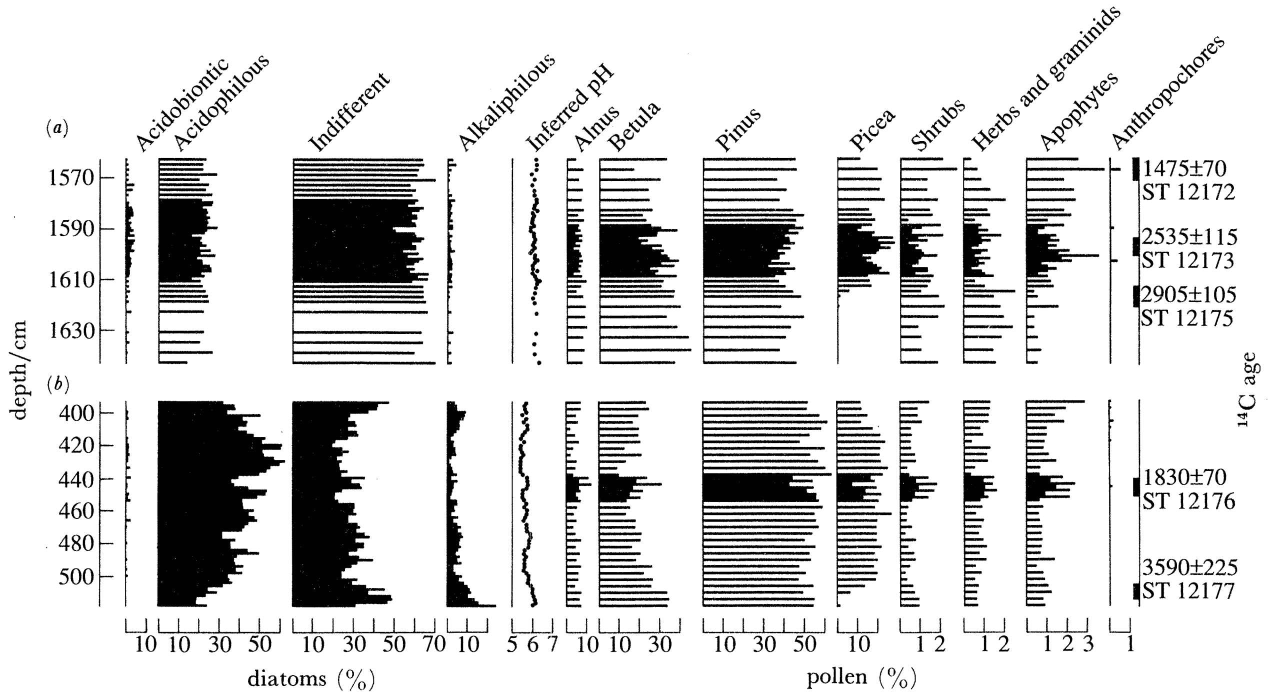

FIGURE 2. Summary diatom and pollen diagrams for (*a*) Sjösjön and (*b*) Lill Målsjön. Depths are centimetres below lake surface. Placement of diatom taxa into pH categories follows the SWAP classification. The pollen sum used for Sjösjön was 500 arboreal grains, but for Lill Målsjön *ca.* 2000 grains were counted to identify the cultural horizon. Grouping of pollen taxa into apophytes and anthropochores follows Engelmark & Wallin (1985). Note scale change for non-tree taxa. Dating: the *Picea* increase in coastal Hälsingland has been dated to *ca.* 2800 BP in varved lake sediments and peat-bogs. The ^{14}C dates, although progressively younger upcore for Sjösjön, are slightly old for both lakes, given contemporary knowledge of the dates of the late Iron Age settlement in this area, and its decline in the Migration period. Similarly, the date for the *Picea* increase at both sites is too old, compared with other sites. The sediments may be contaminated with older carbon from the catchment or ground water.

generally occur at low values (e.g. *A. distans* var. *tenella*, *Asterionella formosa*) although percentages are variable upcore, occasionally $>20\%$; pH reconstructs to 5.4–5.5.

The number of Iron Age archaeological sites in Hälsingland (see, for example, figure 1) indicates substantial populations, sedentary agriculture, and presumably significant effects on the landscape in terms of forest perturbation (Engelmark & Wallin 1985; Liedgren 1989). Animal husbandry was based on the outfield system as the lower-level fields (the home farms) were utilized for arable cultivation and winter-fodder production. The catchments of Sjösjön and Lill Målsjön would have been used for outfield grazing by sheep or goats and cattle, as they lie just outside the homestead areas (Engelmark & Wallin 1985; Liedgren 1989; cf. Hicks 1988). The effect of this grazing on the understorey, and on the regeneration of *Pinus* and *Picea*, would have been substantial (Steen 1958).

Phytosociological studies of the effects of cattle grazing in boreal forest systems in the immediate post-World War II period have been done by Steen (1958). The effects are probably analogous to those resulting from Iron Age agriculture, and importantly, are similar to changes discussed by Rosenqvist (1978, 1979). Grazing of coniferous forest results in the enhancement of grasses, and the appearance of new herbs, whereas shrubs, lichens and certain mosses are reduced and the forest as a whole becomes thinner. It can also result in a transformation of the forest podsols into brown-earth soils (Steen 1958).

The decline of the Iron Age culture and abandonment of the homesteads, associated neglect of arable land and the end of grazing, will have resulted in the regeneration of natural vegetation. On the cleared cultivated land, regrowth of mixed *Picea–Pinus* forest occurred. In the grazed forest areas the natural understorey regenerated with a mixed low shrub layer of *Calluna*, *Vaccinium* and *Empetrum*, eventually leading to the accumulation of raw humus again (cf. Rosenqvist 1978, 1979).

The question of identifying the effects of early people on Scandinavian vegetation from pollen diagrams has been the subject of extensive discussion and remains problematical (Berglund 1985). Substantial disturbance to boreal forest vegetation may leave only a faint pollen record (Hicks 1988). The Iron Age culture in Hälsingland leaves no major signal in the pollen diagrams despite the extensive archaeological evidence for occupation (Engelmark & Wallin 1985). In this context, the changes recorded at Lill Målsjön and Sjösjön are a clear indication of cultural activity around the lake.

The Sjösjön diatom profile shows stability throughout the analysed period and there is no change in pH. At Lill Målsjön there is no decrease of pH below 5.4. The diatom floras and inferred pH values are not similar to those of recently acidified lakes, which are often characterized by the expansion of acidobiontic taxa. These findings are particularly significant as analysis of the recent sediments of Sjösjön demonstrate the sensitivity of the lake to acidification since a characteristic *Cyclotella* decline occurred in the lake before liming (N. J. Anderson, unpublished results).

Human impact on catchment vegetation can undoubtedly cause perturbations to lake ecosystems (Fritz 1989; Renberg, this symposium), but it appears unlikely that changed land-use is itself sufficient to cause lake acidification. Palaeolimnological results do not support the hypothesis that catchment-generated acidity has the ability to acidify surface waters to the extent observed over recent decades in the absence of atmospheric inputs derived from fossil-fuel combustion. In Hälsingland, there is no fossil diatom record of early acidification at the study sites, after the cessation of Iron Age agriculture.

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