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Land-use history in Gamla Uppsala

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Pollen analysis was used to clarify the history of land-use in Gamla Uppsala. Changing edaphic and topographic conditions due to land upheaval processes are estimated. Corings have been made in former lake sediment in areas that are dry ground today. Carbon-14 age determinations show that detailed knowledge of geological processes is crucial in evaluating pollen records. A preliminary land-use history for the area is given, from the Pre-Roman Iron Age up to the Early Viking Age.

Introduction

The aim of this work is to establish the land-use history for the site Gamla Uppsala. Within the area there are no obviously suitable sites for such investigations. However, complicated sampling localities had to be chosen, and the investigations of these have increased our knowledge of pollen deposition in different environments. Complicated stratigraphies cannot be interpreted in the same way as localities where continuous and contemporary deposition of pollen may be expected. With awareness of the processes of sediment deposition, the pollen record may give useful indications of cultural landscape development.

Gamla Uppsala and its region are affected by isostatic land upheaval. It is, therefore, possible in some places to find former lake sediments in areas that are dry ground today. The stratigraphies presented here are taken from such basins.

Gamla Uppsala is a famous ancient monument area (fig. 1). The most striking features are the great mounds in which kings may have been buried. It seems that Gamla Uppsala was the most important kingdom of the small kingdoms in adjacent provinces. Its organisation is considered to be the origin of the Swedish State. Gamla Uppsala has also been mentioned as a religious centre, originally in heathen-times, but also in the Christian era; a church for a Christian bishop was built (c. AD 1100).

Gamla Uppsala is, accordingly, extremely interesting for the knowledge of the history of the Swedish State. Within a project called "Man, economy and environment in Gamla Uppsala – Long-term sustainable land-use planning based upon ancient and modern parallels" palaeoecological investigations as well as archaeological studies are being carried out. A combination of palaeoecological and archaeological knowledge will be used in the establishment of environment impact descriptions of human activities in the landscape from different time periods.

Materials and methods

Physical characteristics of the investigation area

Quaternary geology: The area in the vicinity of Gamla Uppsala is characterised by esker sectors surrounded by a flat agricultural landscape on glacial and post glacial clay. The esker sectors reach about 50 m a.s.l. (metres above sea level), the surrounding clay fields are, on average, at between 16–25 m a.s.l. It is therefore possible to distinguish edaphically clearly separated areas, one with well-drained soils and the other less well-drained, and more compact.

Land elevation: After the deglaciation the whole area lay below sea level. Through isostatic changes (land upheaval), new land was gained from the sea. At present, the land upheaval is 4.9 mm/year (topographic map, Uppsala NV). Uppland is a young district as regards land upheaval.

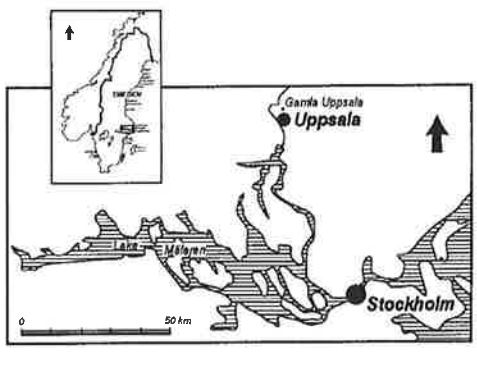

Figure 1. Position of the investigation area in Sweden.

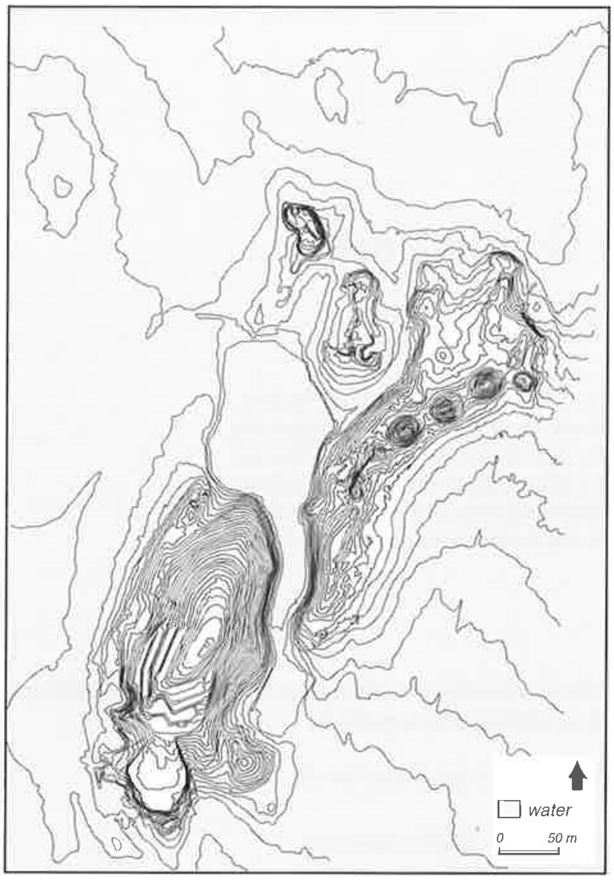

Figure 2. The relation of land and water when the waterlevel was at 25.5 m a.s.l. This level was reached approximately 2900 years BP.

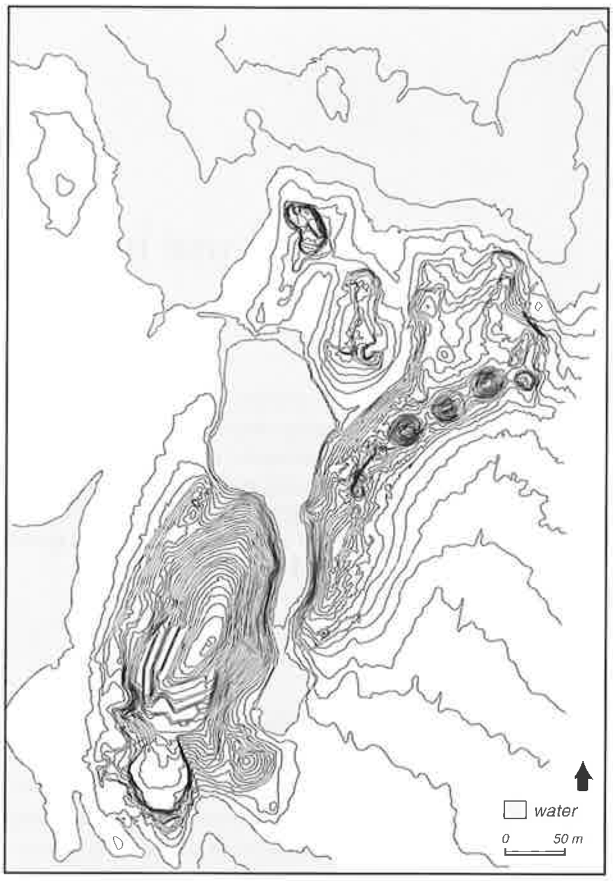

Figure 3. The relation of land and water when the waterlevel was at 18.5 m a.s.l. This level was reached approximately 2500 years BP.

For the investigation area, a map with 1 m contour intervals is presented (figs. 2–3) (redrawn after a map produced by the National Board of Antiquities. In the original map the interval is 0.5 m).

No shore displacement curves have been constructed for the investigation area, as there is a lack of undisturbed lakes at suitable levels above the sea where such studies can be performed.

Available modern shore displacement studies deal with the Lake Mälaren region. Brunnberg et al. (1985) present a simplified curve covering the last 10 000 years for the Stockholm region (cf. Miller & Hedin 1988). The degree of land upheaval differs according to the load of the ice depression. A tilting effect appears, which means that in this area land elevation is greater at Gamla Uppsala than in the Stockholm region.

However, with an awareness of the inexactitude, the Stockholm region is used in this discussion. The land upheaval in the Stockholm region is at present 4 mm/year (Ussisoo 1977). The assumption is made that the difference in land upheaval has been constant for the Stockholm and the Uppsala region (22.5% higher land upheaval in Uppsala). On this basis, two maps illustrating the relation of water and land at two different times are presented (figs. 2 & 3). At about 2900 years BP only esker sectors reached above the water level, which was at about 25.5 m a.s.l. The approximate time when the water level was at about 18.5 m a.s.l. is 2500 years BP.

It is suggested that the main sub-fossil diagram locality "Myrby träsk" became isolated when 18.5 m a.s.l. was reached. In contrast with the approximate isolation time estimated from the Stockholm curve, Åse & Bergström (1982) have produced a curve based on observations of isolation contacts, determing age through ^{14}C-dating, pollen analyses and archaeological methods. In this curve, the level 18.5 m was reached between 3000–2680 BP in the Uppsala region.

About 2000 years ago the water level was around 10 m a.s.l. and that implies that the whole area presented was then above the current water level.

Selection of sites: Two localities have been investigated (fig. 4). Myrby träsk and S Tunåsen. Both are examples of former shallow lakes, which dried out following isolation due to isostatic uplift (cf. Högbom 1905 and Florin 1963). The potential of Myrby träsk as a locality for a palaeoecological investigation has been investigated earlier (Königsson et al. 1993).

Field work: On Myrby träsk and on S. Tunåsen

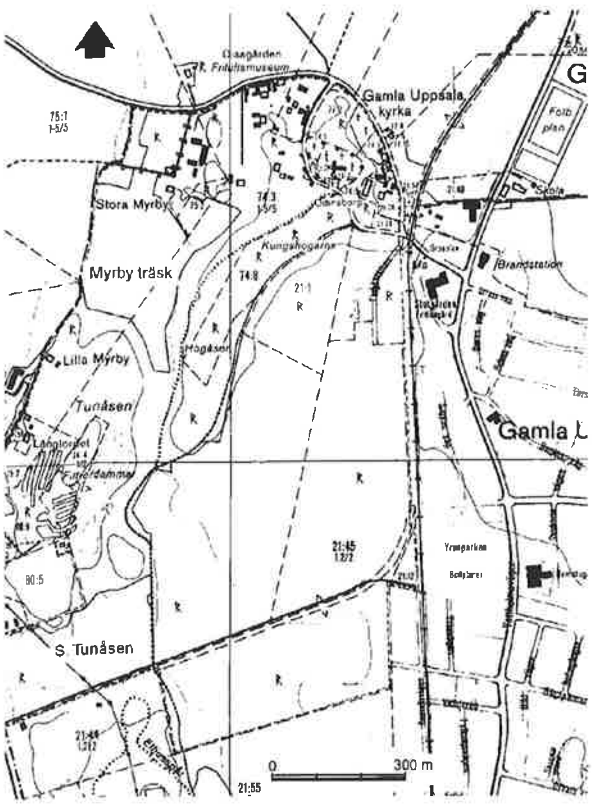

Figure 4. Sampling localities, Myrby träsk and S Tunåsen. Economic map 11I 8a Gamla Uppsala, 1982.

shafts were dug down to the groundwater level. In the shaft walls samples were taken out in metal boxes. Deeper down, coring with a corer of Russian type was carried out.

Other points in the Myrby träsk basin have been checked regarding the extent of different sediments, and pollen analyses have also been conducted. The samples were collected at the best stratigraphical points.

Laboratory work, pollen analysis: The samples for pollen analysis were treated according to the acetolysis method. Samples were left in hydrofluoric acid for some days (cf. Erdtman 1936; Jørgensen 1963; Berglund & Ralska-Jasiewiczowa 1986). *Lycopodium* spores in the form of tablets with a known amount of spores were added (Stockmarr 1971).

A magnification of < 200 was used for routine counting. All demanding determinations were made by using < 1000 magnification and supported by phase-contrast equipment. When making the pollen analysis identification, keys by Fægri & Iversen (1989) and Moore et al. (1991) were used. The reference collections of Institute of Earth Sciences, Quaternary Geology, Uppsala University, were a further help for the determinations.

The degree of destruction was estimated according to the methods of Troels-Smith (1941) and Jørgensen (1963).

Parallel to sub-sampling for pollen analysis, samples comprising 2.5 cm were picked out for disaggregation in order to find macrofossils. The soil classification is based on organic content in the deposits. Loss-on-ignition was performed according to Aaby (1986). The loss-on-ignition content was calculated in per cent of the dry weight of the samples.

Radiocarbon dating: One of the main aims of the palaeoecological investigation is to establish a reliable and well-defined time scale for the land-use history. The representativity of a radiocarbon age for a depositional event depends on the carbon source of the material used for dating. Both macrofossils and pollen of terrestrial origin are considered as well suited for dating sedimentation events. Within this investigation, age determinations have been performed on macrofossils, the pollen fractions and bulk samples. For further information on pollen concentrate datings, see Eriksson et al. (1996).

The datings were carried out at the The Svedberg laboratory, Uppsala University. The tandem accelerator technique based on direct ion counting has been used (Possnert 1990); corrections correspond to $\delta^{13}C$. The dates are given in uncalibrated radiocarbon years before 1950 (BP). The radiocarbon dates are calculated with a half-life of 5568 years.

Diagram construction, pollen diagram: Proposed pollen zones are conventionally defined pollen assemblage zones (PAZ). Charcoal graphs report charcoal fragments with size > 10μm.

In main pollen diagrams the basis for the calculation is the total amount of pollen, apart from aquatic species. Spores and charcoal are calculated outside the pollen sum (figs. 5 & 6).

Results and interpretation

Myrby träsk

Soil material: The soil stratigraphy consists of, from the base: gyttja clay, clay gyttja, gyttja, clay gyttja and gyttja clay.

The sequence of clay gyttja, deposited in a brackish/marine environment succeeded by gyttja, illustrates a shallowing of the basin with increased organic production as a result. A normal development for a former lake should be a peat sequence resting above the gyttja sequence.

In Myrby träsk this is not the case, since clay gyttja and gyttja clay rest above the gyttja sequence. The increased amount of inorganic particles may show some erosional events in the surrounding areas.

Radiocarbon dating: The radiocarbon dates are presented in figure 7.

In the gyttja sequence fruits of *Seseli libanotis* are ^{14}C-dated. *Seseli libanotis* is a plant from the Apiaceae family and grows on dry ground rich in nutrition (Mossberg et al. 1992). Since the plant is terrestrial, the ^{14}C-age should not be affected by the reservoir age (table 1).

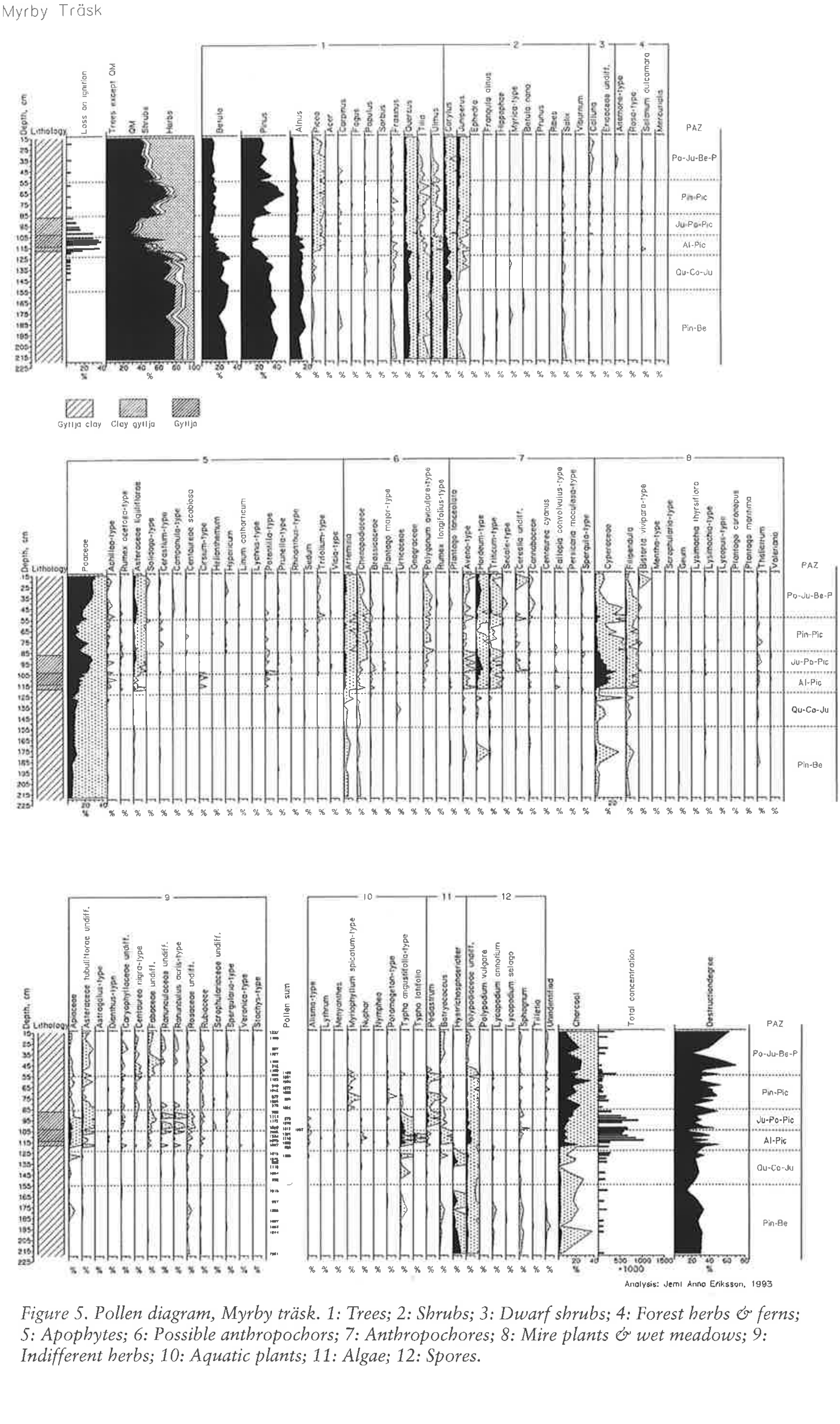

Figure 5. Pollen diagram, Myrby träsk. 1: Trees; 2: Shrubs; 3: Dwarf shrubs; 4: Forest herbs & ferns; 5: Apophytes; 6: Possible anthropochors; 7: Anthropochores; 8: Mire plants & wet meadows; 9: Indifferent herbs; 10: Aquatic plants; 11: Algae; 12: Spores.

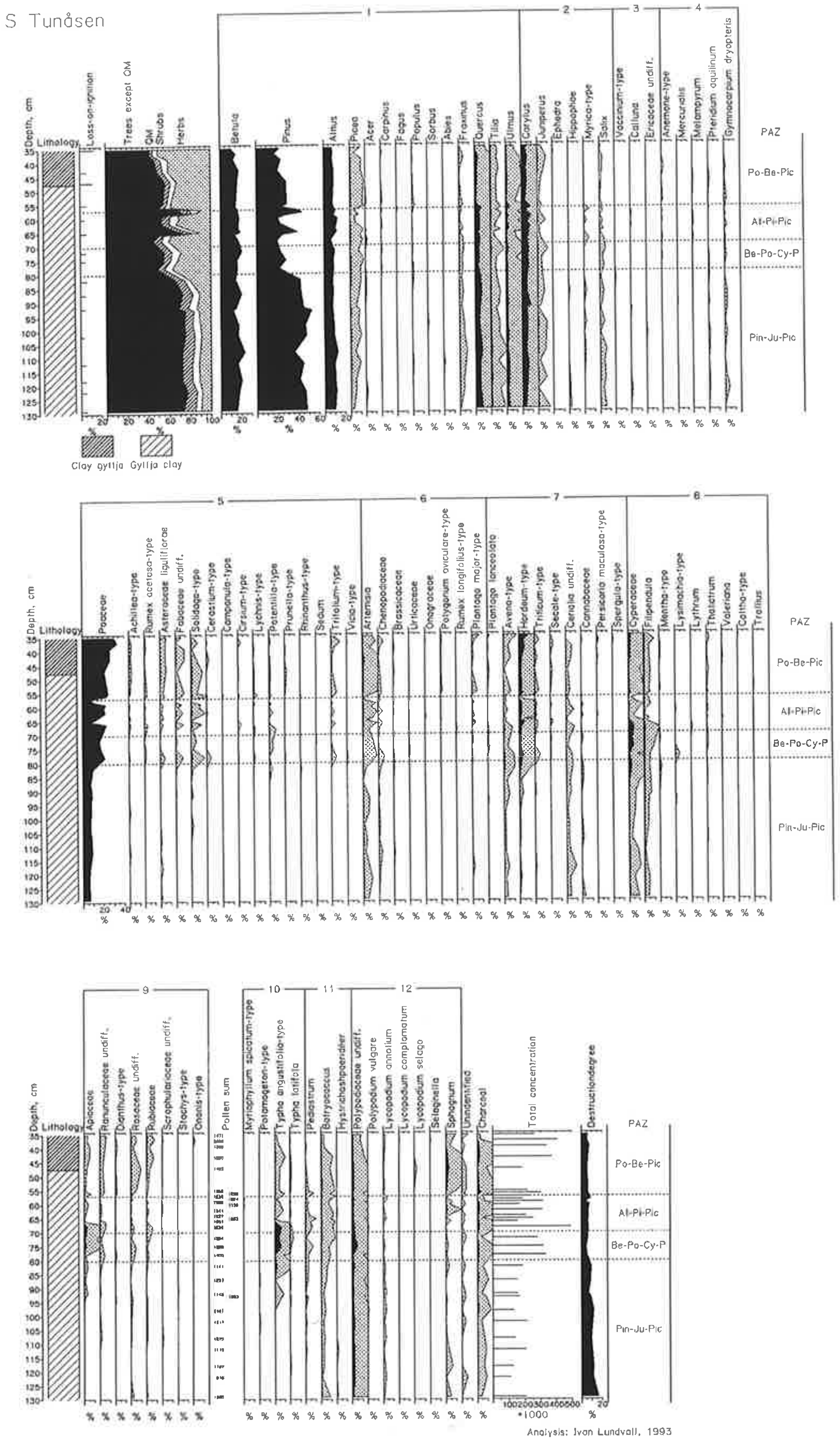

Figure 6. Pollen diagram, S. Tunåsen. 1: Trees; 2: Shrubs; 3: Dwarf shrubs; 4: Forest herbs & ferns; 5: Apophytes; 6: Possible anthropochors; 7: Anthropochores; 8: Mire plants & wet meadows; 9: Indifferent herbs; 10: Aquatic plants; 11: Algae; 12: Spores.

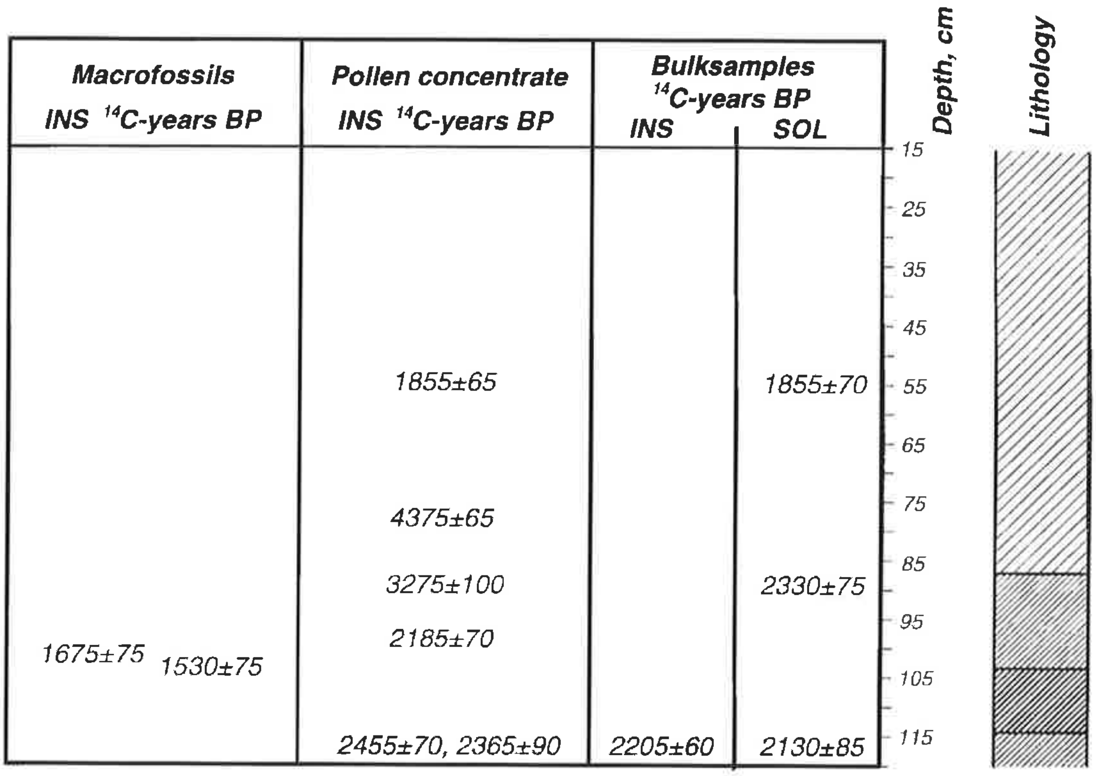

Figure 7. Radiocarbon datings vs stratigraphy in Myrby träsk. For lithology key, see fig. 5.

Table 1. Radiocarbon dated macrofossils calibrated into calendar years.

Level, cm	^{14}C-years BP	1σ	2σ
100–102.5	1675±75	AD 265–445	AD 160–535
102.5–105	1530±75	AD 435–590	AD 345–640

(Calibration: Stuvier et al. 1993).

Considering the age uncertainty and that large samples (2.5 cm thick) were used, the two samples gave more or less the same age, and no high resolution in time was accordingly obtained. In archaeological chronology the dates concern the Roman Iron Age (AD 0–400), the Migration Period (AD 400–550) and the beginning of the Vendel Period (AD 550–800) (cf. Berglund et al., 1991a).

Age determinations on pollen concentrates have been performed at five levels (fig. 7). The deepest dated level has two parallel dated pollen concentrate samples and a bulk sample dated on both the soluble (SOL) and the insoluble (INS) fractions. Considering the age error the two fractions (INS and SOL) gave the same age.

The two pollen concentrate samples yielded higher ages. This may indicate that within the total organic content of the soil there is pollen grains which to some extent are redeposited. The dated samples of pollen concentrate, above the gyttja sequence, have higher ages than the age of the gyttja. The ages of the bulk samples are contemporaneous with or younger than the pollen concentrates. Redeposited organic material is apparently present in the sequence above the gyttja, particular the pollen fraction.

Pollen diagram

PAZ Pinus-Betula

The diagram indicates stable forest conditions. At this time, the area was probably an open archipelago and the pollen spectrum possibly describes the regional vegetation on till in the northeast and to some degree on esker material situated closer to the site. The proportion of land and sea during this pollen assemblage zone made the area close to Myrby träsk uninteresting or impossible for human activities. The pollen source area for this time at Myrby träsk must be considered as fairly large, the pollen being deposited from trees in a zone around the basin several hundred metres wide (cf. Jacobson & Bradshaw, 1981). A regional forest type was probably mixed with both *Pinus* and deciduous trees. The climatic conditions were favourable for the constituents in Quercetum Mixtum forests.

Recorded *Hippophaë* pollen show that seashore environment persisted. Pollen types that are considered as human impact indicators may originate from species on seashores, e.g. *Artemisia* and Chenopodiaceae.

A share of long-distance transported pollen from an agricultural landscape established on land that elevated earlier may also be considered.

PAZ *Quercus-Corylus-Juniperus*

This zone and the preceding one describe the vegetation on eskers and till situated well above the isolation level of Myrby träsk.

The increase of *Corylus* and *Juniperus* pollen indicates that more open forest conditions prevailed. This may be due to people exploiting forested "islands" when possible. One probable land-use is forest grazing. As more land rose above the water level, the share of long distance pollen grains from forest onto till in the north-east diminished and it is probable that this zone should be considered less regional than the preceding one. A situation is reported in the pollen spectrum with vegetation mainly on eskers, consisting of an open mixed coniferous and deciduous tree forest allowing *Juniperus*, *Corylus* and *Quercus* to produce and disperse pollen.

Transitional areas around eskers rose above the water level. These areas are richer in nutrients than esker material but they are, nevertheless, well drained. On such land, conditions favourable for *Fraxinus*, *Quercus* and *Ulmus* were established (cf. Regnell 1989). Alnus and probably also *Betula pubescens* grew in wetter places.

PAZ *Alnus-Picea*

When the pollen in this PAZ was deposited the water level, at least at the isolation level, was 18.5 m a.s.l., the zone is thus less than 2500 years old. As to the *Picea* pollen graph, the uppermost four PAZ are younger than about 2630±40 ^{14}C-years BP (cf. Bradshaw & Hannon, 1992). This implies that greater areas with clay were above the sea level.

For eastern Sweden it is reported that *Alnus* pollen in the subsequent lagoon sediment follows *Pinus* pollen in marine deposits (Florin 1945). Thus, *Alnus* pollen reflects alder carr vegetation bordering on the lagoon. The isolation of the basin prevents water-transported *Pinus* pollen from dominating. The alder carr was probably developed in close connection to the basin.

The NAP increase consists partly of pollen, indicating wet vegetation conditions and is probably mainly due to a biotope in close connection with the basin; dominated by Cyperaceae, Typhaceae and possibly Apiaceae. However, the pronounced NAP increase consists of pollen types originating from a cultural landscape. The pollen values indicating rather high human impact suggest that agricultural activities took place close to Myrby träsk. There are indications of cultivation. Cultivated species are Cerealia pollen types and Cannabaceae. Examples of weed pollen are *Fallopia convolvulus*-type, Brassicaceae and *Spergula*-type. Fresh meadows are indicated by finds of pollen from *Rumex acetosa*-type, *Cirsium*-type, *Potentilla*-type, *Prunella*-type and *Rhinanthus*-type. Examples of species emanating from ruderal communities are *Artemisia*, Chenopodiaceae, Urticaceae and *Polygonum aviculare*-type.

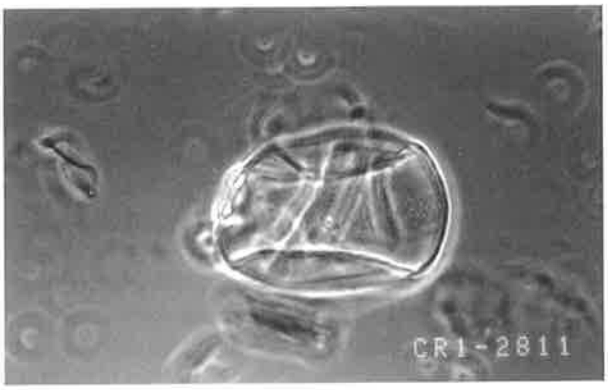

Figure 8. Photograph of a fossil pollen grain from Myrby träsk identified to Hordeum pollen type (magnification of <1000). The size of the grain is ca. 50 µm and the sample is mounted in glycerol.

Human impact fairly close to the site is documented by the increase in abundance of charcoal particles.

Freshwater conditions prevailed since remnants of freshwater algae are noted within this zone.

PAZ *Juniperus-Poaceae-Picea*

Since the representation of *Alnus* pollen decreases compared with other tree pollen, the alder carr around the basin must have been less dense. This made it easier for *Pinus* pollen to be deposited in the basin. The *Pinus* pollen increase may therefore be considered as an effect of over-representation in an open environment.

The dominance exerted by a biotope in close connection with the basin has decreased compared with the preceding zone. There are indications of an increase of areas with light forest conditions on well-drained land as demonstrated by an increase of pollen from *Juniperus* and *Calluna*.

Compared with the earlier zone, there is an increase of pollen considered as cultivation indicators; foremost *Hordeum*-type but also some *Triticum*-type and *Avena*-type. Within the *Hordeum*-type group, wild grasses are included (cf. Andersen 1978) (fig. 8). Possibly *Glyceria fluitans* and *Elymus repens* should be considered. Pollen of *Triticum*-type is a safer indicator of cultivation. The low amount of *Secale* pollen may be explained by the fact that clay soil is not suitable for *Secale* cultivation.

PAZ *Pinus-Picea*

An increase of *Pinus* pollen contemporaneous with decrease of human impact pollen is a contradictory appearance in a pollen diagram. If the agricultural activities diminish in an area like Gamla Uppsala, *Pinus* trees are not the most probable succession. Overgrowth of cultivated and grazed land should consist of an early successional stage of trees such as *Betula* and *Corylus* (cf. Berglund et al. 1991b).

Since *Pinus* tree communities most probably grew on eskers and till deposits, an increase in *Pinus* trees could not be a result of abandoned cultivated ground which is found on substrata richer in nutrients. The Chenopodiaceae and the Rubiaceae pollen graphs and in some degree also the *Polygonum aviculare*-type and *Artemisia* pollen graphs, are NAP graphs which do not show a decrease. They may emanate from a ruderal environment. Together with the charcoal particle record, these diagram features could be an indication that there was no decrease in human activity in the area. Perhaps, instead, they indicate a change in the use and function of the area, and the decreased intensity in agricultural activities does not imply a denser vegetation situation. Cultivated areas were used for settlements and within such a type of open landscape *Pinus* pollen became over-represented.

Another interpretation is connected with the deposition of pollen within the basin. An erosional situation may transport pollen older than the contemporaneous pollen rain to the basin. The vegetation situation before human impact in the area was most probably forest with *Pinus* communities on esker areas. The increase of *Pinus* pollen may then partly consist of redeposited *Pinus* pollen. It is most probable that human activities caused the erosion, for example an increase in the settlements resulted in greater wear on the ground. On these unstable soils, ruderal plants were favoured.

PAZ *Poaceae-Juniperus-Betula-Picea*

An increase for cereal cultivation and pasture is indicated in the pollen diagram record. Open conditions are illustrated by large amounts of NAP, *Juniperus* and *Pinus* pollen. Wet and waterlogged areas diminished around the area. This is suggested by decreasing values of *Alnus* pollen and the pollen considered as emanating from wet meadows. The rises of *Calluna* and *Juniperus* pollen in the graphs indicate increased grazing. The configuration of the pollen spectrum in the uppermost part (level 50 cm below ground) shows that possibly the Early Viking Age (AD 800) has been reached, indicated by finds of *Centaurea cyanus* pollen. It has been suggested that *Centaurea cyanus* arrived with imported cereals during the Viking Age (Svensson & Wigren 1985).

S. Tunåsen

Soil material: The soil in the stratigraphy consists of a layer of peaty soil disturbed by ploughing; clay gyttja and gyttja clay. Since a peaty soil rests above the clay gyttja, the stratigraphy shows a normal succession of a former lake.

Pollen diagram

From this stratigraphy no datings have been made. Disaggregation of deposits in the search for macrofossils has not resulted in any finds. Discussion of a possible dating time must then rely on correlation to the Myrby träsk diagram. Since a continuous *Picea* pollen graph is present in the whole diagram, the stratigraphy cannot be older than about 2600 years (cf. above). Since also the basin was isolated when the analysed part of the stratigraphy was deposited (only freshwater algae), shore displacement curves show that it cannot be older.

The most striking difference between Myrby träsk and S. Tunåsen concerns the increase of cultural indicators and the *Picea* pollen graph. In Myrby träsk these two events are simultaneous, stratigraphically speaking. In S. Tunåsen, a continuous *Picea* pollen graph is developed before a marked increase of human impact indicators. The difference may be explained in at least two ways. Is the marked increase of cultural indicators in the two diagrams simultaneous or not? If not, and less than 600 m separates the two localities, this means that the human impact indicators are really local in origin. If the marked increase of human impact indicators in the two diagrams is contemporaneous, on the other hand, there must be a hiatus in Myrby träsk. Both explanations may, however, be needed for the development noted.

In PAZ *Alnus-Pinus- Picea* there are marked peaks and declines in the pollen graphs and they are interpreted as an effect of erosional events with transportation of older redeposited material as a consequence. In Myrby träsk, the erosional events are not so apparent in the pollen spectrum as they are in S. Tunåsen. During the two erosional stages in S. Tunåsen pollen types indicating a cultural landscape are almost totally lacking. In Myrby träsk, human impact pollen types have lower levels in their graphs in PAZ *Pinus-Picea* but they still exist. No increase of *Calluna* and *Juniperus* pollen is noted in the uppermost PAZ in S. Tunåsen. The interpretation may be that the uppermost sediments at the S. Tunåsen locality are not as young as at Myrby träsk.

Discussion and conclusions

The pollen records from Gamla Uppsala describe the development of vegetation in an area affected by land upheaval processes. It is probably that people exploited the land as soon as the configuration of water and land made it possible.

The temporal span of the two diagrams from Myrby träsk and S. Tunåsen has been discussed and it is impossible to correlate them closely to each other. They report the same vegetational situations. The signals from human impact seem weaker in S. Tunåsen, especially when the charcoal record is considered. The conclusion is that Myrby träsk was closer to the settled area.

It seems probable that there is a hiatus in the Myrby träsk stratigraphy since the distinct increase of the *Picea* pollen curve occurs simultaneously with the increase of human impact indicators, in contrast to S. Tunåsen where *Picea* pollen has a continuous curve before the rise of human impact indicators. It is uncertain whether the pollen concentrate age determinations or the bulk sample determination from level 117 cm in Myrby träsk date the actual sedimentation event. Since the level is in time after the isolation event the obtained ages are probably (cf. Land elevation). In the archaeological timescale the time for the establishment of an agricultural landscape in Gamla Uppsala is Pre-Roman or Roman Iron Age.

The radiocarbon dates of pollen concentrates have revealed that old, redeposited pollen grains are present above the gyttja sequence within the Myrby träsk stratigraphy. A pollen record, which is likely to contain old redeposited pollen grains is the *Pinus* pollen graph. Even severely damaged *Pinus* pollen may be identified. The perceived decrease in agricultural activity in PAZ *Pinus-Picea* may then be an effect of too high *Pinus* pollen values. There may be uncertainties about the actual land-use during the time corresponding to the part of the stratigraphy with high *Pinus* pollen values together with a decrease of pollen from cultivated species, but it is clear that after about 1600 ^{14}C-year BP, erosional events occurred around Myrby träsk. In calibrated years the age of the dated gyttja sequence ranges between 265–590 AD (1σ).

Erosional events depend on land-use, climate or a combination of the two. Surface run-off with contemporaneous erosion within a topographic situation like the one in Gamla Uppsala is most probable. It may also be possible that sediment-carrying water is led to the basin through draining activity in order to make arable fields. A lake situation may have been created during some periods when there was more water than the ground was able to drain. Since pollen from aquatic plants is noted in the gyttja clay, but not with continuous graphs, this may support such an interpretation. There is a risk of the stratigraphy above the gyttja sequence not being continuous.

Some of the dates are so early, however, that it is impossible that the pollen grains reported in the diagram could have given these ages. The *Picea* pollen graph is important in this context. A continuous *Picea* pollen graph cannot be older than 2600 in this region (Bradshaw & Hannon 1992).

The land upheaval timetable for the area makes it clear that the rather high value of human impact pollen types cannot be as old as the dating results suggest. The attitude towards the pollen diagram is that it mainly shows the contemporaneous pollen rain and that redeposited old pollen grains are in such poor condition that they were not recognised and identified during the pollen analyses. A chronology based on absolute dating for the whole stratigrapy from Myrby träsk has not been possible to establish.

From biostratigraphical indications it is suggested that the presented stratigraphy extends upwards to the Early Viking Age.

Acknowledgements

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