

Sub-Local Differences in Late Holocene Land Use at Orstad, Jæren in SW Norway, revealed by Soil Pollen Stratigraphy

Barbara M. Sageidet

Abstract

Four soil profiles along an 84 m transect through a clearance cairn field on podsol soils at Orstad, Jæren, SW-Norway, were investigated. By relating pollen-analytical results to soil stratigraphical and morphological features, it was possible to reconstruct the landuse history of the site, and to reveal differences along the transect, although pollen preservation was poor. Human activity at Orstad began about 4500 uncalibrated 14C years BP. The reason for an intermediate abandonment of the site between about 4000 and 3600 uncalibrated 14C years BP was presumably a higher ground-water level, caused by local deforestation and/or by a climatic change. After that period, people seem to have grown cereals (*Triticum* and *Hordeum*) on at least two different field patches on the site. This land use was presumably occasional, and related to extraordinary needs. Fire-clearance seems to have been practised to prepare the fields for cultivation after long fallow periods. Between 2900 and 3200 uncalibrated 14C years BP, Orstad was possibly permanently inhabited. The agricultural fields were moved to higher levels, as the initial fields had become nutrient-depleted and too moist. Thin black layers in the profile may be remains of manure.

Key words: SOIL POLLEN STRATIGRAPHY, EARLY AGRICULTURE, SOIL MANAGEMENT, SUB-LOCAL AREAS, SW NORWAY, PEDOLOGY

Introduction

Agriculture in the Jæren region, southwest Norway (Fig. 1), is documented in written and archaeological sources (Rønneseth 1974; Sølvberg 1976; Myhre 2002). It is traced back to the Neolithic period by pollen analysis (Fægri 1944; Prøsch-Danielsen 1993a). Plant macrofossils documented cereal cultivation on the west coast of Norway since the Late Neolithic (Bakkevig 1995; Soltvedt 2000, 59). Deforestation and the spread of heather from human activity (*cf.* Kaland 1979; 1986) had already begun in the Late Mesolithic in some areas around Orstad in the municipality of Klepp (Prøsch-Danielsen and Simonsen 2000, 41; Sageidet *in press a*). From the end of the Neolithic and through the Bronze Age, the Jæren region developed into one of the most important agricultural areas in southern Scandinavia (Myhre 1981, 84), and Klepp became a dominant cultural centre (Møllerop 1963). Many

agricultural settlements are found from the end of the Neolithic and from the Bronze Age (Simonsen *et al.* 1982; Løken *et al.* 1991; Børsheim *et al.* 2001; Juhl 2001; Børsheim and Soltvedt 2002), and one of them was Orstad, in the municipality of Klepp (Hemdorff *et al.* *in press*).

Specific knowledge about the way people used land on a site is limited. Pollen analysis is especially useful for palaeoenvironmental reconstructions on in-context sites (Edwards 1980; Bostwick Bjerck 1988; Keith-Lucas 1994, 38), despite the problems present in mineral soils (Dimbleby 1957; 1985; Havinga 1974; Andersen 1979a; Aaby 1990; Kelso 1994). Areas with different land-use activities at Forsandmoen, Rogaland, were distinguished by numerical analysis of pollen and phosphate data (Prøsch-Danielsen and Simonsen 1988). Segerström (1991) traced ancient arable patches in northern Sweden by extracting pollen from thin humus layers. Vuorela (1973) found

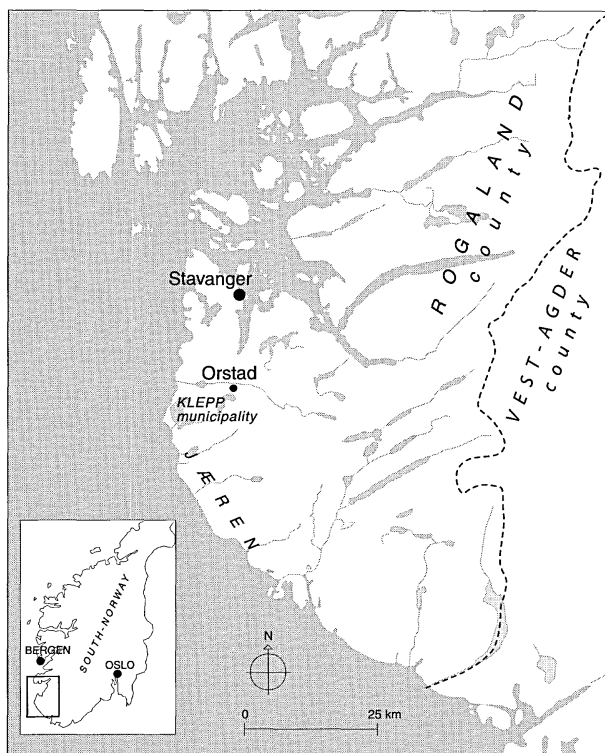


Figure 1. Location of the area, map of southern Norway / Jæren and Orstad (drawn by Tove Solheim Andersen).

high local variations in herb pollen percentages around cultivated fields. Acid forest soils have proved to be suitable for the reconstruction of local ecological successions (Aaby 1983; Dijkstra and van Mourik 1995).

Orstad is an in-context site on podsollic soils, which are widespread in SW Norway. In this study pollen analysis is applied to differentiate the paleo-environmental events on various sub-local parts of the site, based on the differences in pollen stratigraphy and soil characteristics.

The Study Area

Orstad (grid reference: UTM: 32VLL112218) is today a fertilized pasture, located 78–84.5 m a.s.l. in a hummocky till landscape (Andersen *et al.* 1987), upstream of the Figgjo river in central Jæren, SW Norway (Fig. 1). The area has been strongly influenced by cultivation and human activities, indicated by an abundance of charcoal both on and under the surface. Heather was common in the region until about 30 years ago. At the Orstad site vegetation was scarce, and the place was called “burned ground”. During the 19th century and until the 1960s, the location was used for drying turf bricks (David Orstad, pers. comm.). About 30

prehistoric clearance cairns, the oldest dating to the Early Bronze Age, a burial mound and a stone construction were recorded at the site (Hemdorff in press). Hemdorff found remnants of a possible settlement on the top of the hill. They are dated to 3115 ± 75 uncalibrated 14C years BP (1440–1270 calibrated 14C years BC, TUA-1521).

Methods

An 84 metre long SW-NE transect was excavated, cutting three clearance cairns (no. 1, 6, and 11, Fig. 2). Two pollen profiles from below clearance cairns no. 11 and 6 (profiles A and B), and two pollen profiles from the surrounding podsol soil (profiles C and D), were selected (Fig. 3). Lack of pollen, especially up the slope to the southwest, was the reason for rejecting several other profiles for pollen analysis. The soil profiles A-D were described according to FAO and ISRIC (1990).

The samples for pollen analysis (3 or 4 cm³ volume) were collected from the cleaned profile in vertical series using plastic tubes. The preparation procedures followed Fægri and Iversen (1989). Samples rich in sand were treated with hydrofluoric acid. Three tablets of acetylated *Lycopodium clavatum* spores were added to each sample (Stockmarr 1971). A Nikon light microscope was used for palynological analysis with a magnification of 400x. Phase contrast and a 1000x magnification were used to identify pollen grains of *Cerealia*-type. Pollen of *Corylus* and *Myrica* are only separated at the extremes of the ranges for each taxa, following Fægri and Iversen (1989). In any case of uncertainty, they were recorded as “unidentifiable” (*cf.* Edwards 1981). Pollen and spore identification is mainly based on the literature of Beug (1961), Moe (1974),



Figure 2. Part of the excavated ditch, transecting 84 m of the site (photo: Aage Petersen).

Andersen (1979b), Eide (1981), Fægri and Iversen (1989), Moore *et al.* (1991), and Reille (1992; 1995), and on the comparison with reference material at the Museum of Archaeology, Stavanger. The nomenclature follows Lid and Lid (1994). The calculation sum is that of land pollen grains (S P), excluding both fossil and added spores, and aquatic palynomorphs. The percentages of spores and aquatic palynomorphs are based on S P + X, where X is the number of the palynomorphs in question. Charcoal particles of a size between about 10 and 200 μ m were counted during pollen analysis, and recorded on a frequency scale. "Present" means up to 100 particles, "frequent" means between 100 and 500 particles and "abundant" means more than 500 particles. The results are presented in four pollen diagrams, constructed by the computer program Core System (Natvik and Kaland 1994). The palynomorphs too corroded or degraded to be identified (called unidentifiable pollen in this study) are included in the pollen sum, to gain more realistic relative frequencies of the different pollen types in the spectra (Hall 1981, 196). The aim to count > 500 pollen grains per spectrum was frequently prevented by low pollen concentrations. To exploit most of the information available from pollen spectra rich in pollen, the pollen sum is sometimes up to 1000 pollen grains (e.g. in profile A). The locations of the charcoal fragments, used for radiocarbon dating are marked in Fig. 3. The radiocarbon dates are pre-

sented in uncalibrated ^{14}C years BP and calibrated ^{14}C years BC/AD (Stuiver and Reimer 1993; Bartlein *et al.* 1995, Table 1).

Results and Discussion

Pedostratigraphy

The 84 m transect was dominated by weakly-developed iron humus podsoles which were best developed in the northern part. The depth down to the C-horizons varied between 45 and 95 cm. Up the slope towards the southwest, the A- and B-horizons were generally thinner, and the E-horizon was less developed, very thin and partly invisible. The profiles were well drained uphill. In the central part of the transect, the soil was somewhat gleyed and the profiles were moderately to poorly drained (Fig. 3). Macroscopic charcoal fragments were abundant along the transect, especially from the surface down to 45–50 cm. No earthworms were observed. Thin black layers, a few millimetres to a centimetre thick, occurred at depths between 24 and 44 cm as sets of parallel horizontal layers. They were sporadically visible along the transect between 50 and 79 m and at approximately 83.6 m. The micromorphological analysis of these black layers will be presented in a separate paper. Fig. 3 shows the locations of the following four selected profiles:

Lab. Ref.	Location of dated sample	Material	Uncalibrated ^{14}C -years BP	Calibrated ^{14}C -years BP	Depth cm
TUa 3217	Below cairn 6, at 51.10 m	Charcoal of <i>Betula</i>	3580 \pm 50	1975-1785	49
TUa 3214	Below cairn 6, at 49.80 m	Charcoal of <i>Betula</i> and other deciduous trees	3560 \pm 55	1945-1780	44
TUa 3212	Below cairn 1, at 79.03 m	Charcoal of <i>Betula</i>	3540 \pm 65	1940-1750	49.5
TUa 3219	Below cairn 1, at 79.30 m	Charcoal of <i>Betula</i>	3520 \pm 65	1915-1745	55
TUa 3221	Inside of cairn 6, at 51.00 m	Charcoal of <i>Betula</i>	3415 \pm 55	1750-1635	36
TUa 3213	At the edge of cairn 6, at 51.20 m	Charcoal of <i>Betula</i>	3275 \pm 50	1610-1465	28
TUa 3220	Inside of cairn 1, at 79.35 m	Charcoal of <i>Betula</i>	3270 \pm 55	1610-1455	38
TUa 3216	Below cairn 11, at 3.63 m	Charcoal of <i>Betula</i>	2955 \pm 50	1260-1050	28
TUa 3218	Inside of cairn 6, at 51.15 m	Charcoal, unidentified	2830 \pm 50	1025-910	22
TUa 3215	At the edge of cairn 11 at 2.15 m	Charcoal of <i>Salix</i>	2475 \pm 50	765-415	46

Table 1. Radiocarbon dates from Orstad (ca. 80 m a.s.l.), Klepp municipality, Rogaland county, southwestern Norway. Estimated $\delta^{13}\text{C}$ ‰ : -26.1. For location of the dated samples, see Fig. 3 (Calibration, Stuiver and Reimer, 1993).

Profile A at 79.60 m is a well drained podsol profile, located at the northern end of the 84 metre long transect, at the southern part of clearance cairn no. 1 (Fig. 3A, Table 2).

Profile B at 50.10 m is a poorly drained gleyed podsol profile, located below clearance cairn no. 6 in the northern part of the central depression of the transect (Fig. 3B, Table 3).

Profile C at 26.10 m is a well drained podsol profile, located in the southwestern part of the transect (Fig. 3C, Table 4).

Profile D at 1.77 m is a well drained podsol profile, located at the highest point of the transect, southwest of clearance cairn no. 11 (Fig. 3D, Table 5).

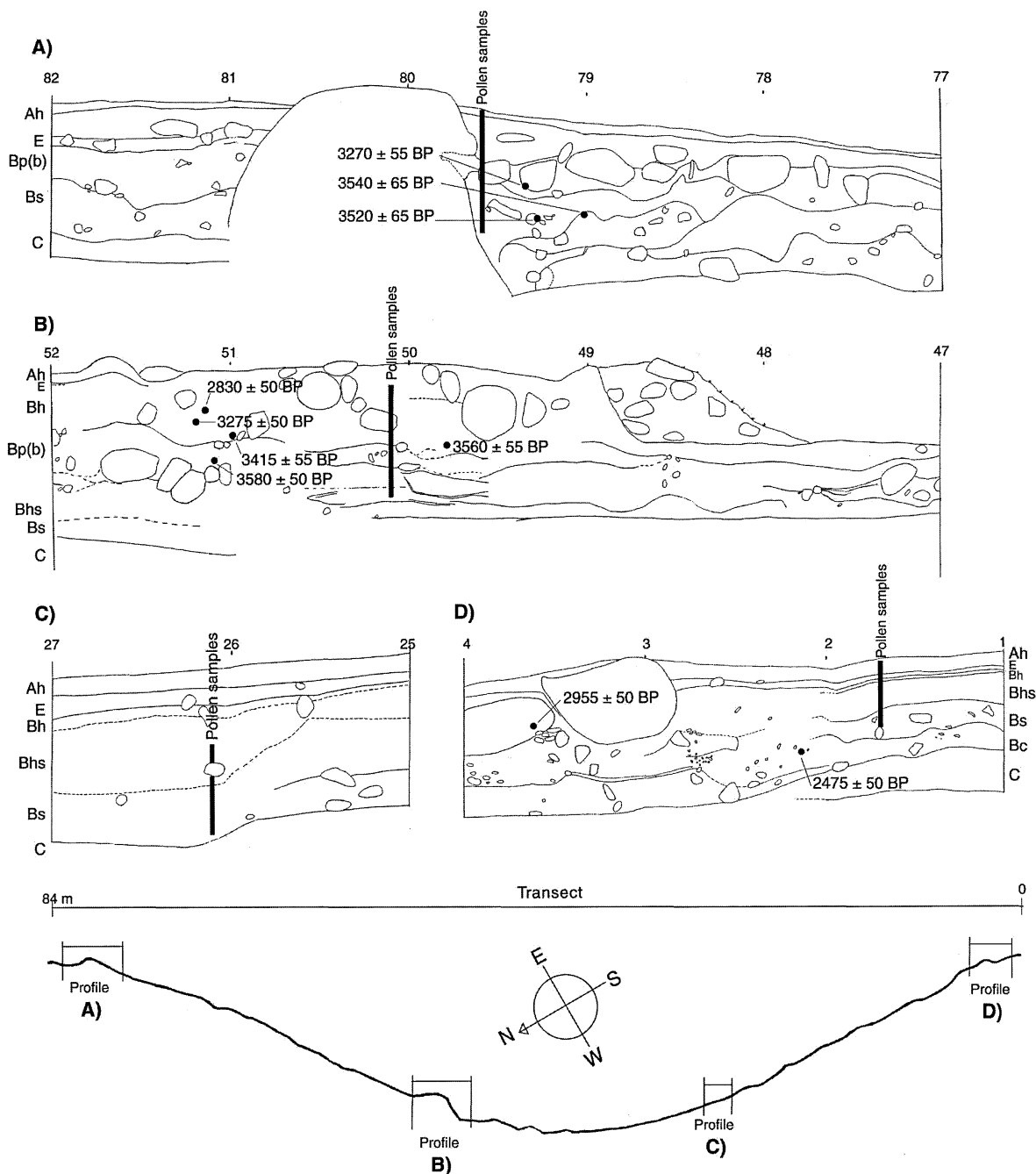


Figure 3. The transect with the four selected profiles A-D (drawn by Barbara M. Sageidet/Astrid Hølland Berg/Tove Solheim Andersen). Pollen samples, 14C dates, and soil horizons are marked. A) Clearance cairn no. 1 at 79.6 m along the transect; B) Clearance cairn no. 6 at 50.1 m along the transect; C) Profile at 26.1 m along the transect; D) Profile at 1.77 m along the transect.

Horizon	Lower boundary	Texture and rock fragments	Structure	Consistency	Organic constituents	Porosity	Munsell colour (moist)
Ah	0-12(19) cm, clear wavy	fine sand, very few sub-rounded boulders, weathered	weak single-grain	soft, loose, slightly sticky and plastic(wet)	many very fine to medium size roots, few charcoal.	high	5 YR 3/2
E	15.5 (ca.) – 29.5 cm, abrupt wavy to irregular	fine sand, many sub-rounded boulders, weathered	weak single-grain	soft, loose, non sticky, non plastic (wet)	few very fine roots, Few charcoal	medium	5 YR 5/2
B	29.5 – 42.5 (45.5) cm, gradual wavy	poorly sorted sand, common sub-rounded boulders, coarse and medium gravel, weathered	moderate medium angular and sub-angular blocky	slightly hard (dry), firm (moist), slightly sticky and plastic (wet), broken compacted to weakly cemented	very few very fine roots. Few charcoal	very low	7.5 R 3/2
Bs	81 – 93(101) cm, gradual wavy	loamy coarse sand, many sub-rounded boulders and stones, coarse and medium gravel, weathered	moderate medium to coarse blocky	hard (dry), firm (moist), and slightly sticky and plastic (wet), broken compacted	very few very fine roots, few charcoal	very low	5 YR 5/8 and 5 YR4/4
C	97 (ca.) – 109(115) cm, diffuse irregular	loamy coarse sand, many angular stones, coarse, medium and fine gravel, weathered	strong coarse blocky	very hard (dry), very firm (moist), and non sticky, non plastic (wet), broken cemented	no roots	very low	10 YR 5/4

Table 2. Soil horizon descriptions of profile A, at 78–80 m (part of clearance cairn no. 1) from Orstad, Klepp municipality, Rogaland county, southwestern Norway (see Fig. 3), according to FAO & ISRIC (1990).

Soil-analytical Features and Biostratigraphy

The four selected pollen profiles (Figs. 3, 4, 5, 6 and 7) were partly interrupted by stones, a dense root system in the upper horizons, or by cemented material. Pollen preservation was generally poor, but worst in profile D, probably due to low acidity. Differential preservation conditions and differential pollen influx seem to be the main reasons for great inter-profile and intra-profile variations in the pollen contents of the different spectra. These features are less typical of acid soils, and they may thus reflect a degree of biological activity and former land-use (Cruise and Macphail 2000, 184). Preservation conditions are progressively worse in the Bhs-horizons and below (cf. Kelso 1994, 481; cf. Havinga

1984). Here, low pollen concentrations, selective pollen deterioration, and overrepresentation of both spores and pollen (cf. Havinga 1968; cf. Dimbleby 1985) provide insufficient bases for paleoecological reconstructions (cf. Florin 1975; Stockmarr 1975; Segerström 1991). *Pinus*, *Ericaceae*, *Asteraceae*, and *Tilia* are among the pollen types which are usually well preserved or easy to identify (Hall 1981, 203). However, only a few pollen of insect-pollinated plants like *Tilia* and *Calluna* may be highly indicative of the plants occurring near the site (cf. Evans and Moore 1985).

The two lowermost pollen spectra in profile A are located directly beneath boulders, suggesting that contamination from overlying sediments is less

Horizon	Lower boundary	Texture and rock fragments	Structure	Consistency	Organic constituents	Porosity	Munsell colour (moist)
Ah	0- 2.5(8) cm, abrupt smooth to wavy	fine sand	weak single-grain	soft, loose	many very fine to medium size roots, few charcoal	high	10 YR 2/2
E	2.5(8) – 4(9) cm	fine sand, horizon very faint	weak single-grain	soft, loose,	few fine roots, few charcoal	medium	10 YR 4/4
Bh	6.5(ca.) – 41.5(44) cm, Gradual smooth to wavy	very fine to medium loamy sand, many sub-rounded boulders, stones and coarse gravel, weathered	weak fine blocky	soft (dry), loose (moist), slightly sticky and plastic (wet)	few to common very fine roots, common organic material	medium	5YR 2/1
B	43 (ca.) – 50 (53) cm, gradual smooth to wavy	fine sandy loam, abundant sub-rounded boulders, stones and coarse gravel, weathered	fine blocky	slightly hard (dry), firm (moist), sticky and very plastic (wet)	very few very fine roots, common charcoal	low	5 YR 3/1
Bhs	51.5 (ca.) - 71(87) cm, gradual smooth to wavy	coarse sandy loam	fine platy	slightly hard (dry), firm (moist), sticky and very plastic (wet), discontinuous weakly to moderate cemented	very few very fine roots	low	7.5 YR 3/2 and 7.5 YR 4/4
Bs	74 (ca.) – 84 (ca.) cm, gradual smooth to wavy	sandy loam, many to abundant sub-rounded boulders, stones and coarse gravel, weathered	weak medium blocky	slightly hard (dry) firm (moist) and sticky and very plastic (wet),dis-continuous weakly to moderate cemented	very few very fine roots	very low	YR 4/4
C	84 (ca.) – 100 (ca.) cm, gradual smooth to wavy	loamy coarse sand, common sub-rounded boulders, stones and coarse gravel, weathered	weak to medium granular and single- grain	soft (dry), friable (moist) and non-sticky and non-plastic (wet)	no roots	very low porosity	10 YR 5/4

Table 3. Soil horizon description of profile B, at 48–53 m (part of clearance cairn no. 6) from Orstad, Klepp municipality, Rogaland county, southwestern Norway (see Fig. 3), according to FAO & ISRIC (1990).

likely (Tipping *et al.* 1994, 398). The pollen concentration is high in profiles A and B, which are rich in organic material down to about 70 cm, and 60–65 cm, respectively. The clearance cairns seem to have sealed and compacted the soils below, and preserved the stages of development before they were buried. This may to some degree have prevented leaching of humus material, and may have

led to a better pollen preservation. Scarcely any pollen was found under clearance cairn no. 1. The soil layers under the clearance cairns in profiles A and B, which correspond to the LPAZ (local pollen assemblage zone) *Cerealia*, seem to have prevented pollen oxidation because of their low porosity. Low porosity may have been caused by cultural activities on the surfaces of these profiles (*cf.* Kelso 1993, 89).

Horizon	Lower boundary	Texture and rock fragments	Structure	Consistency	Organic constituents	Porosity	Munsell colour (moist)
Ah	0 – 7(9) cm, abrupt smooth	loamy coarse to very fine sand, very few sub-rounded fine gravel, slightly weathered	weak fine single- grain	loose, non sticky and non plastic (wet)	many very fine and fine roots, few charcoal	very high	2.5YR2/N2
E	8 – 11(13) cm, abrupt smooth	very fine sand, no rock fragments	weak fine single- grain	loose, non sticky and non plastic (wet)	common very fine roots, few charcoal	very high	5 YR 4/1
Bh	ca.12 – 19 cm, clear smooth boundary	loamy fine sand, very few sub-rounded fine gravel, slightly weathered	weak fine single- grain	loose (dry), firm (moist), slightly sticky and plastic (wet)	few very fine roots, few charcoal	medium	5 YR 2/2
Bhs	19 (ca.) - 53(57) cm, gradual smooth	fine sandy loam, abundant sub-rounded boulders, stones and medium gravel, weathered	weak very fine angular and sub-angular blocky	slightly hard (dry), friable (moist), sticky and plastic (wet)	common fine and medium size roots, few charcoal	medium	5 YR 3/3, 5 YR 5/8 and 5 YR 2/1
Bs	55(ca.) cm – 70(79) cm, gradual smooth	loamy sand, abundant sub-rounded boulders, stones and medium gravel, weathered	weak medium platy (to angular and sub-angular blocky)	loose (dry), friable (moist), and slightly sticky and slightly plastic (wet)	no roots	very low	5 YR 4/4
C	74.5 (ca.) – 85(91) cm, gradual smooth boundary	loamy sand, abundant sub-rounded boulders, stones and medium gravel, weathered	weak medium platy (to angular and sub-angular blocky)	soft (dry), friable (moist), and slightly sticky and slightly plastic (wet)	no roots	low	7.5 YR 5/6 and 10 YR 5/4

Table 4. Soil horizon description of profile C at 25–30 m from Orstad, Klepp municipality, Rogaland county, southwestern Norway (see Fig. 3), according to FAO & ISRIC (1990).

The soil stratigraphy of clearance cairn no. 6 shows that an older soil profile was overlain by a younger soil profile. Today, the lowermost soil layers of profile B are usually under the ground-water level during short periods of the year. This may have entailed horizontal and lateral water movements for a long time. Water may selectively transport pollen through macropores (Russel 1993; Kelso 1994), which may have developed after decay of roots of shrubs or trees. However, the low porosity in the profile may have prevented such transport. The porosity was probably higher in pre-historic time when the soil was presumably a brown earth (Sageidet in press b).

Pollen mixing by water or by bioturbation (in a

brown earth) may usually be detected by the reflection of an unlikely plant community (Frenzel 1964, 16). A single pollen grain is more easily suspected of having been transported down a profile than a greater amount of one pollen type. The small amounts of herb pollen found in the lower part of the Bhs horizon of profile B (corresponding to LPAZ *Varia-Polypodiaceae*) may represent a secondary assemblage of pollen, which did not derive from the same flora (cf. Willerding 1988, 33). The cereal-type pollen grain recorded at a depth of 63 cm (profile B) is likely to have been transported down the profile. The moist conditions in this part of the site may have led to an early start of the podsolization, improving the preservation conditions.

Horizon	Lower boundary	Texture and rock fragments	Structure	Consistency	Organic constituents	Porosity	Munsell colour (moist)
Ah	abrupt smooth boundary	fine sand	weak single-grain	slightly hard (dry), firm (moist), and slightly sticky and plastic (wet)	many very fine, few fine and very few medium size roots, few charcoa	medium	2.5 YR 2/2 and 10 R 2/1
E	abrupt smooth	fine to medium sand, few sub-rounded fine gravel, weathered	weak fine single-grain	soft (dry), friable (moist), non sticky and non plastic (wet)	common roots, few charcoal	low	10 YR 6/2
Bh	abrupt smooth	fine to medium sand, few sub-rounded fine gravel, weathered	weak fine single-grain	loose (dry), loose (moist), non sticky, non plastic (wet)	common very fine roots	medium	10 YR 3/2
Bhs	clear smooth	fine sandy loam, common sub-rounded and angular boulders, stones, medium and fine gravel, weathered	weak fine blocky	loose (dry), very friable (moist), slightly sticky and plastic (wet)	common very fine roots	medium to high	10 YR 4/4
Bs	gradual smooth	sandy loam, common sub-rounded and angular boulders, stones, medium and fine gravel, weathered	weak fine blocky	loose (dry), friable (moist), and slightly sticky and plastic (wet)	few very fine roots	medium	10 YR 5/8
BC	gradual smooth	loamy very fine sand, common sub-rounded and angular boulders, stones, medium and fine gravel, weathered	moderate blocky	loose (dry), friable (moist), non sticky and plastic (wet)	no biological features	very low	10 YR 6/4
C	-	loamy very fine sand, common sub-rounded and angular boulders, stones, medium and fine gravel, weathered	moderate medium blocky	loose (dry), friable (moist), non sticky and plastic (wet), moderately cemented	no biological features	very low porosity	10 YR 7/3

Table 5. Soil profile description of profile D at 0–2 m from Orstad, Klepp municipality, Rogaland county, southwestern Norway (see Fig. 3), according to FAO & ISRIC (1990).

The pollen assemblages are rather similar throughout profile C. This is characteristic in soils with intense bioturbation (Havinga 1984, 551). The pollen grains seem to have been deposited before the podsolization processes started, the soil fauna vanished, and the bioturbation stopped.

Biostratigraphy

The pollen-analytical results are presented in four pollen diagrams, one for each of the soil profiles A–D (profile A (Fig. 4), profile B (Fig. 5), profile C (Fig. 6), and profile D (Fig. 7). The pollen diagrams have been divided into pollen assemblage zones by visual

inspection, and by comparison with earlier diagrams from the site (Sageidet in press a, Sageidet in press b).

Pollen assemblages in mineral soils often occur with diffuse boundaries and may reflect temporal mixing (Larsson 2000). The zone boundaries are not necessarily equivalent to natural breaks (cf. Grimm 1988, 53). The stratigraphic similarities between these pollen assemblages allow correlation of the pollen data of the four profiles, and the recognition of local pollen assemblage zones, although they are not entirely equivalent to LPAZs as defined in standard pollen diagrams (cf. Sageidet in press b).

Three of the six LPAZs from the site reveal characteristic differences in the various profiles along the transect, and they are therefore based on the correlation of sub-local pollen assemblage zones (sub-local PAZs, Tables 6–8).

I LPAZ *Varia*-*Polypodiaceae*

Four spectra between 72 and 61.5 cm in profile B. About half of the few pollen grains are tree pollen, with decreasing amounts from the bottom to the top of *Pinus*, *Betula*, *Alnus*, *Corylus*, *Quercus*, *Tilia* and *Salix*. Pollen of Ericaceae and *Calluna* constitute a quarter of the total. Pollen of Poaceae and Cyperaceae are frequent. The herb pollen is mainly from Rosaceae, *Urtica*, Brassicaceae, and *Plantago lanceolata* L.. Unidentifiable pollen constitutes 2–11 %. Polypodiaceae spores are numerous, and *Polypodium vulgare* L. appears in both high and low values. At 63 cm, deterioration made it impossible to identify about 83 % of all recorded palynomorphs, mainly spores. The number of microscopic charcoal particles is high.

II LPAZ *Tilia*

Three spectra between 61.5 and 52.5 cm in profile B. The amount of tree pollen increases up to 85 %, dominated by *Betula*, and with decreasing amounts of *Tilia*, *Alnus*, *Corylus*, *Pinus*, and *Quercus*. Ericaceae pollen is reduced to nearly zero. The pollen values of Poaceae remain constant, while those of Cyperaceae decrease upwards. *Urtica* is the most common pollen type among the herbs. A few pollen grains of Rosaceae, Ranunculaceae, *Succisa*-type, *Humulus*-type, *Melampyrum*, *Epilobium*, *Thalictrum*, and Asteraceae, are recorded. Unidentifiable pollen constitutes 2–10 %. Polypodiaceae spores are numerous. The number of microscopic charcoal particles is decreasing.

III LPAZ *Cerealia*

Two spectra between 67 and 45 cm in profile A; 8 spectra between 52.5 and 36 cm in profile B; 7 spectra between 41 and 59 cm in profile C. The tree pollen is dominated by *Betula*, and also

includes *Alnus*, *Corylus*, *Quercus*, and *Ulmus*. Pollen of *Salix*, *Myrica*, *Juniperus*, Ericaceae, Cyperaceae, *Succisa*-type, and *Plantago lanceolata* are present. A few pollen grains of *Epilobium*, *Plantago major*-type, Caryophyllaceae, and *Polygonum persicaria*-type are also recorded. The characteristic differences of the sub-local PAZs are outlined in Table 6. Unidentifiable pollen constitutes 1–8 %. Spores of Polypodiaceae and *Polypodium vulgare* are either numerous, or sporadically present. Some *Pteridium* spores were identified. Microscopic charcoal particles are abundant, except in profile B.

IV LPAZ *Betula*

One spectrum between 45 and 34 cm in profile A; 2 spectra between 36 and 30.5 cm in profile B.

The tree pollen include *Betula*, *Pinus*, *Alnus*, *Corylus*, *Quercus*, and *Tilia*. Pollen of *Salix*, *Juniperus* and *Myrica* are present. There are low values of *Calluna* pollen in profile A, but about 40 % in profile B. A few pollen grains of *Empetrum*, *Vaccinium*-type and *Erica* were recorded, and Ericaceae pollen constitutes 3–4 %. Pollen of Cyperaceae and Poaceae are present at about 1 %, with more Poaceae pollen in profile B. Pollen of Asteraceae, Rosaceae and Dipsacaceae occurs, and a few pollen grains of *Humulus*-type, Campanulaceae, *Melampyrum*, *Plantago major*-type, *Plantago lanceolata*, and *Epilobium*. Unidentifiable pollen constitutes 4 %. There are high numbers of spores, including Polypodiaceae and *Polypodium vulgare*. Microscopic charcoal particles are found in low to moderate quantities.

V LPAZ *Calluna*-*Hordeum*

Four spectra between 34 and 26 cm in profile A; 3 spectra between 30.5 and 22 cm in profile B; 8 spectra between 37.5 and 24.5 cm in profile D.

The tree pollen is dominated by *Betula*, followed by *Pinus*, *Alnus*, *Corylus* and *Quercus*. A few pollen grains of *Picea*, *Ulmus*, *Juniperus*, and *Empetrum* were recorded. *Salix* is only present in profile B, where *Myrica* has its highest pollen values. *Calluna* and Ericaceae occur with greatly varying pollen percentages. Pollen of Cyperaceae and Poaceae constitutes low percentages. Pollen of Asteraceae, *Humulus*-type, Dipsacaceae and *Ranunculus acris*-type were found in profile A. The same pollen types also occur in profile D together with pollen of Caryophyllaceae, *Rumex*, *Rumex acetosa*-type, Ranunculaceae, and Chenopodiaceae. In profile B, pollen of Asteraceae, Rosaceae and *Succisa*-type was recorded with a few pollen grains of *Filipendula* and *Ranunculus acris*-type. Pollen of *Epilobium* only occurred in profile A (Table 7). Unidentifiable pollen constitutes 7 %. Spores of Polypodiaceae and of *Polypodium vulgare* are numerous. The numerous other spores in profile A are mainly unidentified. Microscopic charcoal particles are present in moderate to high amounts.

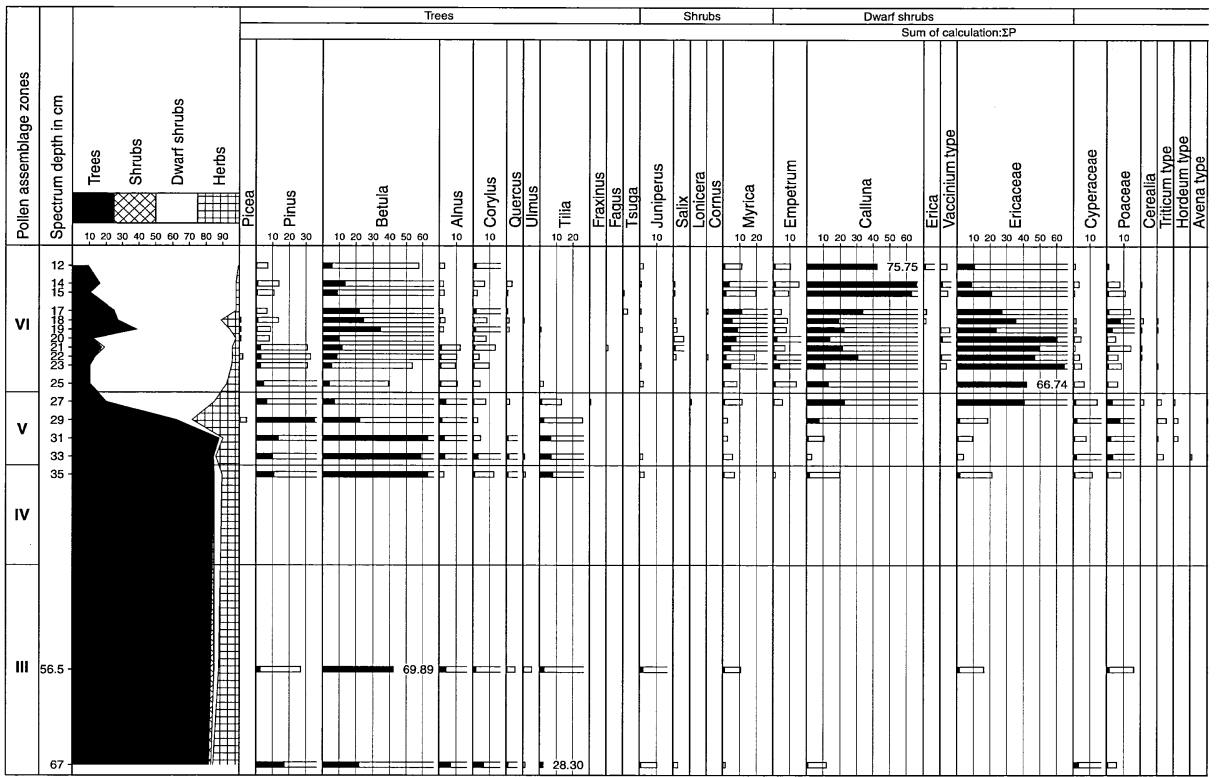


Figure 4. Pollen diagram of profile A at 79.6 m along the transect, Orstad, Klepp, Rogaland county, SW-Norway, Greenwich coordinates $58^{\circ} 46' 50''$ N, $5^{\circ} 44' 30''$ E. (Charcoal frequencies: + = present, ++ = frequent, +++ = abundant).

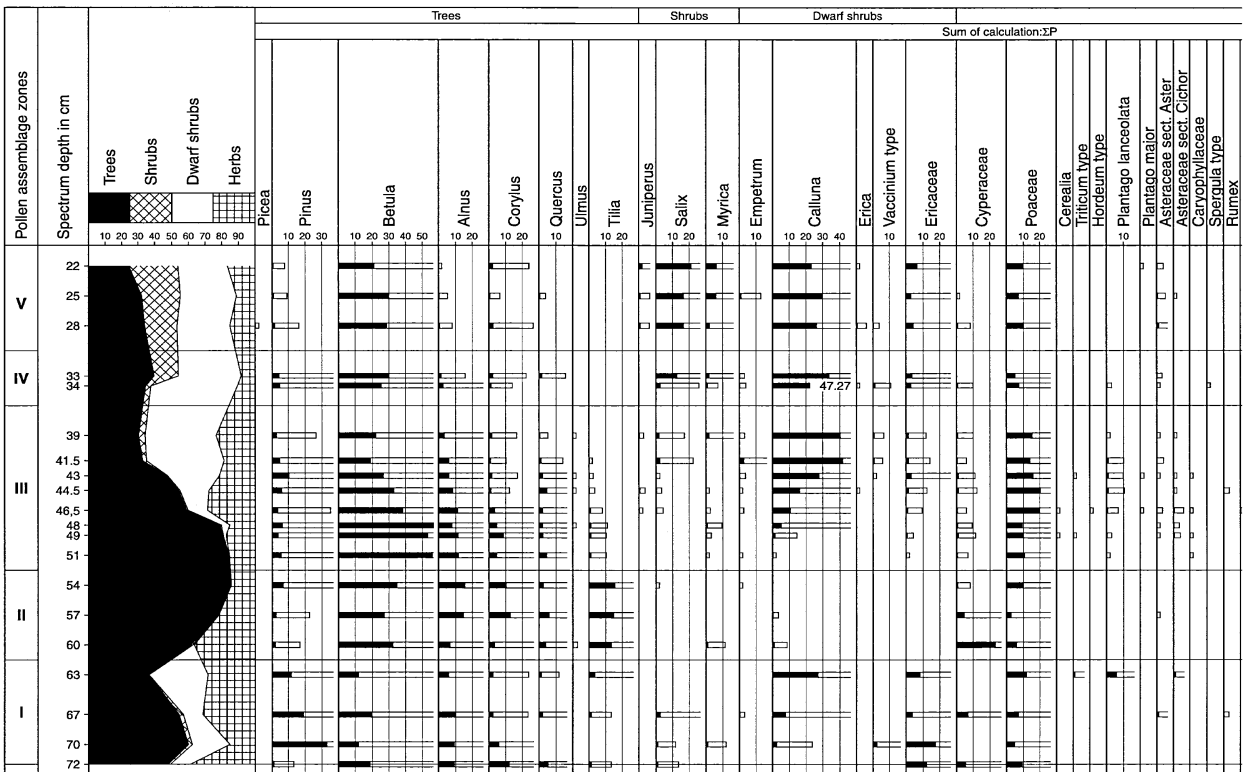
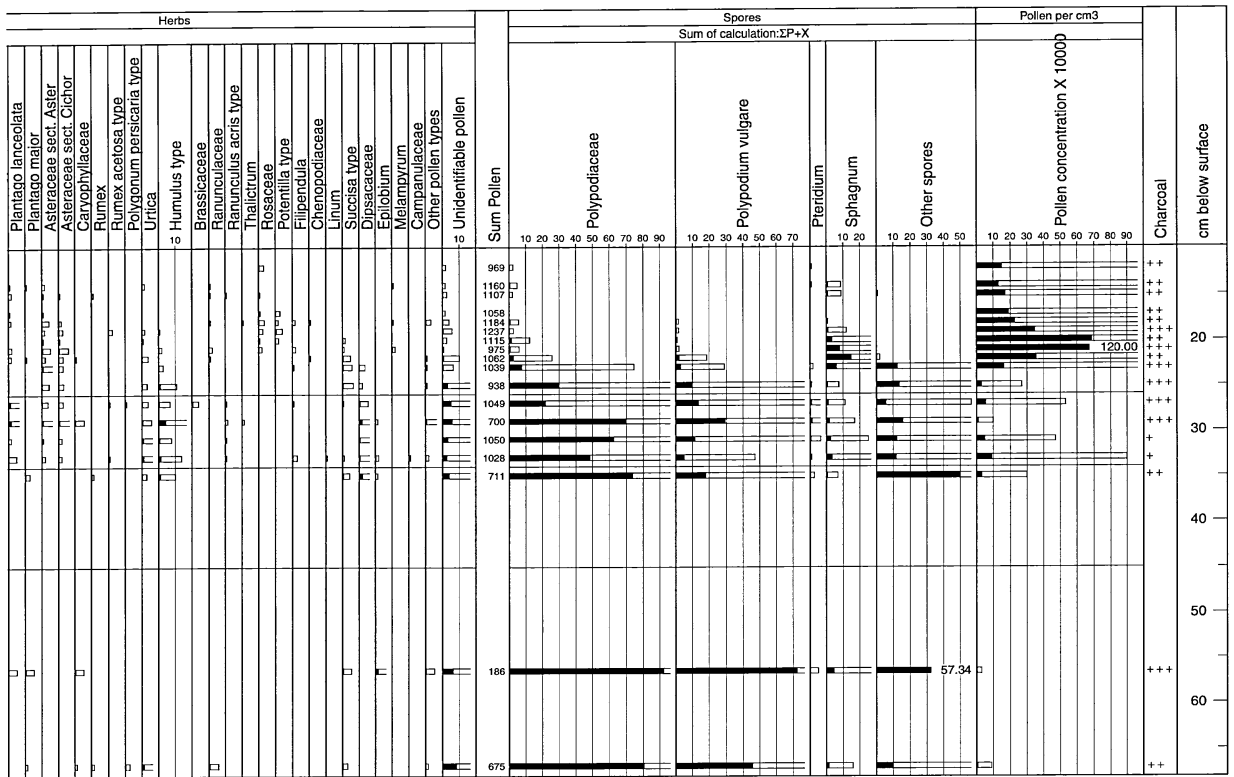
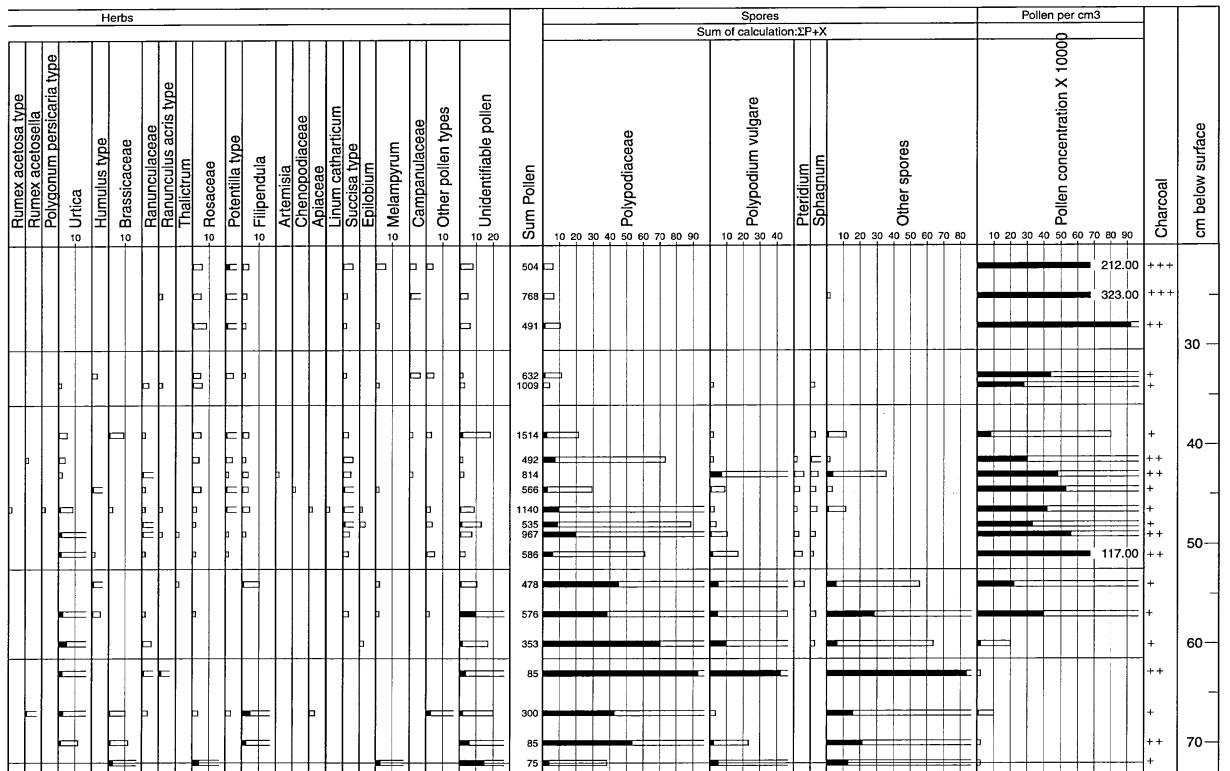


Figure 5. Pollen diagram of profile B at 50.1 m along the transect, Orstad, Klepp, Rogaland county, SW-Norway, Greenwich coordinates $58^{\circ} 46' 50''$ N, $5^{\circ} 44' 30''$ E. (Charcoal frequencies: + = present, ++ = frequent, +++ = abundant).



B.M.Sageidet 2001

Figure 4. Continued.



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Figure 5. Continued.

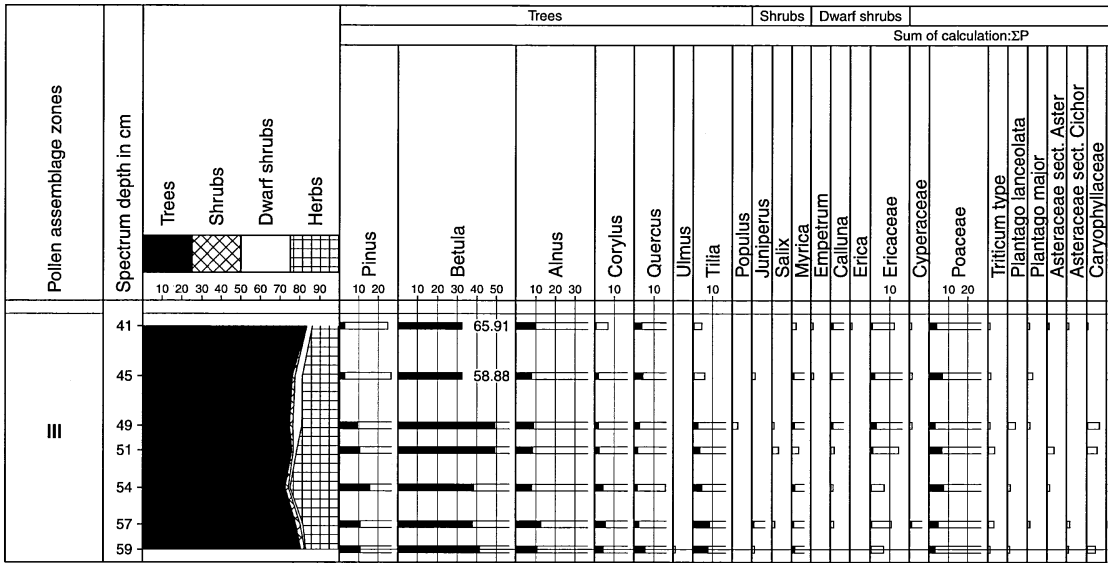


Figure 6. Pollen diagram of profile C at 26.1 m along the transect, Orstad, Klepp, Rogaland county, SW-Norway, Greenwich coordinates 58° 46' 50" N, 5° 44' 30" E. (Charcoal frequencies: + = present, ++ = frequent, +++ = abundant).

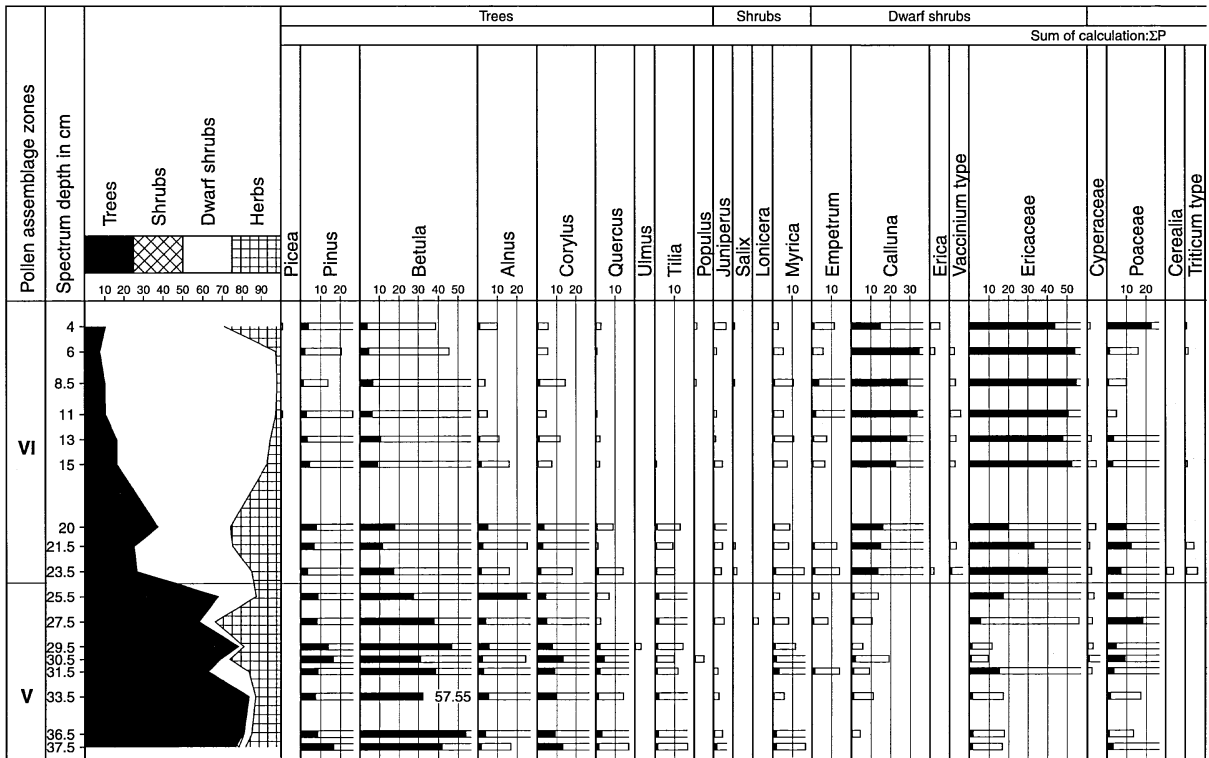


Figure 7. Pollen diagram of profile D at 1.77 m along the transect, Orstad, Klepp, Rogaland county, SW-Norway, Greenwich coordinates 58° 46' 50" N, 5° 44' 30" E. (Charcoal frequencies: + = present, ++ = frequent, +++ = abundant).

	Sub-local PAZ at 79.60 m, profile A	Sub-local PAZ at PAZ 50.10 m, profile B	Sub-local PAZ at 26.10 m, profile C
Tree pollen	80-85 %	decreasing from 85 % to 24 %	80-85 %
<i>Betula</i>	increasing from 20 % to 70 %	decreasing from 56 % to 20 %	increasing from 40 to 66 %
<i>Tilia</i>	decreasing from 28 % to 3 %	decreasing from 1 % to zero	decreasing from 8 % to 0.5 %
<i>Calluna</i>	zero to 1 %	increasing from zero to 41 %	zero to 1 %
Poaceae	4-5 %	14.5 %	4-5 %
<i>Triticum</i> -type	not present	3 grains	8 grains
<i>Hordeum</i> -type	not present	2 grains	not present
undef. Cerealia	not present	3 grains	not present
<i>Potentilla</i>	not present	0.5 %	not present
<i>Urtica</i>	0,5 %	decreasing from 2 % to 0,5 %	decreasing from 5 % to 2 %
Brassicaceae	not present	a few grains	a few grains
<i>Linum</i>	not present	2 single grains	not present
Asteraceae	not present	a few grains	a few grains
<i>Rumex acetosa</i> - type	not present	single grain	2 single grains
<i>Rumex acetosella</i> -type	not present	single grain	not present
Ranunculaceae	a few grains	a few grains up to 1%	1-2 %
Rosaceae	not present	a few grains	a few grains
<i>Filipendula</i>	not present	a few grains	a few grains
Chenopodiaceae		Recorded	recorded
Other herbs		<i>Ranunculus-acris</i> -type, <i>Rumex</i> , <i>Artemisia</i> , Campanulaceae <i>Humulus</i> -type, <i>Thalictrum</i>	Dipsacaceae, <i>Rumex</i> , <i>Humulus</i> - type, <i>Thalictrum</i>

Table 6. Sub-local pollen assemblage zones of the LPAZ Cerealia at Orstad, Klepp municipality, Rogaland county, southwestern Norway.

	Sub-local PAZ at 79.60 m, profile A	Sub-local PAZ at 50.10 m, profile B	Sub-local PAZ At 1.77 m, profile D
<i>Tilia</i>	4,4 %	not present	1-2 %
<i>Corylus</i>	9 %	2 %	1,2 %
<i>Triticum</i> -type	12 grains	not present	not present
<i>Hordeum</i> -type	6 grains	not present	2 grains
<i>Avena</i> -type	1 grain	not present	not present
Undefined Cerealia	2 grains	not present	not present
<i>Plantago lanceolata</i>	in every spectrum, up to 2 %	not present	In 2 spectra, up to 1.6 %
<i>Plantago major</i>	not present	single grain	a few grains
Brassicaceae	a few grains	not present	numerous in several spectra
<i>Linum</i>	one single grain	not present	not present
<i>Polygonum persicaria</i>	one single grain	not present	single grains in four spectra
<i>Urtica</i>	in every spectrum, up to 5 %	not present	in every spectrum, up to 5 %
<i>Thalictrum</i>	one single grain	not present	single grains in three spectra
<i>Pteridium</i>	in every spectrum, up to 1 % Σ P+X	not present	single spores

Table 7. Sub-local pollen assemblage zones of the LPAZ *Calluna Hordeum* at Orstad, Klepp municipality, Rogaland county, southwestern Norway.

VI LPAZ *Calluna*

Eleven spectra between 26 and 12 cm in profile A; 9 spectra between 24.5 and 4 cm in profile D. Tree pollen constitutes 10–35 %, dominated by *Betula*, and followed by *Pinus*, *Alnus*, and *Corylus*. A few pollen grains of *Quercus*, *Picea*, *Ulmus*, *Populus*, *Tsuga*, *Salix* and *Juniperus* are recorded. Pollen of *Myrica* is numerous in profile A. Pollen of *Calluna*, and Ericaceae constitute 11–70 %. Poaceae pollen occurs in low amounts, but reaches 23 % in profile D. Pollen of Cyperaceae is represented by a few grains. A few pollen grains of Asteraceae, *Succisa*-type, and *Plantago major*-type are recorded (Table 8). High percentages of Polypodiaceae spores and moderate percentages of *Polypodium vulgare* spores decrease upward to zero. Spores of *Pteridium* are found in profiles C and D. Moderate to high amounts of microscopic charcoal particles are present.

Reconstruction of the Vegetation and Land-use History at Orstad

The time boundaries are mainly based on the 10 uncalibrated 14C dates from the transect through the site (Table 1).

Phase 1, ca. 4400–4000 BP (LPAZ I *Varia-Polypodiaceae*): clearings in the forest for grazing

A deciduous forest of *Betula*, *Alnus* and *Quercus*, with hazel bushes, pine and some lime, seems to have grown before the start of cultural impact. The high pollen values of the quick regenerating and light-demanding species (birch, alder, hazel, willow) together with the pollen of grass and *Plantago lanceolata*, and the occurrence of charcoal indicate clearings in the forest (Iversen 1941; cf. Kalis and Meurers-Balke 1998). Hemdorff (in press) found macroscopic charcoal at Orstad, dated to 4360±70 BP (TUa-1523). The variety of herb pollen types

Asteraceae, Rosaceae, Brassicaceae, *Rumex acetosella* L., and *Melampyrum*, together with the more numerous pollen of Poaceae, Cyperaceae, and *Calluna vulgaris* (L.) Hull and *Urtica*, may indicate grazing of a livestock in clearings (Behre 1981, 233, cf. Prøsch-Danielsen 1993b, 32).

Phase 2, ca. 4000–3600 BP (LPAZ II *Tilia*): the disappearance of human impact

No distinct anthropogenic pollen indicators are left, suggesting that the site was no longer in use. As indicated by the presence of *Sphagnum* spores, perhaps the site had become too wet for grazing. The *Epilobium* pollen may originate from plants on earlier disturbed and subsequently overgrown patches. The ground-water level may have risen as a consequence of nearby deforestation. Shrubs of *Betula* and *Alnus* spread over moist ground, forming swampy habitats with grasses and sedges, in which *Humulus* could grow naturally. Hazel preferred drier areas. As grazing animals no longer destroyed saplings, the growing conditions for *Quercus* were improved. *Tilia* prevailed on light-textured till. Pine pollen from further away was filtered out by the now denser vegetation on the site. Elm seems to have grown in the nearby forest.

Phase 3, ca. 3600–3200 BP (LPAZ III *Cerealia*, LPAZ IV *Betula*): cereal growing on different parts of the site

At about 3600 BP, people began to use the land at Orstad again, as indicated by an apparently abrupt deforestation and a flora with Caryophyllaceae, Brassicaceae, Asteraceae, *Rumex acetosa*- and *R. acetosella*-types, *Polygonum persicaria* L., and *Plantago major* (cf. Behre 1981, 233; cf. Hicks 1988). People probably cleared the land with fire, as indicated by an abundance of charcoal particles and dust. In connection with the high amounts of more or less evenly distributed macroscopic charcoal all over the transect (cf. 'Study Area' and 'Pedostratigraphy'), it

	Sub-local PAZ at 79.60 m, profile A	Sub-local PAZ at 1.77 m, profile D
<i>Tilia</i>	a few grains	from 1 %, disappearing upwards
<i>Triticum</i> -type	3 grains	12 grains
Undef. Cerealia	6 grains	one single grain
<i>Plantago lanceolata</i>	a few grains	a few grains to 1%
Other herbal types	Asteraceae, Rosaceae, <i>Urtica</i> , Ranunculaceae	Caryophyllaceae, Brassicaceae, Ranunculaceae, <i>Polygonum persicaria</i> -type, <i>Filipendula</i>

Table 8. Sub-local pollen assemblage zones of the LPAZ *Calluna* at Orstad, Klepp municipality, Rogaland county, southwestern Norway.

seems unlikely that the charcoal may only be the result of other domestic activities like heating and cooking.

The presence of *Epilobium*, may confirm the use of fire (e.g. if it were referable to *E. angustifolium* L.) or could indicate broken ground or disturbances (Simmons and Innes 1996, 617), perhaps in connection with the activities for creating arable land. People seem to have removed some lime trees (cf. Lüning 2000, 41). This led to an intermediate overrepresentation of birch, alder and hazel pollen. The oak trees on the site may not have been cut, as their pollen values remained constant.

cereal cultivation on parts of the site

Cultivation is indicated by pollen grains of cereal-type, mainly of the autogamous species wheat and barley, and by the presence of Poaceae, Asteraceae, *Linum*, Brassicaceae, *Urtica*, and Chenopodiaceae (cf. Behre 1981). The high numbers of pollen of *Potentilla*, which are light-demanding plants with restricted pollen dispersal, confirms the presence of open ground (cf. Kvamme *et al.* 1992, 22). People seem to have grown both barley and wheat on the central field (profile B, Table 6). At the same time, wheat seems to have been cultivated on a field at the southwestern border of the site, where two clearance cairns were 14C dated to 3615 ± 85 BP and 3450 ± 75 BP (Hemdorff *et al.* in press; Sageidet in press b). Wheat has a long vegetative period, and the southwest exposed slope may have provided a suitable microclimate for the growth of wheat.

Wheat and barley usually seem to have been sown together in Bronze Age fields in Rogaland (Prøsch-Danielsen 1988; 1993a), but at Rugland in South-Jæren, people presumably only have cultivated barley (Simonsen *et al.* 1982). For the Late Neolithic in central Europe, it is generally assumed that the different cereal types were cultivated separately (Brombacher and Jacomet 1997, 251ff.). In any case, the fields have surely been full of gaps with weeds instead of crops, indicated by weeds from species of the Brassicaceae, Asteraceae, Chenopodiaceae and Polygonaceae, and species of *Linum* and *Artemisia* (cf. Behre 1981). Grasses may also have been an important component of the weed flora.

The field around profile B must have been somewhat sheltered from wind, as it was located in a depression. If this field had included the part of the site at profile C, then this part would have faced north (Fig. 3). Such an orientation would have been unfavourable to crops and was unusual in prehistoric times (Linke 1976). It is possible, that the area close to profile C had a function related to the harvesting of cereals, and the eight pollen grains of *Triticum*-type (Table 6) may have been deposited here. Hemdorff (in press) found fewer clearance cairns in this

area than on the slope facing towards the southwest.

The absence of cereal pollen (Table 6) and of typical indicator species for cultivated ground in the two spectra of profile A may indicate that there was no cultivated field on the northern part of the site.

grazing

Some lime trees, birches and heather seem to have grown close to both profiles A and C. Pollen of *Juniperus*, Asteraceae, *Succisa*-type, *Plantago major*-type, *Rumex acetosella*, *Campanula*, *Plantago lanceolata*, Caryophyllaceae and bracken (*Pteridium aquilinum* (L.) Kuhn), indicate grazing (cf. Behre 1981; Lüning 2000, 41; Andersen *et al.* 1983, 187, 190). For grazing, people may have used the moister parts of the area, where grasses were common and heather began to spread (cf. Linke 1976, 29).

farming practices

The methods of arable farming at Orstad can only be deduced indirectly (cf. Behre 1988, 634, Lüning 2000, 72). Deforestation and the use of fire on the site, followed by the occurrence of cereal pollen types, indicate the involvement of fire in making the field productive for arable (Iversen 1941; Kalis and Meurers-Balke 1998). The LPAZ III (*Cereal*) covers a time period of 100–200 years. If the soil layers that correspond to the LPAZ III in profile B represent the remnants of a field that was cultivated continuously, then the pollen content in the various spectra of these layers would appear similar, blurred by bioturbation. However, profile B reveals a decrease in birch, hazel, lime and alder, and an increase in heather. Nevertheless, there seem to have been continuity in use of the site, as the quantities of agricultural indicator species appear more or less constant, and charcoal amounts are high throughout this layer. A connection between the permanent cultivation of small fields and fire-clearance husbandry in prehistory is not yet documented for Norway (Steensberg 1993, 120). In the earliest settlements in Finland, the forests were burned and only one crop harvested after which the area was used for grazing for some years (Vuorela 1986, 55). At Orstad, the clearance cairns provide evidence of stone clearance over many years. It may have been an area used occasionally for cultivation in times of hardship. Pollen of *Plantago lanceolata* and spores of bracken indicate cultivation, followed by fallow (Behre 1981). During these probably long fallow periods, the field was presumably used as a pasture (cf. Mikkelsen and Høeg 1979; cf. Wiethold 1998). It is laborious to cultivate a field that has lain fallow and has become overgrown (Bakkevig 1998, 57). If Orstad was only needed occasionally, burning must have been the

easiest way for rendering the fields arable again (Steensberg 1979, 32; cf. Hagen 1987, 50). Burning destroys the vegetation, liberates nutrients, and consequently improves soil productivity. Sowing on burned ground in times of additional needs has the advantage that it is unnecessary to weed the crop during a single year of cultivation (Steensberg 1979, 32). This would have been ideal, as the settlement may have been far from the site. Burning, however, increases the leaching of nutrients, accelerates soil deterioration (cf. Steensberg 1979; Vuorela 1986, 55), and makes cultivation less rewarding in the long term.

As time passed, the herb flora at Orstad became poor in cultural indicators. People seem to have forsaken cultivation of the field on the central part of the site (profile B) and it was finally overgrown by heather and willow (*Salix*). People seem to have continued to use the site for grazing.

Phase 4, ca. 3200 BP – Early Iron Age (LPAZ V Calluna-Hordeum): new cultivation

The abundance of charcoal may indicate a new phase of fire clearance on the site. When people continued to build the clearance cairns no. 1 and no. 6 (see TUA-3220 and TUA-3213 in Table 1), they seem to have buried the surface of the former field at profile B with soil. The form of clearance cairn no. 6 resembles a field terrace border towards the southwest. Pollen analysis of profiles A and D indicates that the new fields were laid out some metres upslope towards the north, and from the top of the hill downslope towards the southwest. The greyish-brown coloured parts of the B-horizons along the northern part of the transect may be associated with remnants of a field. The radiocarbon dates for clearance cairn no. 11 indicate farming activity at least until the Late Bronze Age and the transition to the Early Iron Age (Table 1). However, clearance cairn no. 11 seems to have been disturbed, as the older date is from a higher stratigraphic position in the profile than the younger one (Table 5, Fig. 3D). Orstad seems to have become a permanently inhabited farm place (cf. Løken 1989, 144; cf. Myhre 2002), in accordance with the assumption of Hemdorff (in press).

People seem to have cultivated wheat and barley again. The cultivation of vegetables, harvested before flowering, as for example cabbage (*Brassica oleracea*), cannot be excluded, as some pollen of *Brassicaceae* was found in profile D (many of the species of this family are insect-pollinated). The different species of the *Brassicaceae* family are not distinguishable palynologically. The occurrence of *Urtica* may point to root crops (Behre 1981, 233), or nettles may have grown on manure (Vorren 1986, 14). In Neolithic times, there was perhaps no sharp

limit between tolerated wild plants and weeds on the fields (Kreuz 1993, 25), thus *Urtica* may even have been used for making textiles (cf. Hoffmann 1991, 62).

A decrease of pollen of lime, alder, hazel and oak, may be an indication of the exploitation of these taxa for animal fodder (Austad 1988; cf. Rösch 1994; cf. Lüning 2000, 146).

farming practices

After a time period of 10–20 years, manure must have been necessary on prehistoric fields (Bakkevig 1998, 57). The grazing indicators suggest that people at Orstad have had livestock, but using manure from animals may require stables (Bakkevig 1998, 57). Neither stables nor houses were found at Orstad (Hemdorff in press), nor could phosphate analysis distinguish anthropogenic from natural phosphorus (Anders Forsberg, pers. comm.). The observed “thin black layers” were visible along the transect exactly where pollen analysis indicates cultivation activity (from clearance cairn no. 1, down the slope to the northern end of clearance cairn no. 6). Here, people seem to have supplied some organic material as fertilizer. No such material has been supplied to the part of the transect facing northwards, presumably because it was not cultivated. The high content of stones and boulders must have limited the use of mechanized agricultural equipment (Rønneseth 1974, 46). The above-mentioned black layers would not be preserved as distinctly as they are if people had used a plough.

Although it is hardly possible to separate *Avena*-type from *Triticum*-type pollen (Andersen 1979b; Edwards 1989), one single pollen grain may represent the wind-pollinated *Avena*-type, according to Beug (1961). Macrofossil studies from other sites in Rogaland indicate that oats were about to be introduced to the county in the Late Bronze Age (Bakkevig *et al.* 2002). Bakkevig (1992: 49) suggests that before this time, oats were presumably like weeds in the fields of barley and wheat (cf. Willerding 1980, 438ff).

Phase 5, Early Iron Age – modern time (LPAZ VI Calluna): grazing on heather

Since the Early Iron Age, people obviously continued to cultivate at Orstad. Two notes from the 17th century tell us that the place had a rather good soil for cereal growing and was suitable for meadow and marsh (Brunes 1963, 180). The fields of this time period, indicated by 22 pollen grains of cereal-type, may have been located outside the investigated part of the site. Soil management (for example with a plough) and possible crop roots would otherwise have disturbed the older soil layers. On the Orstad site, heather spread, as was

typical in the region. The site was presumably used for grazing for some time, before people used the windy location for the drying of turf bricks, and the vegetation cover became scarce.

Conclusions

Sub-local differences in the pollen stratigraphy along a continuous site transect were used to distinguish the vegetation development on different parts of the site. Low porosity of soil material, which probably originates from prehistoric cultivation, seems to have had a positive effect on pollen preservation.

The Orstad site was cultivated during two main phases in prehistory. People moved the fields in accordance with the suitability of the soil, and used different kinds of soil management through time:

The initial use of the Orstad area, from about 4500 until 4000 BP, was presumed to be for grazing in a partly cleared deciduous forest.

After an intermediate phase until 3600 BP, when the site was not in use, people began to cultivate both barley and wheat in the centre of the site. The site was used sporadically for cereal cultivation and grazing, and fire-clearance seems to have been a suitable form of management. Later, the fields perhaps became infertile, and the site was only used for grazing.

From about 3200 BP, the Orstad site may have become permanently inhabited. The new fields, which were laid out further up the slope towards the north, seem to have been fertilized with organic material. The southern part of the site, exposed to the north, is presumed never to have been cultivated.

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