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Soil pollen analysis of a podsol and a clearance cairn confirms Bronze Age agriculture at Orstad, south-western Norway

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Archaeological investigations, soil pollen analyses, and ^{14}C-dating in a field rich in clearance cairns at Orstad, southwestern Norway, gave evidence of human activity extending back to the Late Neolithic period and/or Early Bronze Age. Pollen of *Triticum* type confirmed agriculture on the site. In this case study, pedo-stratigraphic and pollen-stratigraphic results from two soil profiles made it possible to reconstruct three stages of the very local palaeoenvironment at the two neighbouring sites, and gave evidence for one phase of cultivation. Hyphae analysis suggested that the soil was in a brown earth stage, when people began to cultivate it, probably between 2120–1675 cal BC. A comparison of the pollen distributions in the two profiles shows evidence of pollen translocation. The study confirms the archaeological correlation of a layer in the soil under the investigated clearance cairn with a layer in the profile of a surrounding podsol, although ^{14}C-dates from the two layers differ. Uncertainties in the records from mineral soils related to soil disturbance, soil development, pollen destruction and pollen translocation can be compensated for by the complementary information from profiles of different types from the same site.

Keywords: pollen analysis, podsol, brown earth, early agriculture, pollen translocation, hyphae analysis

Introduction

The analysis of pollen in mineral soils is commonly used in interdisciplinary archaeological investigations, yet there are different opinions about how to interpret the pollen content of soils. Havinga (1968) stressed the importance of considering the various processes, such as mixing, destruction and overrepresentation of pollen, which contribute to the development of a pollen profile in a sandy soil. S. T. Andersen (1979a) proposed that the fauna in mineral soils was mainly responsible for its observed pollen stratigraphy. Dimbleby (1985) suggested that “humus complexes” contribute to keeping the pollen grains broadly in the layers in which they were originally deposited. He also provided a model of pollen distribution in a soil profile affected by pollen percolation. Kelso (1994) focused on selective downwash of pollen through soil pores and propounded that pollen percolation into underlying deposits may help to preserve pollen records which otherwise would have either eroded away or would have become undecipherable as a continuous accumulation in the humus zone. Davidson et al. (1999) rejected down-washing through void spaces as an important factor for the redistribution of pollen in a soil profile and emphasized that the thickness of a layer that contains material of different ages in soils with restricted bioturbation, like podsols, is dependent on the history of the profile. Tipping et al. (1999) stated that in most soils it would be difficult to achieve a useful temporal resolution from the pollen record.

According to S. T. Andersen (1986:173), the original features of the vegetation development can be faintly recognized in a podsol which contains pollen assemblages from former brown earth stages, although most soil horizons incorporate pollen grains of varying ages. It is possible to obtain valuable evidence concerning vegetation history from pollen stratigraphies

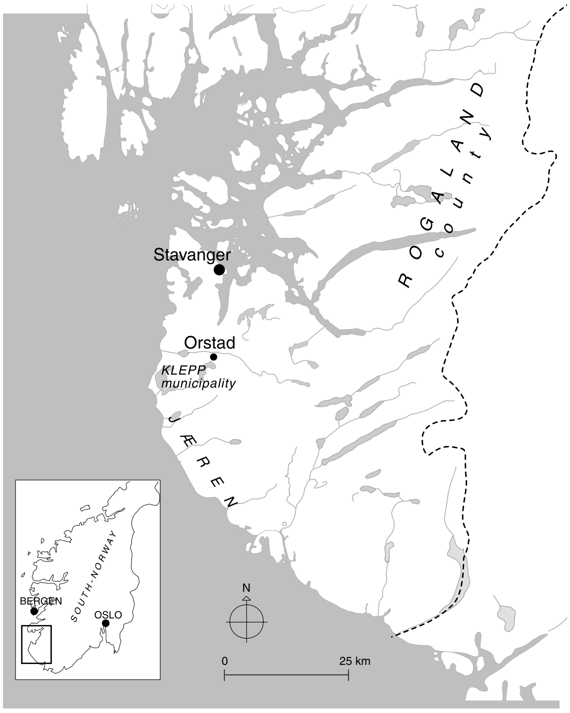


Figure 1. Location of the area, map of southwestern Norway / Jæren and Orstad. Drawing Tove Solheim Andersen.

(Stockmarr 1975; Casaldine & Matthews 1985:102; Affleck et al. 1988). Segerström (1991:166) suggested that A horizons provide satisfying stratigraphies for identifying ancient tilled land, even though some vertical mixing and some pollen down-wash may occur.

In this study the pollen content of a brown earth profile underneath a clearance cairn is compared with that of a neighbouring podsol profile to investigate on a very local scale, the remains of Bronze Age human activity. The clearance cairns at Orstad alone suggest prehistoric cultivation. As the vegetation history of the region is well investigated (Prøsch-Danielsen & Simonsen 2000; Sageidet in press), it was expected that even a low pollen content would be useful for elucidating local details of the palaeo-ecological history. The study provides an example of the interrelated processes of cultural activity and soil development and their effects on the local pollen distribution.

The area investigated

The two neighbouring profiles are from a field rich in clearance cairns located at Orstad in the municipality of Klepp, Jæren, Rogaland, southwestern Norway (Fig. 1). Jæren is a lowland with till and fluvioglacial deposits (B. G. Andersen 1964; B. G. Andersen et al. 1987) stretching about 50 km along the North Sea coast. Depressions in the area were once occupied by lakes and mires (nowadays drained), and prehistoric agriculture was only possible on the stony but well-drained till ridges (Rønneseth 1974). The climate in the Jæren region is oceanic. Mean annual precipitation, about 1260 mm measured at Klepp for the period 1960–1990 (DNMI 1993), is lower than elsewhere in western Norway. Podsol is the most common soil type, due to a combination of a moist climate, nutrient-poor parent material and plant remains with an acidic reaction (Semb & Nedkvitne 1957). Heathland dominated by ling heather (*Calluna*), which was used for grazing, was typical of the area until the 20th century. Deforestation and the establishment of a heath landscape in the region started in the Bronze Age, caused by human activity (Prøsch-Danielsen & Simonsen 2000). Jæren is an old cultural landscape with traces of agricultural activity going back to Neolithic times (Fægri 1944; Rønneseth 1974; Prøsch-Danielsen 1993).

The two soil profiles, located at the foot of a till ridge a few metres high, were investigated in connection with an interdisciplinary archaeological project at the Museum of Archaeology, Stavanger, in 1994–1999 (Hemdorff et al. in press). About 30 clearance cairns, one possible grave cairn and a dwelling site were found at Orstad. The Orstad site was one of the agricultural settlements investigated which were dated to the end of the Neolithic to Early Bronze Age (4000–3600 uncalibrated ^{14}C years BP, Hemdorff & Sageidet 1997; Hemdorff in press).

The area rich in clearance cairns at Orstad is located in hilly terrain between 78 and 84.5 m a.s.l.. The two profiles investigated are located on a slope exposed to the southwest, twenty metres below a hilltop. During excavation, a dark layer under a clearance cairn (profile II) was correlated in the field with the dark-coloured Bh horizon of the surrounding podsol soil (profile I) on the basis of colour and stratigraphy (see Fig. 2). Charcoal from the dark layer below clearance cairn 14 (profile II) was ^{14}C dated to 1880–1675 cal BC, while charcoal from below the Bh horizon in the podsol profile (I) was dated to 1160–995 cal BC (Table 1). This date is obviously too young, and Hemdorff et al. (in press) have suggested that the two layers were most likely contemporary. The charcoal particles used for the dating of profile I might have been dislocated from younger layers above by some unknown process. A layer below the clearance cairn 15/16 was ^{14}C dated to 2120–1790 cal BC. No archaeological remains were found in the layers in question. Soil description and pollen and hyphae analysis were used to reveal possible

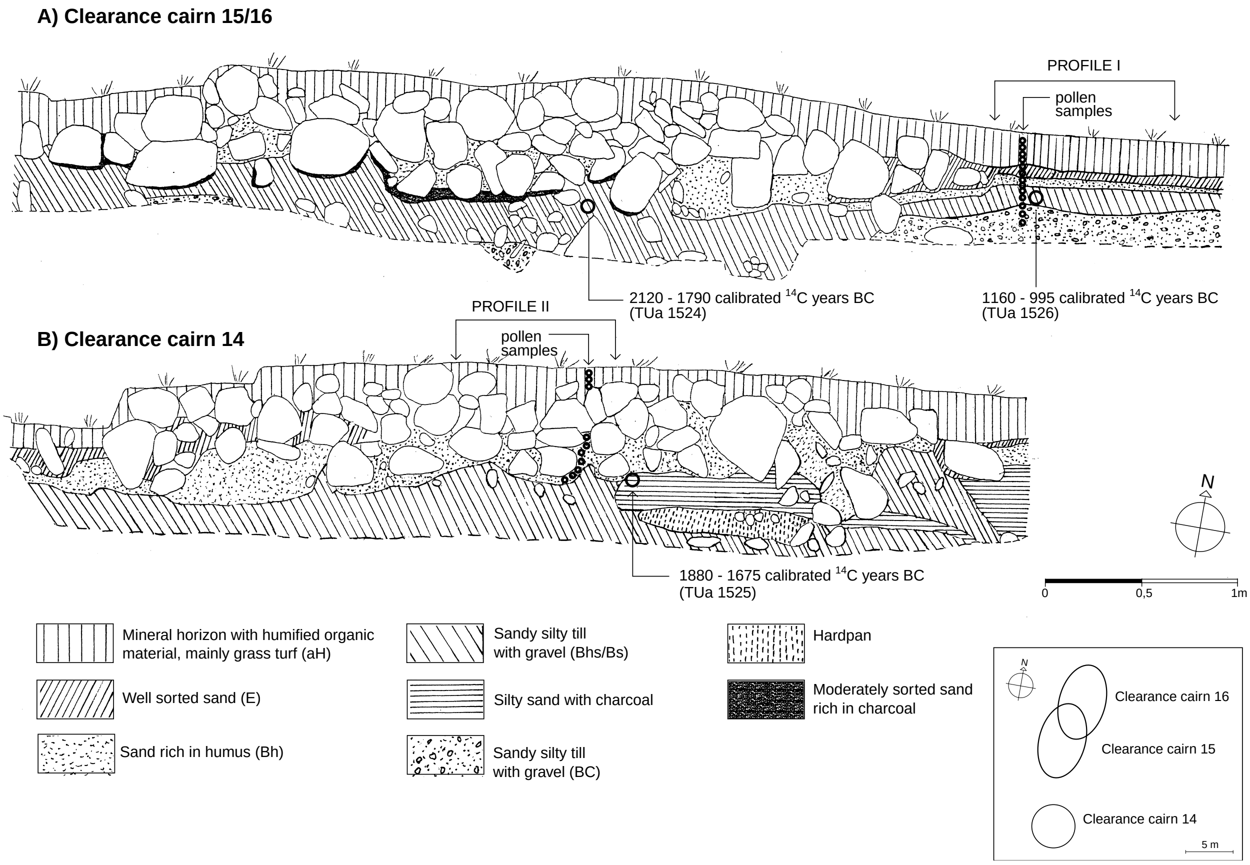


Figure 2. Archaeological field sketches of clearance cairn no.15/16, with the surrounding podsol profile I, and clearance cairn no.14, profile II. The soil horizons were tentatively labelled (in parentheses). Redrawn from a field sketch by Elisabeth Eriksen and Arne Håkon Thomassen (Hemdorff et al. in press), and converted by Tove Solheim Andersen and Astrid Hølland Berg. (Abbreviations in brackets: TUa = laboratory reference; aH = humous surface horizon; E = eluvial horizon; Bh = humous illuvial horizon; Bhs = humous illuvial horizon with accumulation of sesquioxides; BC = transitional horizon with the parent material).

Table 1. Radiocarbon dates for Orstad, Jæren, southwestern Norway (Hemdorff in press). The dated material is charcoal of *Betula*. Calibrated according to Stuiver & Reimer (1993).

Lab. Ref.	Location of dated sample	Uncalibrated ^{14}C-age BP	Calibrated ^{14}C age BC (1σ)	δ^{13}C ‰ (estimated)	Depth cm below surface
TUa-1524	Beneath clearance cairn 15/16	3615±85	2120–1790	–26.1	62–66
TUa-1525	Beneath clearance cairn 14	3450±75	1880–1675	–26.1	55–60
TUa-1526	Beside clearance cairn 15/16	2900±60	1160–995	–26.1	28–32

Table 2. Description of profile I, east of clearance cairn 15/16, according to FAO (1990). Geographical coordinates: 58°46'50" N lat., 5°44'30" E long., grid reference: UTM: 32VLL112218.

Horizon	Lower boundary (cm below surface)	Munsell colour	Texture and rock fragments	Structure	Consistency	Porosity	Organic constituents
Ah	16–20 abrupt, smooth	10 YR2/2	sandy loam, with few small, subrounded stones	weak single grain structure	loose, soft, slightly plastic	high, many fine interstitials	many fine and medium roots, few charcoal
E	24–28 abrupt, smooth	7.5 YR N5	fine sand, with few small, subrounded stones	weak single grain structure	friable, non-sticky	high, few fine interstitials	common fine roots, common charcoal
Bh	26–31 abrupt, smooth	YR 3.1	loamy sand, with few fine gravel, slightly weathered	weak single grain structure	friable, slightly sticky	low, very few, very fine interstitials	few fine roots, few charcoal
Bhs	33–38 gradual, wavy	7.5 YR 5/8	sandy clayey loam, with common coarse gravel, frequent stones, weathered	weak fine and medium subangular and angular blocky structure	friable, slightly plastic	medium, fine to medium interstitials	few to common fine roots, few charcoal
Bs	64 gradual, wavy	10 YR 7/6 few to common coarse black mottles	sandy loam, with common subrounded medium and coarse gravel, weathered	weak coarse granular structure	slightly hard, sticky	interstitials medium, fine	few fine roots, few charcoal

traces of prehistoric agriculture, and to assist in the correlation of the soil/sediment stratigraphy.

Materials and methods

The clearance cairns, no. 15/16 and no. 14 (Fig. 2), were sectioned. Profile I, from beside cairn 15/16, and profile II, from beneath cairn 14, were described according to the guidelines of the FAO (1990) (Tables 2–3). The cairns were built up of stones and the interstices were filled with soil. Cairn no. 15/16 was oval, 4.5×7 m at the base, and had a maximum height of c. 0.5 m, while no. 14 was round, c. 5 m in diameter and had a maximum height of 0.9 m.

Two vertical series of samples located 12 m apart were collected for pollen analysis, profile I from a point 20 cm east of cairn no. 15/16 and profile II from the centre of cairn no. 14 (Fig. 2).

The samples for pollen analysis (1 cm^3) were collected by pressing small plastic tubes of 1 cm in diameter into the cleaned profiles in the field. Due to the stones of the cairn, sampling was not possible between 9 and 36 cm below the surface in profile II. The chemical treatment of the samples followed Fægri & Iversen (1989). Samples rich in sand were treated with hydrofluoric acid (HF). Three tablets of acetylized *Lycopodium clavatum* spores were added to each sample (Stockmarr 1972) to allow estimates of palynomorph concentration.

The pollen samples were washed through a 1 mm sieve to remove large pieces of organic material while retaining the fungal hyphae. The lengths of up to 500 hyphae fragments per level were measured during the pollen analysis of profile I to distinguish earlier stages in podsol development (cf. S. T. Andersen 1979a, 1984, 1986; Aaby 1983).

Table 3. Description of profile II, clearance cairn 14, according to FAO (1990). Geographical coordinates: 58°46'50" N lat., 5°44'30" E long., grid reference: UTM: 32VLL112218.

Horizon	Lower boundary (cm below surface)	Munsell colour	Texture and rock fragments	Structure	Consistency	Porosity	Organic constituents
Ah	6–32 abrupt, broken	5 YR 2/2	loamy sand	weak single grain	soft, slightly sticky	medium, many fine interstitials	frequent fine and medium roots, few charcoal
(Ap)	35–58 abrupt, broken	–	fine sand, dominant stones and boulders, few soil material in interstitials	–	slightly hard, slightly sticky	high, very coarse interstitials	common fine roots, common charcoal
Apb	52–63 abrupt, wavy	YR 3.1	loamy fine sand	weak single grain structure	friable, slightly sticky	low, very few, very fine interstitials	common charcoal
Bhs/Bs	86–90 gradual, wavy	7.5 YR 3/2	silty loam, with common coarse gravel, weathered	weak medium subangular and angular blocky structure	friable (moist), and slightly sticky (wet)	low, fine interstitials	few charcoal

A Nikon Optiphot light microscope was used for the pollen analysis, with a magnification of 400–1000×. To identify pollen grains of the *Cerealia* type, phase contrast and a 1000× magnification were used. Pollen was identified using the descriptions in Beug (1961), S. T. Andersen (1979b), Fægri & Iversen (1989), Moore et al. (1991) and Reille (1992) and the pollen reference collection at the Museum of Archaeology, Stavanger. It was tried to reach a pollen sum of 500 terrestrial pollen, but this was not possible in the lower halves of the profiles. Whole slides were always analysed. The sum on which the calculations are based is the sum of pollen grains (Σ P) excluding spores and aquatic palynomorphs. The percentages of spores, charcoal particles (about 10–200 µm) and aquatics are based on Σ P + X, where X is the sum of each individual type. The results are presented in two pollen diagrams, constructed by using the computer program Core System (Michelsen 1985). Pollen grains which were too corroded or too degraded to be identified are included in the pollen sum in order to provide more realistic relative frequencies of the different pollen types in the spectra (cf. S. A. Hall 1981:196). The plant names are translated into English in Table 4.

Hyphae were analysed following S. T. Andersen (1979a, 1984, 1986), who found characteristic distributions of pigmented, and thereby corrosion-resistant hyphae fragments (Gray & Williams 1975) in podsol profiles that had developed from earlier brown earth stages. Living fungal mycelia are restricted to the uppermost soil layers (Nagel-de Boois & Jansen 1971). Further down in a soil profile, the hyphae are fragmented to varying lengths, initially through the action of macroarthropods. Further consumption by microarthropods, particularly oribatids, means that the hyphae fragments are broken into still smaller pieces (S. T. Andersen

Table 4. List of plants mentioned in the text, figures and tables (Lid & Lid 1994).

Latin names	English names
HERBS	
Apiaceae	carrot family
Asteraceae (sect. Asteroideae/sect. Cichorideae)	aster family
Avena	oats
Brassicaceae	cabbage family
Campanulaceae	bellflower family
Cannabis	hemp
Caryophyllaceae	pink family
Cerealia	undefined cereals
Chenopodiaceae	goosefoot family
Cyperaceae	sedge family
Dipsacaceae	teasel family
Elymus	wild rye
Epilobium	willow-herb
Euphorbiaceae	spurge family
Fabaceae	legumes
Filipendula	meadowsweet
Geranium	crowfoot
Geum	avens
Hordeum	barley
Hornungia	hutchinsia
Humulus	hops
Knautia	knautia
Liliaceae	lily family
Melampyrum	cow-wheat
Plantago lanceolata	buck's-horn plantain
Plantago major	greater plantain
Plantago media	sweet plantain
Plantago maritima	sea plantain
Plumbaginaceae	leadwort family
Poaceae	meadow-grass family
Polygonum aviculare	knotgrass
Polygonum persicaria	redshank
Potentilla	cinquefoil
Ranunculaceae	buttercup family
Ranunculus acris	meadow buttercup
Rosaceae	rose family
Rubiaceae	madder family
Rumex	dock
Rumex acetosa	garden sorrel
Rumex obtusifolius	broad-leaved dock
Saxifraga	saxifrage
Scrophulariaceae	figwort family
Spergula	spurrey
Succisa	scabious
Thalictrum	meadow rue
Tofieldia	asphodel
Triticum	wheat
Urtica	nettle
TREES	
Alnus	alder
Betula	birch
Cornus	dogwood
Corylus	hazel
Pinus	pine
Quercus	oak
Tilia	lime
Ulmus	elm
SHRUBS	
Juniperus	juniper
Salix	willow
DWARF SHRUBS	
Calluna (vulgaris)	heather
Empetrum	crowberry
Ericaceae	heath family
Erica	heath
Myrica (gale)	sweet gale
Vaccinium (myrtillus)	blueberry
AQUATICS	
Menyanthes	bog bean
Nymphaea alba	white water lily
Typha	bulrush
SPORES	
Botrychium	grape fern
Botryococcus braunii	green alga
Equisetum	horsetail
Gymnocarpium dryopteris	oak fern
Huperzia selago	fir club moss
Lycopodium annotinum	interrupted club moss
Lycopodium clavatum	club moss
Polypodiaceae	polypody family
Polypodium vulgare	common polypody
Pteridium	bracken
Selaginella	selaginella
Sphagnum	peat moss

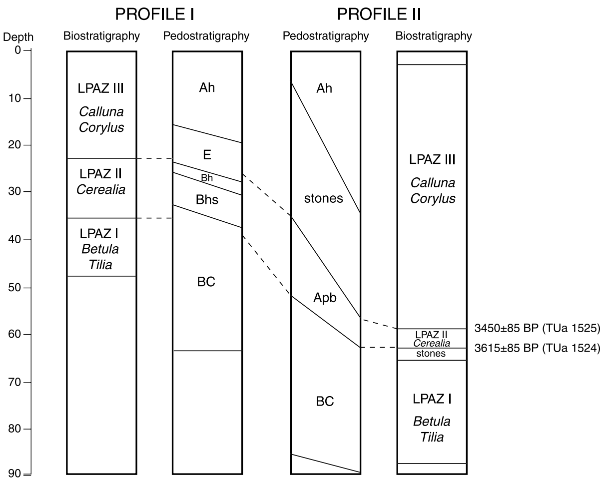


Figure 3. Correlation of the stratigraphical records (radiocarbon dates in uncalibrated ^{14}C years BP). Drawing by the author.

1979a). The result is an increase in hyphae fragments of length c. 20 µm or less in the soil (Aaby 1983:89). In the case of oribatids, the fragments can be identified even after they have passed through the digestive tract. In a brown earth soil, microarthropods such as oribatids can be found deep down in the profile, but in a podsol soil all faunal activity is restricted to the uppermost few centimetres of the acid humus (Haarløv 1960). Consequently, short hyphae fragments that may be recorded in the layers of a podsol soil below these uppermost centimetres must have been fragmented during a previous brown earth stage.

The radiocarbon dates in the text are expressed in calibrated ^{14}C years BC/AD. For the uncalibrated dates (BP), see Table 1.

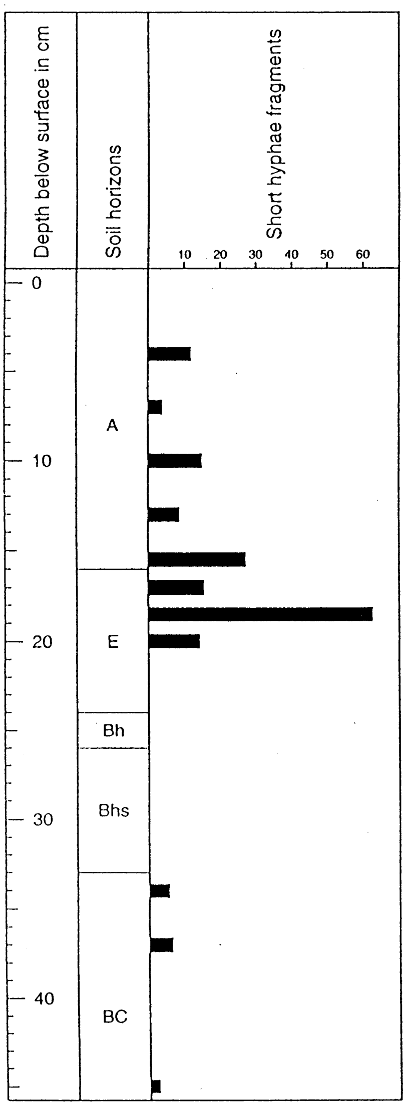


Figure 4. Distribution of short hyphae fragments of length up to 21 µm in profile I as a % of all hyphae fragments counted. Drawing by the author.

Results

Soil description

Profile I showed a clear stratification, with Ah–E–Bh–Bhs–Bs horizons (FAO 1990; Table 2), which corresponds to an *Orthic Podsol* (Mokma & Buurman 1982) on morphological criteria. The highest content of organic material was found in the lower part of the Ah horizon, in the Bh horizon and in the upper part of the Bhs horizon. The organic material in the B horizons may include remains of the layer which may be assumed from the pollen evidence to have been cultivated in prehistory (cf. Courty & Nørnberg 1985:61). The stratification of the brown earth profile (II), Ah–(Ap/stones)–Apb–Bhs/Bs (FAO 1990; Table 3) revealed a layer (Apb) buried by the cairn and presumably disturbed, as charcoal is common (for the pedostratigraphy of the two profiles, see Fig. 3).

Hyphae analysis

The distribution of short, dark brown hyphae fragments of length 21 µm or less in profile I is shown in Fig. 4.

Pollen analysis

The pollen diagrams (Figs. 5–6) have been divided into pollen assemblage zones, or groups of samples with boundaries based on visual inspection of criteria which are reflected in the pollen spectra but which need not necessarily reflect changes in the vegetation with time.

The main criteria for this zone division are summarized in Tables 5 and 6. The charcoal content is generally high throughout in both profiles.

Discussion

Soil analysis of the two neighbouring profiles reveals a soil development. But as soil material has in all likelihood been added from the hill-top by erosion and slope wash as time has passed, the soil profiles have an element of sedimentary stratigraphy in them.

The short hyphae fragments recorded in the BC horizon of profile I (Fig. 4) may be remains of a former brown earth stage (cf. S. T. Andersen 1979a, 1984, 1986). Hyphae fragments cannot be used as the only criterion (Aaby 1983:92), but the brown earth of profile II, obviously sealed under the clearance cairn, seems to confirm an original brown earth soil type on the site.

The two profiles reveal very similar stratigraphic sequences of pollen assemblages, raising the question of whether a correlation between depth and time may be possible in spite of the uncertainties about the age of individual pollen grains in soil layers. The soil development in the two profiles is very similar up to (and including) the Bhs/Bh and Apb horizons, respectively (see Table 2, Table 3, Fig. 3).

The pollen data indicate a development that is typical of the region (cf. Kaland 1986). The brown earth developed under a phase with deciduous forest, which was followed by clearance and an agricultural phase. Podsolization was caused by the change to a dense heather vegetation when the fields were abandoned (cf. The area investigated).

The radiocarbon dates for this local vegetation change at the site (Table 1) correspond to the pollen and ^{14}C data for a bog at Vagleskogen, 2 km from Orstad (Sageidet in press), and can be correlated with the well-dated regional expansion of heather (Prøsch-Danielsen & Simonsen 2000).

The differences in soil development in the upper parts of the two profiles (above the Bhs/Bh and the Apb horizons, see Tables 2–3, Fig. 3) are caused by the building of the clearance cairn on top of profile II, which impeded the spread of the heather vegetation and thus also podsolization.

These facts give reasons to correlate the pollen data of the two profiles and to combine them into three local pollen assemblage zones (LPAZ) representing the same time periods, although they are not entirely equivalent to local pollen assemblage zones as defined on standard pollen diagrams. In contrast to bogs and lake sediments, soils have a pore system. The macropores, e.g. those remaining after the decay of the roots of trees and shrubs, may provide a passage for a downwash of pollen for several tens of centimetres down to the lower root boundaries. Even though the pollen assemblages have been subject to selective deterioration and possibly selective movement down the profile, they seem to reflect features of the vegetation development in broad outline, as presented in the reconstruction below.

The considerable amount of pollen from insect-pollinated species such as *Calluna* and *Tilia* provides evidence that local vegetation communities dominate (cf. Florin 1975:137; Evans & Moore 1985; Prentice 1985:77), as is typical of soil pollen profiles (Havinga 1974; Jacobson & Bradshaw 1981:82). The time boundaries are based on ^{14}C dates (Table 1), and the correlation between the biostratigraphy and pedostratigraphy in the two profiles is presented in Fig. 3.

Period 1
(c. 3800–3600 BP; LPAZ I Betula–Tilia)

Traces of this period were found in the BC horizons of both profiles (cf. Fig. 3). The close situation of the two sites suggests that the original pollen assemblages were rather similar. The high biological activity during the brown earth stage (indicated by the hyphae analysis) seems to have intensified ventilation in the soil and caused extensive pollen deterioration and corrosion. The worst preservation conditions were found in the coarse, porous gravel material of the BC horizons. Reconstruction of the vegetation reflected in these lower soil layers is restricted by the scarcity of pollen and the high proportion of pollen grains that are too corroded or degraded to be identified (cf. Havinga 1968; S. A. Hall 1981:194; Dimbleby 1985). Spores and pollen types that are resistant to destruction, such as *Alnus* and *Tilia,* are over-represented and therefore cause an under-representation of other pollen types (cf. Havinga 1968, 1984:547; Jacobsen & Bradshaw 1981). The incomplete pollen assemblages (due to low pollen content) can nevertheless easily be correlated with the regional picture of an initial woodland stage (Prøsch-Danielsen & Simonsen 2000).

The presence of pollen of Ericales, dominated by *Calluna,* in profile I, and the absence of heather pollen in profile II may be explained in the sense that the latter reflects the initial forest phase as preserved under the clearance cairn. After the abandonment of the later fields, heathland dominated by *Calluna* was established, and the *Calluna* pollen in profile I may have been subject to pollen translocation from upper layers through the relatively porous sandy soil (Table 2).

Five pollen grains of *Cerealia*-type pollen were recorded at depths of 41 cm and 45 cm in profile I (Fig. 5). It is unlikely that these could be considered evidence of agriculture during this woodland period, as they are not accompanied by any other agricultural indicators (cf. Havinga 1968:1), and it is probable, instead, that they were translocated, either by bioturbation during the early brown earth stage, or by down-wash through the porous gravel material of the BC horizon later (cf. Fig. 7). Pollen grains of any species may have moved, but translocated grains are difficult to detect unless they appear in an unexpected context.

Pollen translocation seems to have been prevented in the lower part of profile II, where porosity is low (Table 3). The overlying stones and boulders of the clearance cairn, which was built prior to the establishment of a heather vegetation, caused compaction that presumably acted like a seal. The conditions for pollen preservation, however, were better in the acid podsol profile (I), where twenty-two different pollen types were recorded in contrast to ten in profile II.

The pollen types point to a mixed forest dominated by birch, lime, pine and alder on the site. A light, open character is indicated by the presence of grasses, *Melampyrum*, *Thalictrum*, *Filipendula* and presumably *Succisa*, *Sphagnum*, *Selaginella*, *Humulus* and Ranunculaceae, are species associated with moisture. Since such a place would not be typical for natural forest fires, the charcoal recorded here may indicate an occasional human presence. The single level with bracken (*Pteridium*) in profile II may reflect the spread of this plant to a burned site (cf. Tryon & Lugardon 1991:280). Together with the grasses, *Melampyrum* and *Urtica*, bracken may also indicate that the forest was occasionally grazed. The site could also have been a pathway where *Urtica* thrived, and the possibility cannot be excluded that the cereal pollen may have come to the site in such a context.

Period 2 (c. 3600–3400 BP; LPAZ II Cerealia)

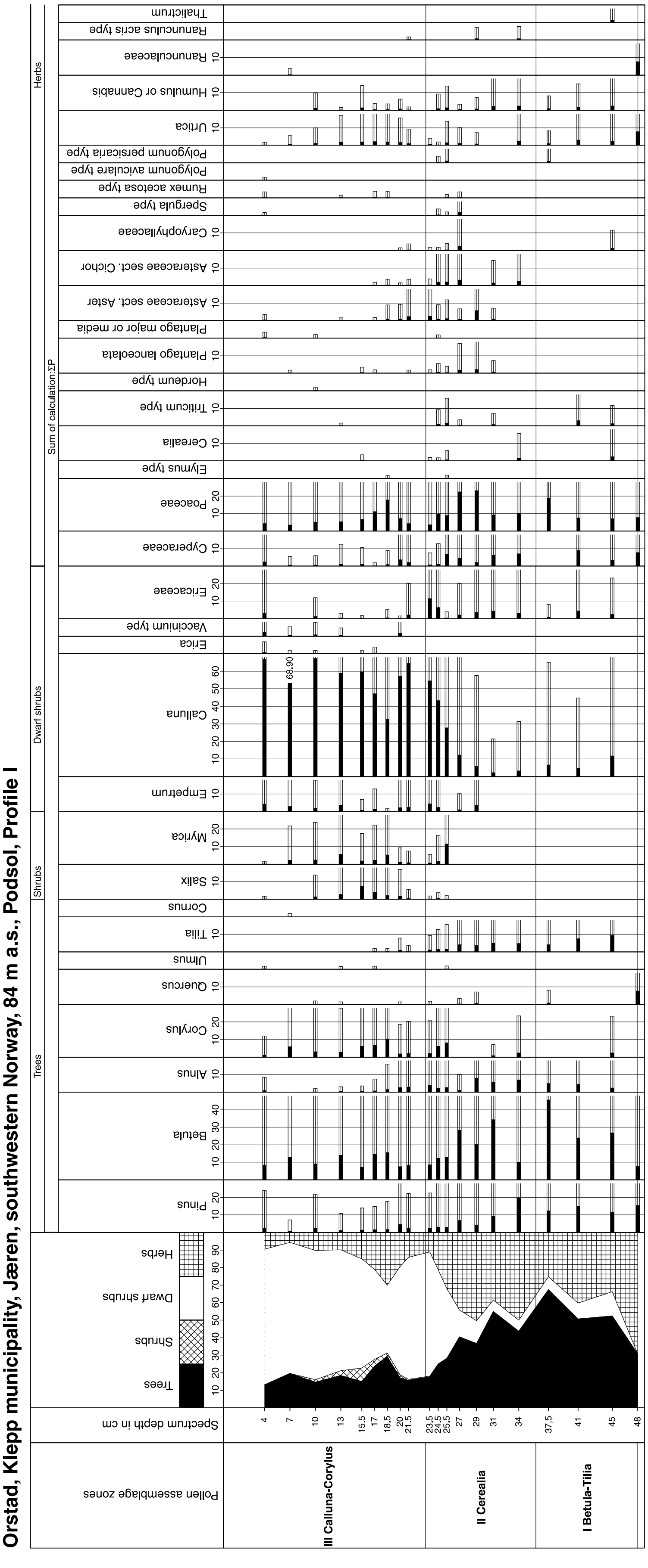
Cereal-type pollen together with pollen of Poaceae, *Spergula*-type, Asteraceae, Chenopodiaceae and Caryophyllaceae, recorded mainly in profile I, give evidence of a prehistoric field. The weeds of the cultivation, included *Polygonum persicaria*, which is an autogamous plant recorded in the tilled fields of central Europe back to early Neolithic times (Lang 1994). The fertile brown earth (cf. hyphae analysis) may have been one of the reasons why people chose the site for cultivation purposes and cleared the natural forest vegetation around 2120–1790 cal BC (Table 1). The recorded numbers of pollen grains of cereals and weeds associated with cultivated fields are not very high, but that is typical of the region (Prøsch-Danielsen 1996).

The pollen of *Triticum* type includes oats (*Avena*, Beug 1961; S. T. Andersen 1979b) and some weed species associated with settlement (cf. Dörfler 1989:43). Macrofossil analysis suggests that oats was not cultivated in the region before the transition to the Early Iron Age (Bakkevig 1992; Prøsch-Danielsen 1993; Soltvedt 2000). Wheat and barley usually seem to have been sown together in Bronze Age fields (Prøsch-Danielsen 1988; 1993).

The relation of germ to chaff is higher for wheat than for barley, and the wheat types were presumably easier to separate from the chaff using the Bronze Age grinding methods. Bronze Age people must have been conscious of this, and in all likelihood tried to sow wheat where possible (Sverre Bakkevig, pers. comm.). Consequently, this southwest-facing, sloping and probably well-drained field at Orstad may have preferably been cultivated with a type of wheat (Sageidet in Hemdorff et al. in press). The cleistogamic (permanently closed and self-fertilizing) wheat species do not disperse their pollen far away from the source (Raynor et al. 1972; Berglund 1985; Vuorela 1985), and an investigation based on a modern tilled wheat field as pollen source has shown that less than 1% of the cereal pollen grains were recorded 20 m away from the field (V. A. Hall et al. 1993).

The arable field layer at Orstad cannot be subdivided chronostratigraphically, as soil material from different levels, together with pollen deposited during the entire period of agriculture, has been mixed by soil management and by the soil fauna (see Fig. 7; cf. van Zeist 1967:49; Odgaard & Rostholm 1987:98; S. T. Andersen et al. 1983:190; Smith 1996:200).

Cairn 14 was built about 1880–1675 cal BC (Table 1), presumably gradually during the period of cultivation. In this way the stones may have covered patches of the field which had earlier been cultivated, or at least sown. Such a patch may later have been protected against both future soil management and future pollen rain, and bioturbation (mixing by the soil fauna) may have been impeded by the compaction caused by the cairn. This may be the reason why cereal pollen was only found in a small depth interval in profile II (equal to one pollen spectrum).


Orstad, Klepp municipality, Jæren, southwestern Norway, 84 m a.s., Podsol, Profile I
Pollen assemblage zones
III Calluna-Corylus
II Cerealia
I Betula-Tilia
Spectrum depth in cm
4
7
10
13
15,5
17
18,5
20
21,5
23,5
24,5
25,5
27
29
31
34
37,5
41
45
48
Trees
Shrubs
Dwarf shrubs
Herbs
10 20 30 40 50 60 70 80 90
Sum of calculation:ΣP
Pinus
Betula
Alnus
Corylus
Quercus
Ulmus
Tilia
Cornus
Salix
Myrica
Empetrum
Calluna
68,90
Erica
Vaccinium type
Ericaceae
Cyperaceae
Poaceae
Elymus type
Cerealia
Triticum type
Hordeum type
Plantago lanceolata
Plantago major or media
Asteraceae sect. Aster
Asteraceae sect. Cichor
Caryophyllaceae
Spergula type
Rumex acetosa type
Polygonum aviculare type
Polygonum persicaria type
Urtica
Humulus or Cannabis
Ranunculaceae
Ranunculus acris type
Thalictrum
10
20
30
40
50
60

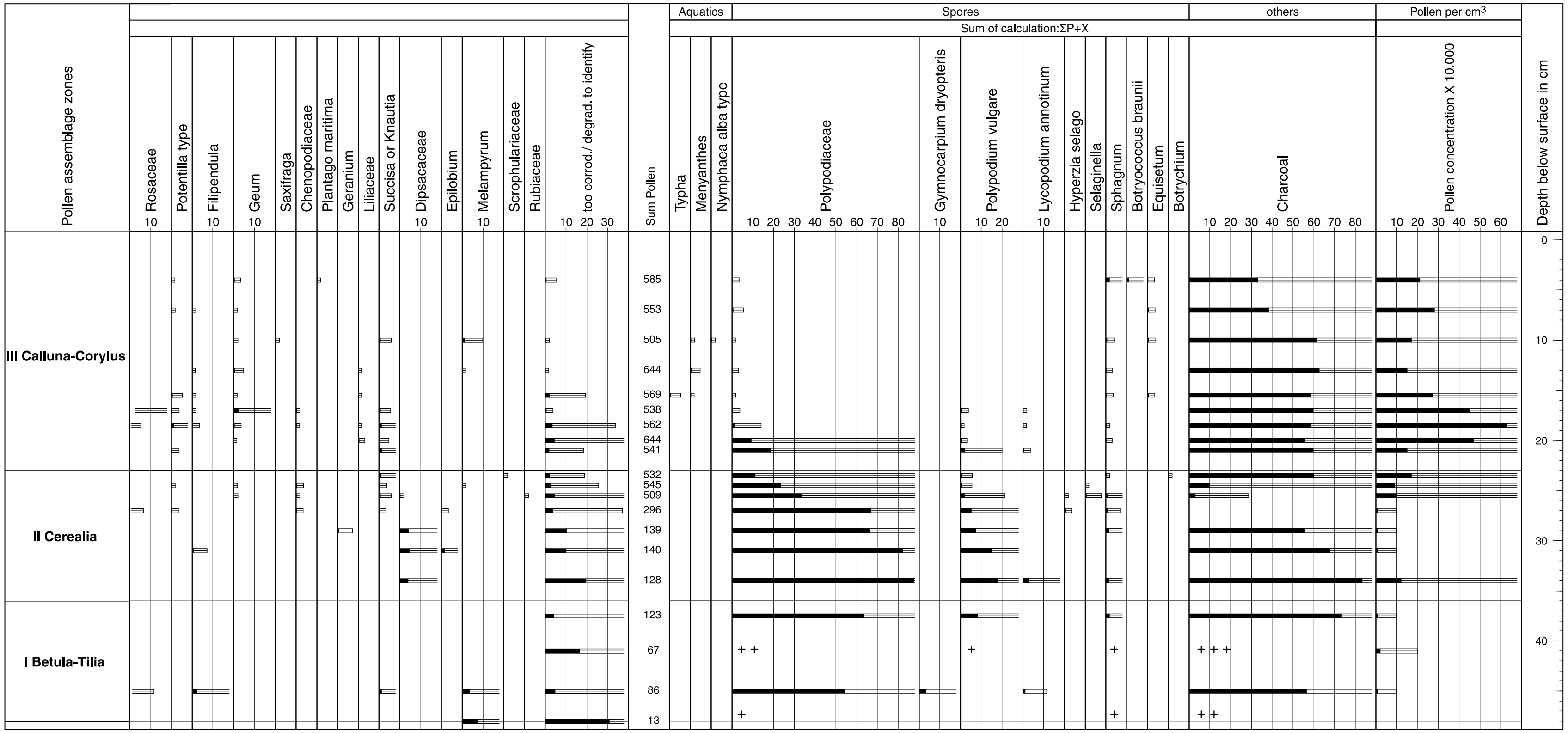


Figure 5. Pollen diagram of podsol profile I, Orstad, Klepp, southwestern Norway. (Black bars = %; white bars =‰; Abbreviations: corr. =corroded, degrad. = degraded; symbols: + = present, ++ = frequent, +++ = abundant). Analysis and drawing by the author.

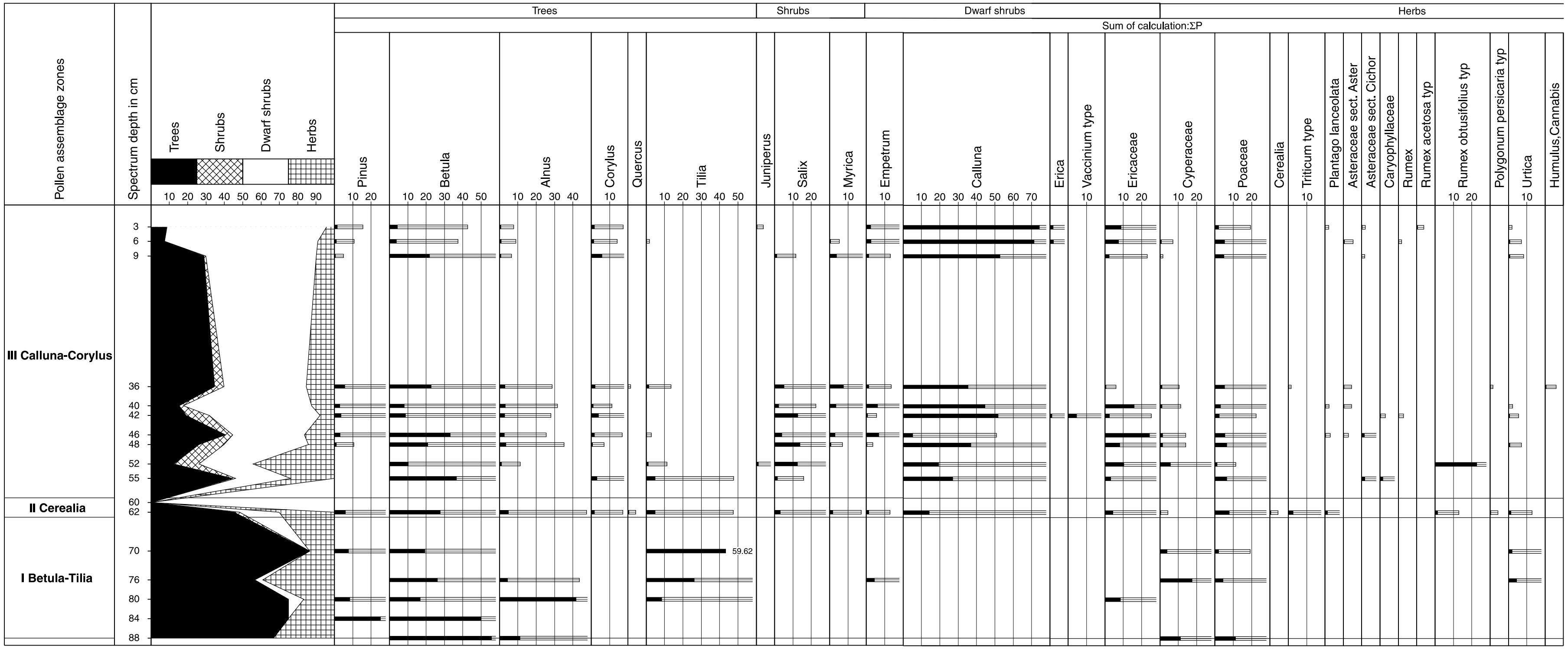
Table 5. Summarized criteria for the pollen assemblage zone divisions in profile I.

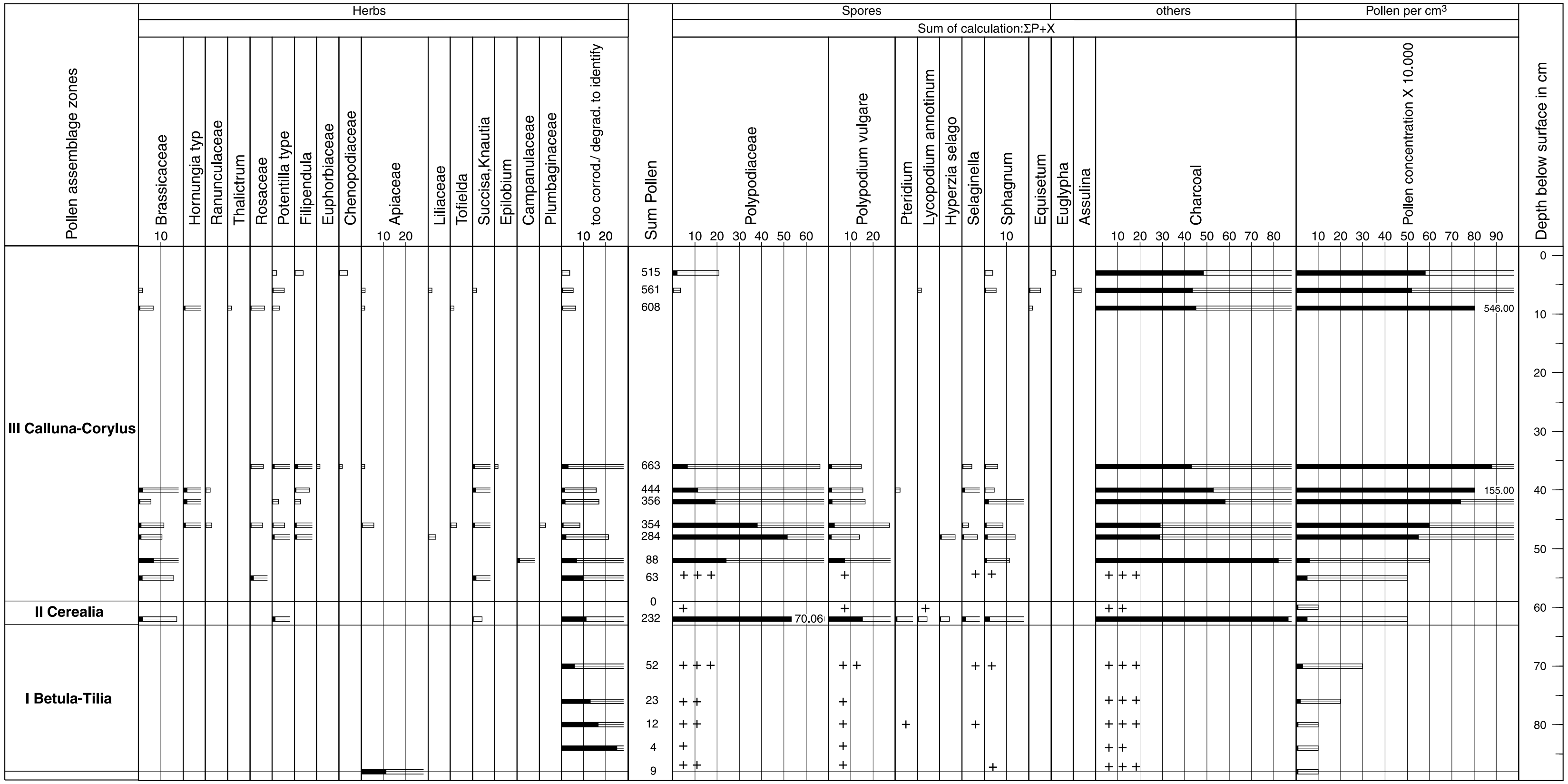
	Pollen concentration	Spores	Corroded or degraded pollen	Tree pollen in decreasing amounts	Shrub pollen in decreasing amounts	Ericaceae	Poaceae, Cyperaceae pollen and herb pollen	*Cerealia*-type
Assemblage zone III: 4–23 cm, 9 spectra		decreasing upwards	0–4%	*Betula*, *Corylus*, *Alnus*, *Pinus*, *Tilia*, *Quercus*, *Ulmus*	*Myrica*, *Salix*	dominated by *Calluna*, increasing upwards to 70%	Poaceae, Cyperaceae, Pollen of Asteraceae, *Urtica*, Rosaceae, *Succisa/Knautia*-type, Polygonaceae, *Plantago*, Chenopodiaceae, *Humulus* /*Cannabis*-type, *Rumex acetosa*-type, Caryophyllaceae and Liliaceae are recorded in both profiles	*Triticum*-type (2), *Hordeum*-type (1), *Cerealia*-type (1)
Assemblage zone II: 23–36 cm, 7 spectra	improving	high values	2–20%	*Betula*, *Pinus*, *Alnus*, *Tilia*, *Corylus*, *Quercus*	*Myrica*, *Salix*	*Calluna* increasing upwards from 2 to 55%, other Ericaceae up to 15%	Poaceae (4–23%), Cyperaceae, *Urtica*, *Plantago lanceolata*, *Polygonum persicaria*-type, *Succisa/Knautia*-type, *Rumex*, Rosaceae, Asteraceae, Cichoriaceae, Dipsacaceae, *Polygonum aviculare*-type, *Spergula*-type, Caryophyllaceae, Chenopodiaceae, *Ranunculus acris*-type	*Triticum*-type (15), *Cerealia*-type(7)
Assemblage zone I: 36–48 cm, 4 spectra	low	high values	high values	*Betula*, *Tilia*, *Pinus*, *Alnus*, *Corylus*, *Quercus*		dominated by *Calluna*	Poaceae, Cyperaceae, *Urtica*, *Humulus/ Cannabis*-type, *Melampyrum*, Ranunculaceae, Rosaceae, *Succisa/ Knautia*-type, *Polygonum persicaria* and Caryophyllaceae	*Triticum*-type (two at 41 cm, and one at 45 cm), *Cerealia*-type (two at 45 cm)

Table 6. Summarized criteria for the pollen assemblage zone divisions in profile II.

	Pollen concentration	Spores	Corroded or degraded pollen	Tree pollen in decreasing amounts	Shrub pollen in decreasing amounts	Ericaceae	Poaceae, Cyperaceae pollen and herb pollen	*Cerealia*-type
Assemblage zone III: 3–59 cm, 10 spectra		decreasing upwards	1–10%	*Betula*, *Corylus*, *Alnus*, *Pinus*, *Tilia*, *Quercus*	*Salix*, *Myrica*	dominated by *Calluna*, increasing upwards to 80%	Poaceae, Cyperaceae, Brassicaceae, Asteraceae, *Urtica*, Rosaceae, *Succisa/Knautia*-type, Polygonaceae, *Plantago*, Chenopodiaceae, *Humulus/Cannabis*-type, *Rumex acetosa*-type, Caryophyllaceae, Liliaceae, *Rumex obtusifolius*-type	*Triticum*-type (1)
Assemblage zone II: 59–63 cm, 1 spectrum	improved	high values	12%	*Betula*, *Pinus*, *Alnus*, *Tilia*, *Corylus*, *Quercus*	*Myrica*, *Salix*	*Calluna* (14%), other Ericaceae (5%)	Poaceae, Cyperaceae, Brassicaceae, *Urtica*, *Plantago lanceolata*, *Polygonum persicaria*-type, *Succisa/Knautia* -type, *Rumex*, Rosaceae	*Triticum*-type (6),*Cerealia*-type (1)
Assemblage zone I: 66–88 cm,	low	high values	high values	*Betula*, *Tilia*, *Pinus*, *Alnus*		present	Cyperaceae, Poaceae, *Urtica*, Apiaceae	

Orstad, Klepp municipality, Jæren, southwestern Norway , 84 m a.s., Clearance Cairn 14, Profile II





Analysis: Barbara Maria Sageidet 1996

Figure 6. Pollen diagram of clearance cairn 14, profile II, Orstad, Klepp, southwestern Norway. (Black bars = %; white bars =‰; Abbreviations: corr. =corroded, degrad. = degraded; symbols: + = present, ++ = frequent, +++ = abundant). Analysis and drawing by the author.

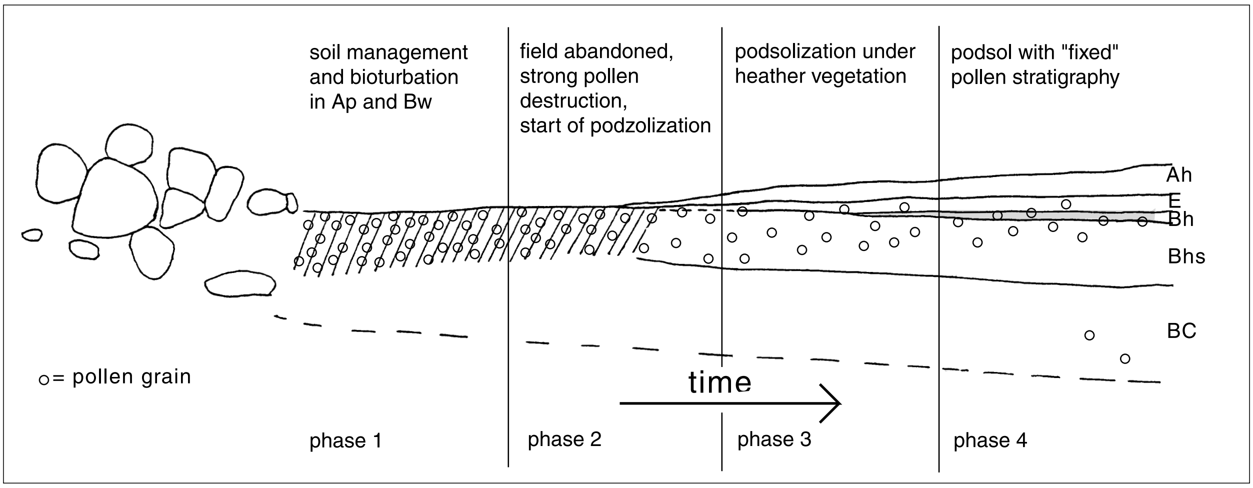


Figure 7. Development of a cultivated field to a podsol soil with reference to pollen transport in the soil profile. Drawing by the author.

The scarcity of agricultural indicator pollen in profile I may suggest an agricultural phase of relative low intensity. Pollen of *Plantago lanceolata* is correlated with cereal cultivation that involves fallow periods (Behre 1981, 1986). With regard to further radiocarbon dates from Orstad (Sageidet 2005), the duration of cultivation could hardly have exceeded a hundred years (cf. van Zeist 1967:50; Simmons & Innes 1996:617).

On the archaeological field sketch (Fig. 2), the upper illuvial horizon (Bh) of the podsol profile (I), and the Apb horizon underlying both cairns, 14 and 15/16, were correlated. This layer was assumed to represent the ancient surface of cultural activity on the site (Hemdorff in press). The pollen stratigraphy revealed traces of the ancient cultivated field in the Bh horizon, as well as in the Bhs horizon and parts of the E and BC horizons of profile I (see Fig. 3). Macroscopic charcoal particles and dust in the Apb horizon under cairn 14 (profile II) may be the remains of a field surface cleared by fire prior to the building of the cairn. The soil layers encompassed by LPAZ II *(Cerealia)* in profile I (Fig. 3) contained considerably less macroscopic charcoal than the Apb horizon of profile II. The concentration of microscopic charcoal particles in the pollen samples of profile I was notably small, except for the lowermost spectrum, possibly suggesting that just little use was made of fire during the period of agriculture. If people had burned the field, it would have accelerated soil deterioration in the long term. In any case, cultivation is likely to have enhanced soil deterioration (Bakkevig 1998:57). The building of cairn 14 seems to have come to an end after the onset of podsolization, as an E horizon has developed under its northern part. The field at Orstad was presumably abandoned when cultivation by simple techniques came up against environmental constraints (cf. Provan 1973:41). Soil formation, leaching and podsolization were presumably accelerated by the moist climate of the region, and an already acid brown earth may show podsolic features in about 100 years (S. T. Andersen 1979a). Thus the present podsol at Orstad may have developed over a period of approximately 3000 years (cf. De Coninck 1980:123).

Period 3 (c. 3400 BP until the present; LPAZ III Calluna–Corylus)

No further chronological subdivision of the profiles is possible from about 1880–1675 cal BC up to recent historical time. Profile II, through cairn 14, is restricted to material deposited between the stacked-up stones. The pollen content of the two profiles is very similar, clearly reflecting the dominance of heather at the site. The regional forest seems to have still been dominated by birch and some pine. The abundance of charcoal is most probably the result of occasional burning of the heather (Kaland 1986).

The disappearance of *Tilia* suggests that the species may have been cut and/or could not compete on the podsolized soil, while the pollen of grasses, *Urtica* and *Plantago lanceolata* indicate that the site was used for grazing. Some individual cereal pollen and pollen grains of Brassicaceae and *Rumex acetosa* may have come from cultivated fields in the vicinity. The herbaceous flora becomes poor in species in the upper levels, indicating that the meadows may have diminished in area towards recent times.

The advancing podsolization processes imply soil acidification, decreasing soil biological activity and improvement of the pollen preservation conditions. Pollen grains which earlier may have been translocated to a certain layer or depth by bioturbation or soil management will finally have become fixed in their present locations.

To some degree, pollen grains may still have been subject to the continuous water flow in the soil pores, in spite of their hydrophobic properties (cf. van Zeist 1967:49; Caseldine & Matthews 1985:103).

Today the original Bronze Age surface horizon is only recognisable under cairn 14, profile II (Apb in Table 3, parts of the "sand rich in humus" in Fig. 2). In profile I the original soil colours are obscured, as the Bh horizon became dark in colour during podsol formation through the accumulation of humus from the upper layers, showing a typical diffuse lower limit and a more distinct upper limit (Fenwick 1985). The organic material may include remnants from the ancient cultivated field (cf. Jenkins 1985), and these remnants may have had an influence on the final depth at which the Bh horizon was later established. The relatively low porosity (cf. Kelso 1993) and the organic material that has accumulated in the Bh horizon seem to have been favourable for pollen preservation. The low porosity in the Bh horizon may have restricted the translocation of pollen down to the lower layers, contributing to the maintenance of the original pollen stratigraphy in and below the Bh horizon.

Conclusions

Uncertainties in the records from mineral soils related to pollen destruction, soil disturbance and pollen translocation can be compensated for by complementary information obtained from soil profiles of different types at the same site.

The pollen in the podsol profile (I) was better preserved than that in the brown earth profile (II), and the higher diversity of pollen types in profile I provided more detailed information about the vegetation history at the site, even though the pollen stratigraphy had partly been blurred by bioturbation, soil management and soil formation processes (Fig. 7). The compacted soil below the clearance cairn in profile II maintained the original pollen distribution, which revealed the approximate depth at which the ancient cultivated field was located.

Translocated pollen may be detected from the presence of different amounts of the same pollen type in two neighbouring profiles, or from the occurrence of single pollen grains with a special indication which is different from the indication given by the whole pollen assemblage in which they were found.

Three phases in the very local vegetation history of the site can be distinguished. A mixed deciduous forest dominated by birch, lime, pine and alder seems to have grown on the site in Late Neolithic times, with light-demanding herbs, grasses and bracken, together with traces of fire, indicating occasional use of the site, perhaps for grazing. Between 2120–1790 cal BC and 1880–1675 cal BC, the site was cleared and used for growing cereals. The clearance cairn 15/16 investigated here was one of the first to be built in relation to the discovered cultivated field, and cairn 14 one of the last. Cultivation was of low intensity, and was presumably interrupted by fallow periods. From about 1880–1675 cal BC until historical times a heather vegetation expanded at the site, and cultivation was abandoned, presumably on account of soil impoverishment and podsolization processes. The heather may have been occasionally burned and the area used for grazing, while there may have been other cultivated fields in the vicinity.

The vegetation record reflects one single period of cultivation at the site. The horizons with traces of cultivation in the two profiles therefore seem to be of the same age, as assumed by Hemdorff (in press). This result also provides evidence for excluding the ^{14}C date TUa-1526 (Table 1) from the dates related to this period of cultivation (Fig. 3).

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