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Palaeoenvironments in the north European lowlands between 50 and 10 ka BP

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Abstract. Frost wedge casts, remnants of frost mounds, slope deposits, aeolian activity and vegetation records dated between 10 and 50-55 ka BP are used for a tentative, general reconstruction of palaeoenvironmental conditions in the north European lowlands. The sedimentary and vegetational records are discontinuous, and various types of subenvironments and deposits represent different periods. From the scattered and sometimes apparently contradictory evidence, it is suggested that during the Weichselian there were swift climatic and environmental changes, often too brief for the establisment of stable vegetational communities and soil developments.

Key words: Pleniglacial, Palaeoenvironments, periglacial, vegetation.

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I. INTRODUCTION

This paper deals with environmental conditions in the north European lowlands (Fig. 1) during the Weichselian Pleniglacial and the Late Glacial (Fig. 2).

In northern Europe there are no continuous palaeobotanical records from the Ice Ages, and the reconstruction of past developments must therefore be based upon discontinuous series, each representing a short time span. When such intermittent organic records are seen in relation to other sediments and post-sedimentary phenomena of ice age origin, the discontinuity of the botanical records can turn out to be an advantage for a differentiated reconstruction of past environmental conditions within an area where glacial, periglacial and boreal conditions alternated. When geomorphological and palaeobotanical evidence is integrated, the many-sidedness of nature can be approached.

The interval between 10,000 and 50-55,000 years BP is chosen here, because this part of the geological record can be dated by radiocarbon and thermoluminescence methods. Thereby the apparently scattered data can be arranged both relatively and chronologically, so that an idea of the succession and dynamic of climatic and environmental changes can

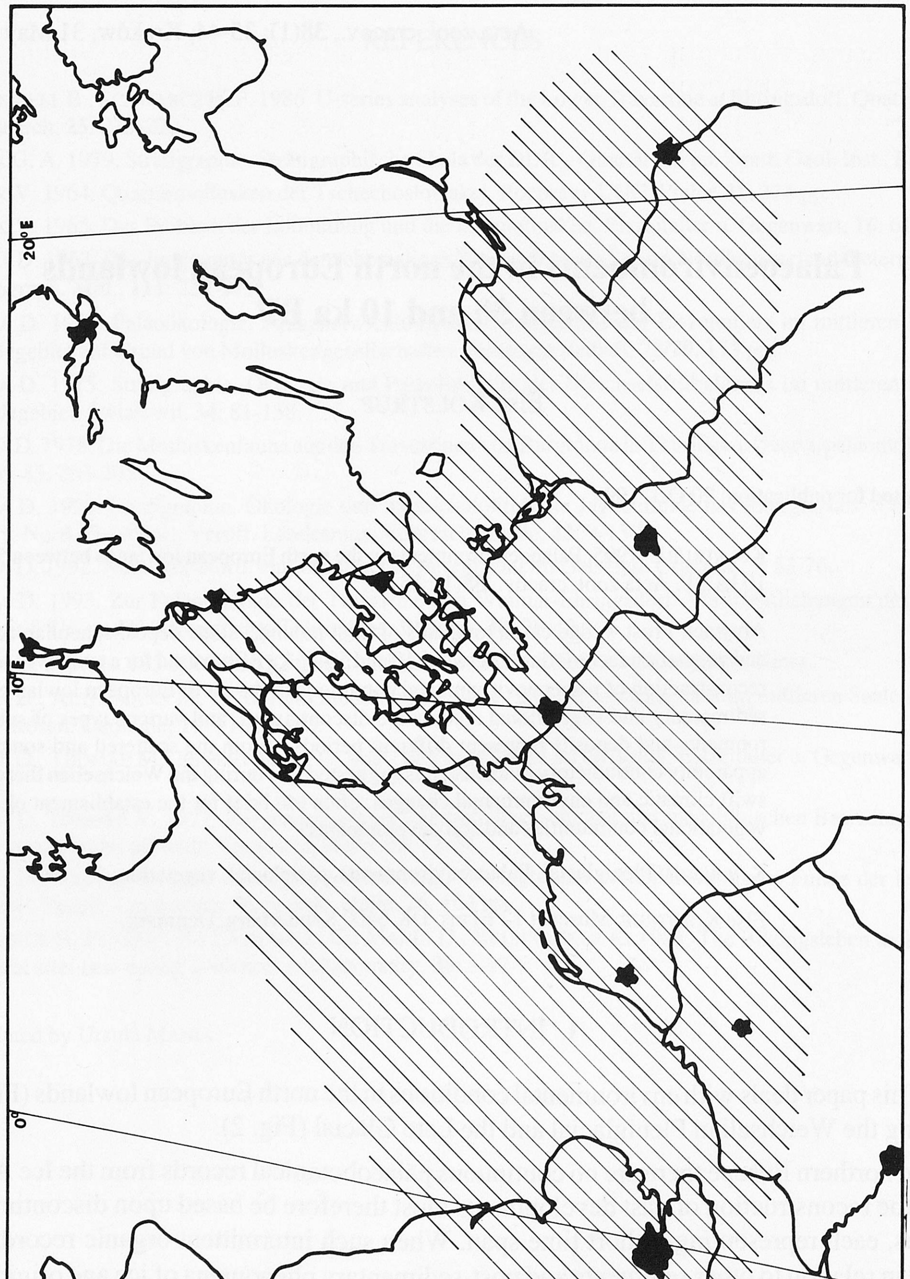

Fig. 1. The north European lowland area is indicated by hatching. Some large cities and rivers are shown for orientation.

be obtained. An attempt to deduce holistic palaeoenvironmental reconstructions from different but contemporaneous subenvironments can also be made.

In the following the various disciplines and their uses in the reconstruction are discussed.

II. FROST WEDGE CASTS

Patterned ground or frost polygons develop in frozen ground during sudden negative temperature drops. In vertical cuttings the polygons are bordered by cracks, which are initially open, but can become filled with ice or non-ice sediment or a mixture of the two (FRENCH 1976). During successive years cracking and filling can take place repeatedly along the same zones, whereby the wedges grow in width (e.g., MACKAY 1988).

Small wedges, about 1 m deep or less, can form outside the permafrost zone, but large features seem to be restricted to the continuous permafrost zone, where cold air and ground conditions prevail (FRENCH 1976). As long as the temperature conditions remain sufficiently cold, any kind of primary filling will remain in the wedges. Following a temperature rise, no sediment deformation takes place where the original filling is minerogenic, but where ice was dominant, its thawing caused collapse of the host sediments into the wedge and frost wedge casts remained.

Since the development of frost wedges is dependant on permafrost conditions with relatively low temperature regimes and insufficient snow cover to protect the ground from cold spells, abundant frost wedge casts at certain Pleistocene stratigraphic horizons are taken as indications of former time-restricted, cold climatic conditions. Wedge casts with primary filling of aeolian sand have an additional advantage in the palaeoenvironmental reconstruction, because from these forms it can further be concluded that during the growth of the wedges, the soil surface layers were unstable, or that conditions were very dry, whereby sand ended up in the open cracks before ice and snow got there. Wedge casts with primary aeolian fill also have the advantage that the aeolian filling, and thereby the time of growth, can be dated directly by means of the thermoluminescence method.

Attempts at general stratigraphic overviews of past periods of frost wedge formation are given in KARTE (1981) and RAN & VAN HUISSTEDEN (1990). The forms in those papers are dated indirectly. In Fig. 2 forms with aeolian filling dated directly by means of the thermoluminescence method (DROZDOWSKI & FEDOROWICZ 1987; KOLSTRUP & MEJDAHL 1986) are also included.

It is stressed that the scheme in Fig. 2 is only tentative, because there are still too few datings to provide more than a very general outline of the stratigraphic levels of frost wedge casts.

III. FROST MOUNDS

Frost mounds are also related to cold climatic conditions, mainly permafrost regimes. The mounds have cores of ice which grow during successive years. There are different types of frost mounds, depending on temperature, snow cover, sediment and hydrological

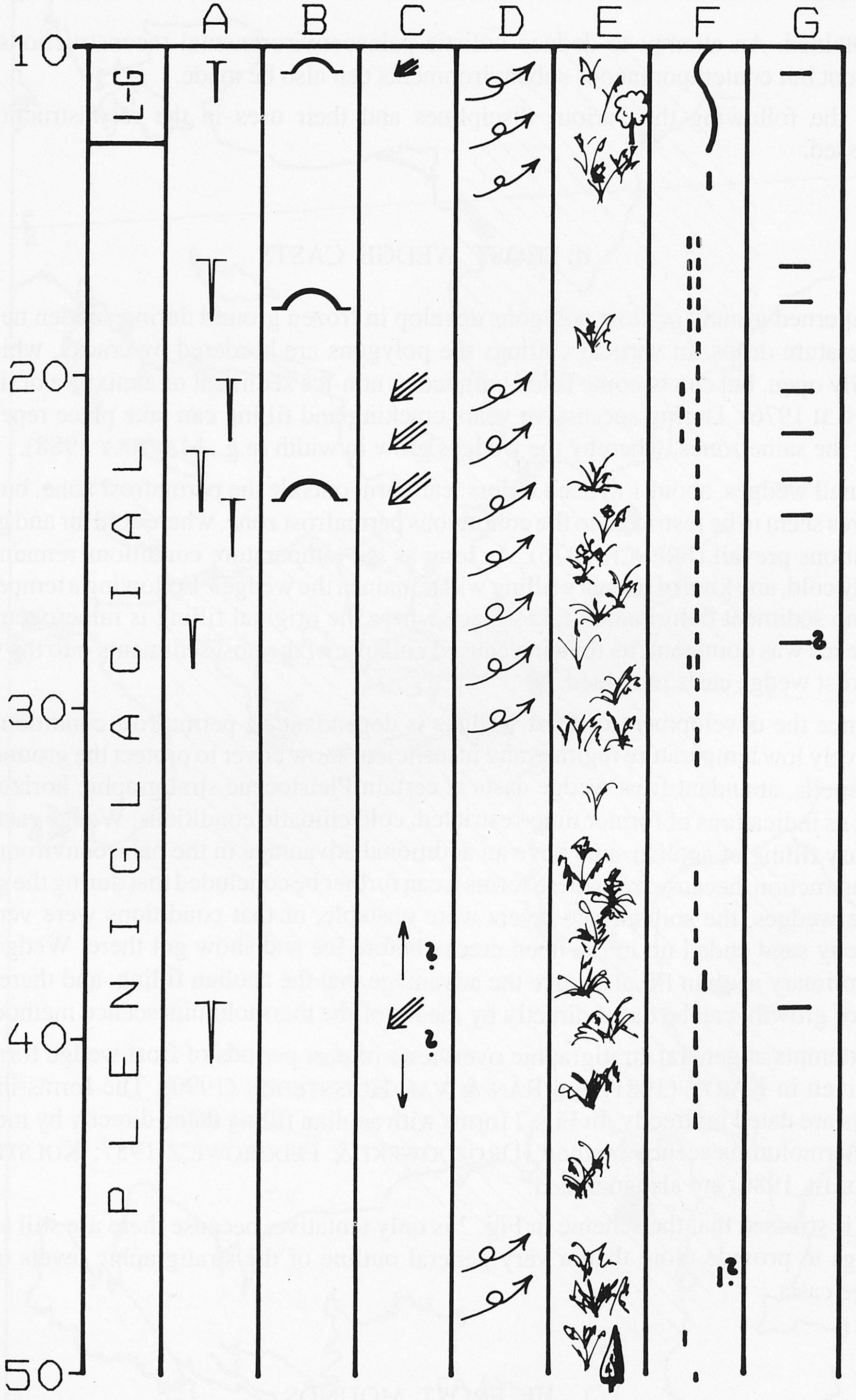

Fig. 2. Overview of environmental parameters for the time between 10 and 50 ka BP, i. e., the Late Glacial and the Pleniglacial of the Weichselian, in northern Europe. The time scale to the left is in k years. A: frost wedge casts, B: frost mounds, C: slope deposits, D: aeolian activity, E: vegetation records, F: generalised trend of mean July temperature without absolute values, G: periods with cold soil surface condition.

conditions. Through time the forms grow in height rather than in width (MACKAY 1979), and thereby their sides gradually become steeper until the sediment cover becomes unstable and slides downward. The sediments accumulate at the perimeter, and when the ice at the summit becomes exposed to the air, the ice core melts.

In the coldest permafrost areas, pingos can be up to 50 m high (MACKAY 1972). Due to aspect and hydrological conditions, specific subenvironments exist on pingo slopes, and plants that are normally found farther south grow on the better drained, south facing pingo slopes, which thereby provide "out of place" habitats (KORANDA 1960 cited in EVERETT 1983).

In boggy areas at the fringe of permafrost, palsas can develop. They are ice cored peat mounds which owe their existence to the insolation effect of the peat (SEPPÄLÄ 1982).

The natural cycle of frost mound development ends with decay of the mound, whereby a lake (where the ice core used to be) develops, surrounded by a ring wall (rampart) of slope sediment.

The record of ice age remnants of frost mounds shows that such forms were rather frequent in NW Europe and that their development is restricted to certain periods (DE GANS 1981); as yet, far from all remnants are well dated. So far it seems as if there was growth of pingos some time around 18 ka y BP in the Netherlands (PARIS et al. 1979) and possibly also earlier (DE GANS 1981), and of unspecified types of frost mounds, possibly at least some of them palsas, during the Late Dryas (PISSART 1983, KOLSTRUP 1985). The difficulty to conclude from the fossil forms what kind of active frost mound is represented makes palaeoenvironmental reconstruction from the ramparts somewhat tentative.

IV. SLOPE DEPOSITS

Records of ice age slope deposits in the north European lowlands are rare. There may be two main reasons for this. First, these sediments are difficult to distinguish from glacial deposits which are very abundant in the glaciated part of the area. Second, they are difficult to date unless directly related to datable deposits, which then usually get the main attention. Slope processes testify to unstable soil surfaces and discontinuous/ruptured vegetation cover, whereby the soil surface became exposed to erosion by wind and water. Presence of underlying permafrost would have promoted the slope processes, though it is not a prerequisite for the activity.

Weichselian slope deposits within the northern European area include deposits in Sweden (HILLEFORS 1974), the Harz Mountains (STEINMÜLLER 1967), Poland (MANIKOWSKA 1991) and SE Denmark (KOLSTRUP & HOUMARK-NIELSEN 1991), dated between 25 and 20 ka BP, and deposits from the Late Dryas, dated between 11 and 10 ka BP. In Poland there are also older deposits (KRZYSZKOWSKI 1990).

V. AEOLIAN ACTIVITY

Past aeolian activity can be recognised from deflation surfaces with polished stones and ventifacts, and from loess and wind blown sand deposits.

Large areas in northern Europe have a cover of wind blown sand layers with horizontal layering, the so-called cover sands (e.g., VAN DER HAMMEN et al. 1967), dunes (e.g., KOZARSKI & NOWACZYK 1991) and, locally, deposits of loess (CATT 1977; KOLSTRUP & HOUMARK-NIELSEN 1991). Further south, loess deposits become more widespread and their chronostratigraphy becomes increasingly well known (JUVIGNÉ & WINTLE 1988). Often the aeolian deposits are thought to be related to cold climatic conditions (e.g. KOSTER 1988), but there is an additional possibility that they could have occurred also in warmer climates during periods of unstable soil surfaces with discontinuous vegetation cover. Such unstable conditions could have existed where rapid environmental changes occurred repeatedly (KOLSTRUP 1990). Usually the cover sand areas make up relatively dry parts of the landscapes, and only rarely are organic remains preserved within them.

VI. VEGETATIONAL RECORDS

Palaeobotanical records from the north European Ice Ages represent only short time spans (e.g. BEHRE & LADE 1986, KOLSTRUP 1992, MAMAKOWA & ŚRODON 1977; RAN 1990; VANDENBERGHE 1985), and by far the majority of the organic deposits that have been preserved, represent wet and moist depressions with favourable taphonomic conditions for plant material. This means that past growing conditions as deduced from plant remains are usually biased toward moist and wet subenvironments, and that the vegetation in dryer, surrounding environments can only be analysed from pollen blown into the depressions.

Comparisons between Ice Age plant associations and present day vegetational communities show that there are no existing parallels with which the past records can be compared. In addition, present day communities are the result of about 10,000 years of relatively stable climatic conditions, where people, rather than nature itself, may have been the main disturbing influence. In the reconstruction of past climates, therefore, comparisons with and palaeoenvironmental deductions from similarities between present and past plant communities cannot be expected to provide reliable conclusions. Instead, it seems necessary to use the species approach in as far as the autecology, including extremes, of the plants found as fossils is known (cf. e.g., ELLENBERG 1974; KOLSTRUP 1980). Further, even if north European landscapes seem to have been without tall trees during the Pleni-Weichselian, this does not necessarily imply insufficiently high temperatures. Instead migration of species following climatic change, soil development/instability, hydrological conditions and other factors of a non-temperature nature may have been the limiting factors. Likewise, absence of botanical records for parts of the Weichselian may be the result of such factors, and erosion, rather than of too low temperatures.

An integration of the palaeovegetational records from the north European lowlands shows that most of the time between c. 50 and 10 ka BP is represented (Fig. 2), albeit from different environmental contexts, but as mentioned previously, usually only short time spans from the respective different subenvironments are found. In most cases the vegetational development seems to represent pioneer stages, i. e., there is dominance of plants with a tolerance of or preference for raw soils such as can be found, e. g., in relation to unstable soil surface conditions.

VII. TEMPERATURE CONDITIONS

The mean July temperatures reconstructed from the various plant taxa represented in the fossil records point to ±10°C for many intervals, but other parts were probably somewhat warmer, possibly up to 15° C, as deduced from warmth requiring plant species (KOLSTRUP 1990) and beetles (COOPE 1987) (see also KEDING 1993). In Fig. 2 the temperature outline is tentatively indicated as a discontinuous record without absolute values. It may be noted that the Pleni-Weichselian traditional Moershoofd, Hengelo and Denekamp "interstadials" (VAN DER HAMMEN et al. 1967; ZAGWIJN & PAEPE 1968, KOLSTRUP & WIJMSTRA 1977) can not be clearly recognised from the outline. The reason is that with increasing palaeobotanical information it looks as if there is no longer a reason to distinguish such periods from the intervening ones (e.g., KOLSTRUP 1990; RAN 1990). Instead it is suggested that the warm spells were of too limited duration and random occurrence to provide conditions for successions of plant associations toward forest communities.

Periods with relatively cold winter temperatures, in most cases with permafrost conditions, are suggested in the right hand part of the figure. No absolute values are given, but presence of lines indicate sufficiently cold temperature conditions for rather wide-spread growth of frost wedges and frost mounds.

VIII. PALAEOENVIRONMENTAL CONDITIONS

The discontinuous geomorphological and palaeobotanical records from a variety of sub-environments within the north European lowlands suggest that soil surface conditions were repeatedly disturbed within the area. The overall hydrological conditions may have been relatively dry, although the records show that moist localities where organic material could accumulate and become preserved did exist locally. Besides, during periods of permafrost the ground may have been swampy during the thaw season.

The discontinuous records in combination with the association of plants could be explained as a result of abundant, quick changes of temperature and hydrology conditions. One might visualize a situation where time was often too short for the establishment of a stable and continuous plant cover that could protect the ground from erosion and provide a soil development where long lived plant species such as trees could thrive. Instead, the plant sequences show presence, sometimes abundance, of taxa that can survive on undeveloped soils and repeatedly disturbed ground. The hypothesis of swift climatic changes as the underlying factor for the discontinuous records and the repeated aeolian activity and surface runoff at our latitudes is indirectly supported by the oxygen isotope records and electric conductivity variations from the Greenland ice cores (JOHNSEN et al. 1992; TAYLOR et al. 1993) where rapid shifts are clearly recorded during the Weichselian, the Pleni-Weichselian in particular (TAYLOR et al. 1993).

A consequence of this line of thinking is that at intervals there may have been irregularly occurring, short, warm spells ("favourable" in some terminologies) but their effects do not seem to have improved conditions in the sense of providing continuous vegetation cover within the area. Instead, the effect of such sudden temperature increases was to destroy existing plant communities adapted to or requiring cooler conditions. Conversely, if warmth requiring species had had sufficient time to become established within an area, a rapid change towards colder conditions would, once again, destroy the plant cover and give rise to soil surface instability until other plants had had time to spread into the area. With regard to survival of faunal elements within such shifting environments, the presence/absence of food and water (and protecting snow cover) may have been more important than temperature conditions.

IX. CONCLUSIONS

Figure 2 is a preliminary and incomplete outline of the above mentioned features used for the reconstruction of palaeoenvironmental conditions. The underlying concept of swift climatic and environmental changes through time and the diversity of subenvironments even over short distances will have to be taken into account when the scheme is used. The figure can be used to cut out "time slices" for tentative conclusions on the environment during a certain period (for comparison see also BÖSE 1991), and then combine these with other data not included here, e. g., faunal evidence. As an example the time around 24,000 years BP is chosen. During that time permafrost seems to have existed, giving rise to frost wedge and frost mound formation, and solifluction. Aeolian activity also took place, and it is thought that soil surface conditions were unstable in many places, probably aided by the slope activity. Yet within this unstable environment there were also vegetated areas with grasses, sedges and various herbs in a mean July temperature regime of around +10°C. In spite of a probably generally relatively dry environment, there was sufficient moisture for plant growth, possibly aided by underlying permafrost that prevented free drainage; and locally there were humid-wet places where swamp- and water plants could grow. Locally, taphonomic conditions were adequate for accumulation and preservation of the organic material. Within this 24,000 BP environment there was sufficient food and habitat for large animals such as mammoth (AARIS-SØRENSEN et al. 1990) as well as for smaller animals like lemming (BENNIKE et al. 1993).

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