A DIFFERENT LATE-GLACIAL VEGETATION AND ITS ENVIRONMENT IN FLANDERS (BELGIUM)

BY

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SOMMAIRE. — A Langelede, dans le nord-ouest de la Belgique, un diagramme pollinique discontinu a été daté comme weichselien tardiglaciaire sur la base de la lithostratigraphie locale et des datations au C14. La composition pollinique est profondément différente de celle d'autres diagrammes classiques en raison des faibles pourcentages d'AP, en particulier *Betula*, et des pourcentages élevés de NAP. Le développement de la végétation est lié à l'instabilité des couches sableuses superficielles dues à l'activité éolienne. Le diagramme présenté ici peut être considéré comme représentatif de la végétation dans les régions de sables de couvertures pendant le Tardiglaciaire.

Introduction.

Late-Glacial pollen diagrams from Belgium, the Netherlands, northern Germany, and Denmark are generally rather similar in that they show fairly high *Betula* percentages during the Bolling time, low percentages of *Betula* and high percentages of herbs during the Earlier Dryas, high percentages of *Betula* during the Allerod and also of *Pinus* during the upper part of this time, and somewhat lower percentages of *Betula* and *Pinus* compared to the Allerod during the Late Dryas time (VANHOORNE, 1954 ; VERBRUGGEN, 1979, VAN DER HAMMEN, 1951 ; CLEVERINGA *et al.*, 1977 ; BEHRE, 1966 ; USINGER, 1975 ; IVERSEN, 1954).

From Langelede (coordinates 51°11'50"N, 3°52'00"E) in Flanders in Belgium, a different composition of a Late-Glacial pollen diagram is found and the vegetation deduced herefrom is related to the former geomorphology of dry coversand ridges and wet depressions.

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Outline of the geomorphology.

Langelede is situated in the Flemish valley which is a Pleistocene valley system that drained into the North Sea area (TAVERNIER and De MOOR, 1974 ; De MOOR and HEYSE, 1974).

During the Upper Pleniglacial and the Late-Glacial of the Weichselian, the northward draining direction of this valley became dammed by west-east running aeolian sand ridges (Fig. 1, Ib), the so-called coversand ridges, which here are more than 90 km long (HEYSE and De MOOR, 1979). The sand that composes these ridges came from the north where a deflation area is found with a pebble layer on top (Fig. 1, Ic) [HEYSE, 1979a].

During the Holocene the lower (northern) part of the Flemish valley became inundated by Dunkirk transgressions (until 4 m above present sea level, O.P.) and clayey sediments were deposited on parts of the deflation surface (Fig. 1, II).

The coversand ridge in which the Langelede excavation was situated (Fig. 1, Ib) is about 3 km wide and rises a few metres above the surrounding flat areas (Fig. 1, Ia and Ic). It slopes up to 4 % towards the south, while the northern slope is very gentle (HEYSE, 1979 a, b).

There is a micromorphology of small ridges and irregularly shaped, elongated depressions on the large ridge. East-west oriented ridges are dominant, but southwest-northeast running ones are found as well. Furthermore, small dune fiels and parabolic dunes are sometimes later deposited upon these smaller ridges (HEYSE, 1979 a).

Stratigraphy.

In the Langelede excavation six types of sedimentary units were distinguished : older and younger coversands, dune sands, fluvio-periglacial deposits, lake sediment, and organic deposits.

The older coversands are aeolian sediments built up of white-grey sand layers alternating with grey loam or sandy loam layers (compare VAN DER HAMMEN *et al.*, 1967).

The younger coversands are well sorted, yellow to white-yellow, horizontally or subhorizontally layered medium to fine grained aeolian sands (compare VAN DER HAMMEN *et al.*, 1967). Steeper sloping laminae can occasionally be seen.

The dune sands are rather similar to the younger coversands in colour and composition but they are generally loosely packed and often have steeply sloping laminae.

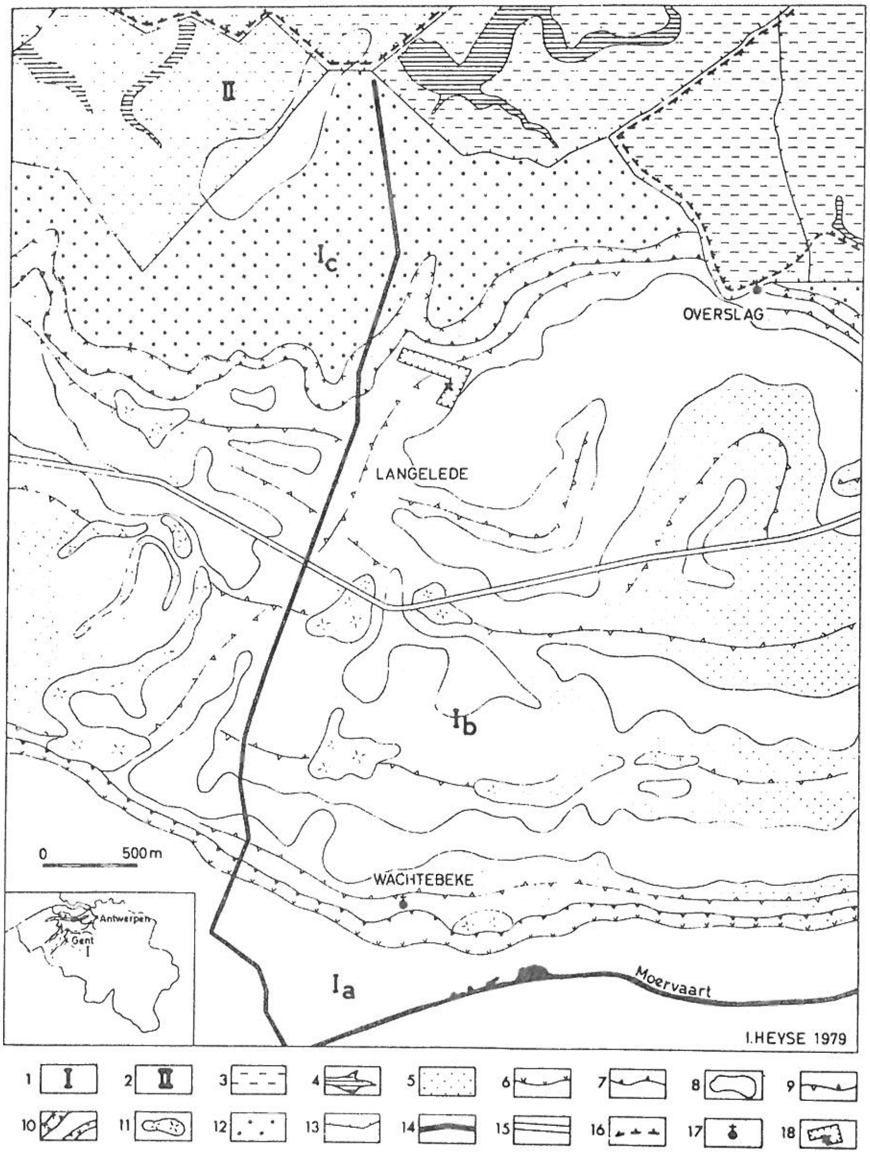


FIG. 1. — Outline of the geomorphology in the Flemish valley around Langelede. 1 a : fluvio-periglacial deposits ; b : coversand complex ; c : deflation surface ; 2 : coastal plain ; 3 : clay deposits ; 4 : creeks ; 5 : sand deposits (coversand ridge) ; 6 : concavity in coversand ridge ; 7 : convexity in coversand ridge ; 8 : larger depression in coversand ridge ; 9 : larger summit in coversand ridge ; 10 : ridge complex in coversand ridge ; 11 : dunes ; 12 : gravel surface (deflation surface) ; 13 : dike ; 14 : canal ; 15 : highway ; 16 : state border ; 17 : village center ; 18 : Langelede excavation with site of profile.

The fluvio-periglacial deposits consist of sand with a few loam laminae. Involutions and frost fissure casts are present, and cross-bedding sometimes occurs.

The lake sediment is generally horizontally laminated sand that may have small-scale cross-bedding. Thin layers of organic material may be intercalated. Laterally, towards the southeast, the lake sediment becomes calcareous and finally passes into a marl (De Moor and Heyse, 1978 ; Heyse and De Moor, 1979).

The organic deposits consist of thin moss layers, weakly organic loamy sand, or fairly compact, slightly sandy or loamy peat layers.

The lithological section which is shown schematically in Fig. 2 has fluvio-periglacial sediment at the bottom (below 2.36 m). Pebbles may occasionally be found at the top (at 2.36 m). This layer is termed the layer of Middelburg (De Moor and Heyse, 1972) and lithostratigraphically it probably corresponds to the Beuningen Gravel Bed in the Netherlands (compare Van der Hammen *et al.*, 1967). From 2.36 m to 1.94 m the section is composed of an undisturbed older coversand deposit with a few weakly organic horizons. Shallow, very narrow (max. 2 cm wide), vertical fissures (frost fissure casts ?) were occasionally seen in this deposit. From 1.94 m a sequence of alternating younger coversand deposits and organic layers is seen. Vertical rootlets are present throughout the whole profile, and laterally in this deposit, single, small, vertical fissures were present.

The organic layers, V1, V2, and V3 (from bottom to top, see Fig. 2) were only a few centimetres thick. V1 and V2 were almost horizontal, while V3 was ondulating or involuted, the single involutions being up to 20 cm deep. Laterally, into the coversand ridge, V3 passed into a humic, slightly peaty layer with pieces of charcoal.

It was noted that a well developed podzol was present on top of the younger coversand deposit in other parts of the pit. This podzol is locally overlain by dune sand.

From investigations within the whole pit and its surroundings, and from the palynological record, it is concluded that the sampling site may have lain in the transitional area between the coversand ridge and the depression as sketched in Fig. 3.

Three radiocarbon dates have been made on samples from the section. Samples of each of the peat layers from 0.98 m to 1.01 m, and from 1.91 m to 1.94 m (V2 and V1) were collected. As these layers are both thin, and roots from a younger level were present in the profile (Fig. 2), the datings from these samples might be too young. However, a sample from the moss layers at 1.80 m and 1.83 m was

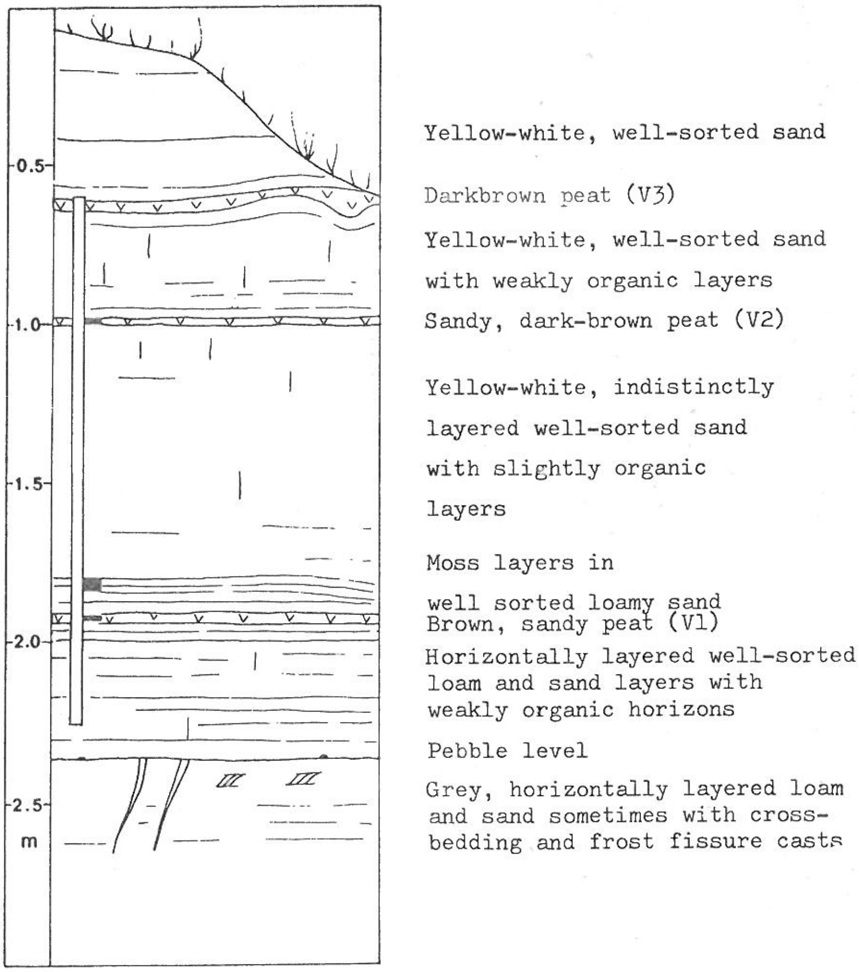


FIG. 2. — The lithological sequence at the Langelede locality. The vertical rod indicates the site of the samples for the pollen analysis and the black rectangles indicate the sites of the samples for ^{14}C datings. The top of the profile is 5.5 m above sea level (O.P.).

expected to give a fairly reliable date because the moss fragments could be selected.

The three samples gave the following results :

GrN-8445 Langelede 1 - 11.190 ± 120 B.P. (0.98 m - 1.01 m, V2)
GrN-8286 Langelede 2 - 11.730 ± 120 B.P. (1.80 m and 1.83 m)
GrN-8446 Langelede 3 - 11.490 ± 110 B.P. (1.91 m - 1.94 m, V1)

These dates place the sequence in the Late-Glacial, and the probably reliable radiocarbon date of 11.730 ± 120 B.P. from the moss layers at 1.80 m and 1.83 m suggests that the transition from the Earlier Dryas to the Allerod should be found at or just below this level.

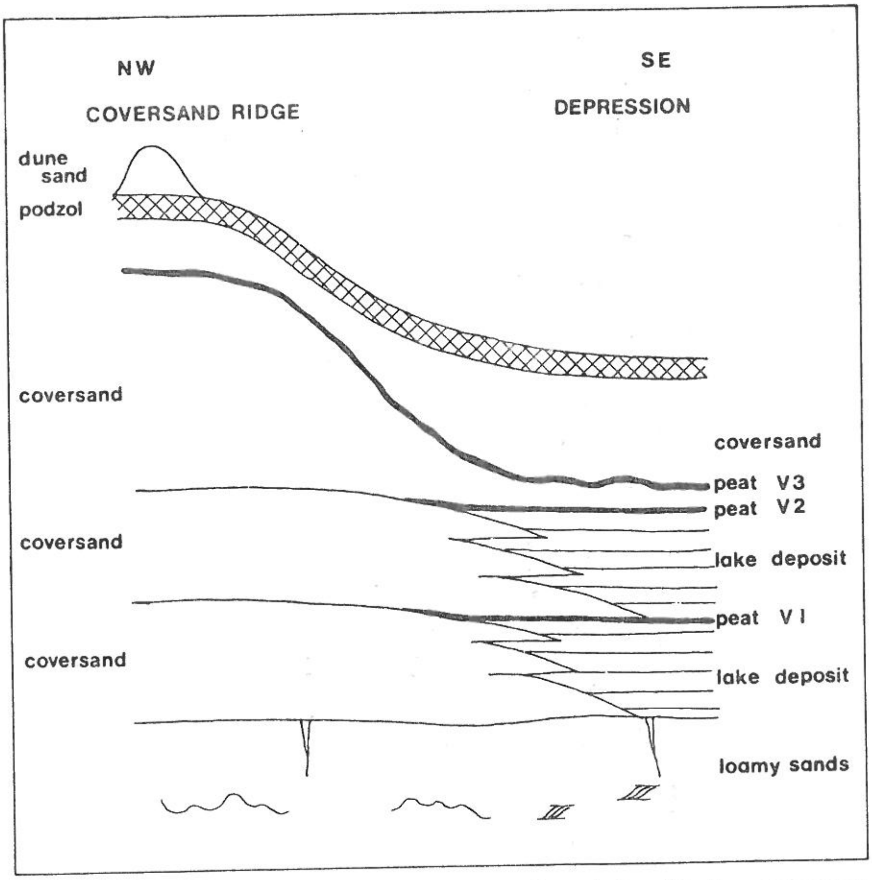


FIG. 3. — Schematic outline of the situation at Langelede with the coversands on the left hand side and the lake sediments on the right hand side. Small-scale cross-bedding, involutions, and small vertical fissure casts are found locally in the loamy sands in the bottom layer.

Laboratory methods.

All samples for the palynological analysis were prepared with KOH followed by acetolysis and bromoform separation. Glycerine-gelatine was used as an embedding medium.

The organic layers V1, V2, and V3 were analysed with 1 cm intervals between consecutive samples. Each of the moss layers and slightly organic layers were analysed.

From each sample, a sum of 300 or more arboreal pollen (A.P.) and « dry » non-arboreal pollen (N.A.P.) were counted when possible. Water plants and spores are thus excluded from the sum. Single pollen finds are indicated by a black dot in the diagram. Some of the slides have furthermore been investigated for pollen types not found during the counting. These types are indicated by an o in the diagram and are thus represented by less than 0.3 % of the sum.

Description of the pollen diagram (Fig. 4).

The pollen diagram is dominated by herbs, especially Cyperaceae and Gramineae, while the tree pollen percentage is rather low except for the uppermost peat layer.

In the three lower spectra of the pollen diagram (2.25 m, 2.23 m, and 2.21 m) the percentage of arboreal pollen is around or slightly more than 10 % while the remaining part of the pollen is constituted by herbs, predominantly Cyperaceae and to a lesser extend Gramineae. Among the water plants *Potamogeton* is present in all three layers.

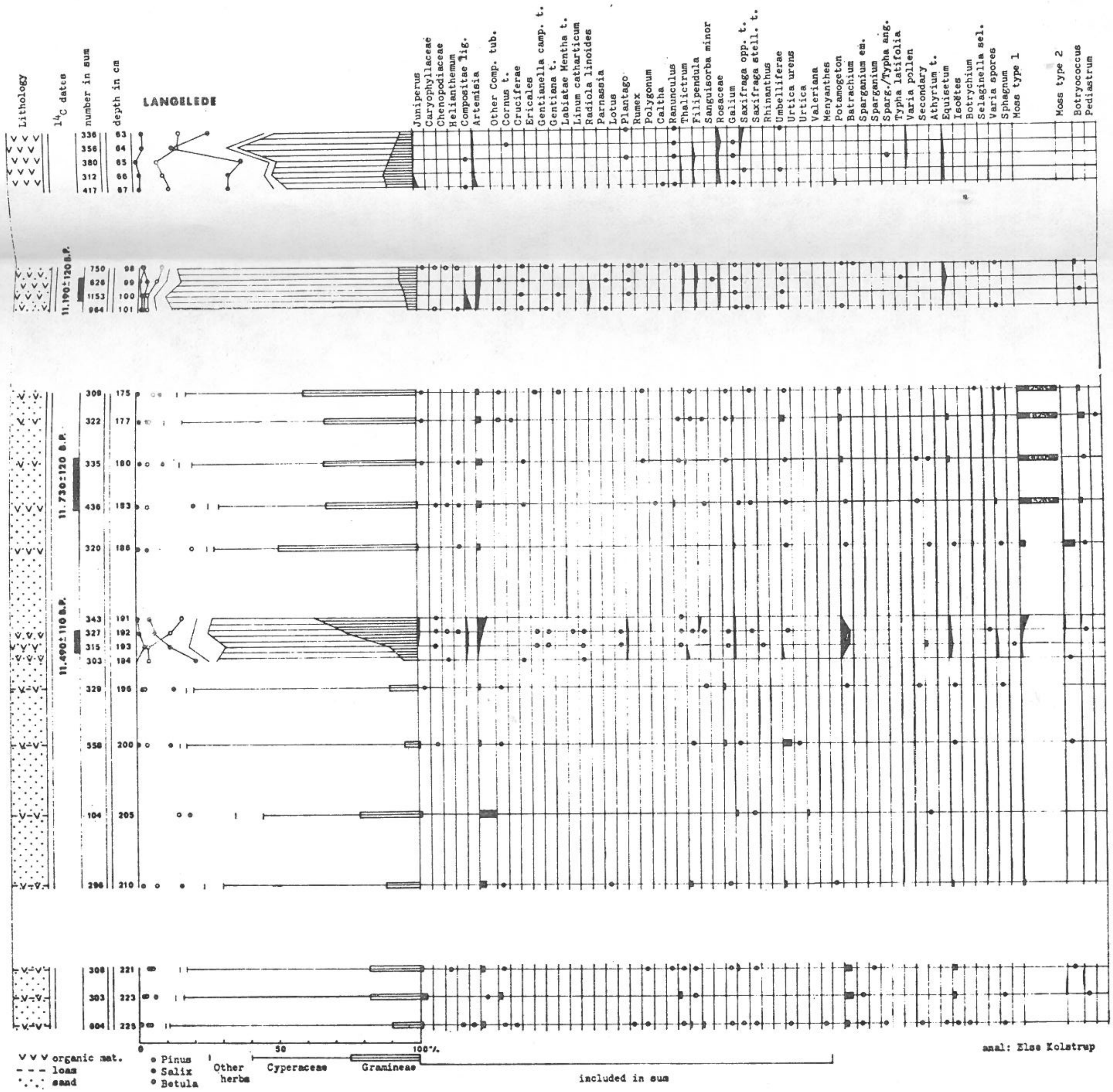
In the spectra between 2.10 m and 1.94 m, *Salix* attains a rather high percentage while the percentages of *Betula* (except for the spectrum at 2.05 m) and *Pinus* remain low. Waterplants are practically absent.

In the peaty layer from 1.94 m to 1.91 m (V1), the percentages of *Salix* and Cyperaceae decrease while those of *Betula* and Gramineae increase. *Potamogeton* is fairly well represented in this layer.

The pollen composition in the following layer (1.86 m) is very similar to the spectra at 1.91 m and 1.92 m of the underlying layer (V1) except that *Potamogeton* has practically disappeared. In the layer at 1.83 m *Salix* has again become an important component with 20 %, and moss spores have become abundant. The following spectra (1.80 m, 1.77 m, 1.75 m) have a very low percentage of trees while the percentages of Gramineae and Cyperaceae are both rather high and moss spores are abundant, especially in the spectrum at 1.80 m. Some *Potamogeton* and *Botryococcus* are also present.

The peat layer from 1.01 m to 0.98 m (V2) also has a very low percentage of tree pollen while Cyperaceae is by far the most numerous pollen. Moss spores are not present and pollen of water-plants is scarce.

In the upper peaty layer from 0.67 m to 0.63 m (V3) *Pinus* attains a high percentage. The percentage of *Betula* has become higher compared to the underlying layer but it is not abundant. Among the herbs Cyperaceae is dominant and there are only few water-plants.


LANGELEDE
Lithology
14C dates
number in sum
depth in cm
Juniperus
Caryophyllaceae
Chenopodiaceae
Helianthemum
Compositae lig.
Artemisia
Other Comp. tub.
Cornus t.
Cruciferae
Ericales
Gentianella camp. t.
Gentiana t.
Labiatae Mentha t.
Linum catharticum
Radiola linoides
Parnassia
Lotus
Plantago
Rumex
Polygonum
Caltha
Ranunculus
Thalictrum
Filipendula
Sanguisorba minor
Rosaceae
Galium
Saxifraga opp. t.
Saxifraga stell. t.
Rhinanthus
Umbelliferae
Urtica urens
Urtica
Valeriana
Menyanthes
Potamogeton
Batrachium
Sparganium em.
Sparganium
Sparg./Typha ang.
Typha latifolia
Varia pollen
Secondary
Athyrium t.
Equisetum
Isoëtes
Botrychium
Selaginella sel.
Varia spores
Sphagnum
Moss type 1
Moss type 2
Botryococcus
Pediastrum
11.190±120 B.P.
11.730±120 B.P.
11.490±110 B.P.
organic mat.
loam
sand
Pinus
Salix
Betula
Other herbs
Cyperaceae
Gramineae
included in sum
anal: Else Kolstrup

The mosses.

The mosses from the layers at 1.80 m and 1.83 m have been investigated by B. ODGAARD (Danish Geological Survey, Copenhagen). Two species, namely *Scorpidium turgescens* (T. JENS.) LOESKE and *Drepanocladus sendtneri* (SCHIMP.) WARNST. were present.

S. turgescens is predominantly found in dune-slacks and fens, and may occasionally be submerged. It is usually found on calcareous ground (ALBERTSON, 1940 ; NYHOLM, 1974) but is reported from less calcareous environments as well (BIRKS and DRANSFIELD, 1970). The species is found scattered in many parts of the world and seems to have a fairly wide climatic range (DICKSON, 1973 ; NYHOLM, 1974 ; SMITH, 1978).

D. sendtneri is also predominantly found in dune-slacks and fens ; furthermore, it is often submerged (NYHOLM, 1974 ; SMITH, 1978). It is found in calcareous environments (JENSEN, 1923 ; NYHOLM, 1974). As is the case with *Scorpidium turgescens*, *Drepanocladus sendtneri* seems to have a wide geographical and climatic range.

Environmental and vegetational development.

In the lower part of the pollen diagram (2.25 m to 2.21 m), the distances between the organic layers are relatively small and the sand accumulation may consequently have been moderate. The plant community suggests a damp to wet environment in the locality, which may have been situated at the edge of or in the depression at that time, but the pollen of some plants such as e.g. *Juniperus* and *Artemisia* must have come from drier areas such as the coversand ridge.

The abundance of coversand together with the scarcity of pollen of aquatic plants between 2.20 m and 1.96 m point to increased aeolian activity and somewhat drier conditions at the sampling site. *Salix*, however, was probably fairly abundant in moist parts of the surroundings. The continued accumulation of sand in this part of the sequence may have limited the immigration of certain plant species, e.g. of *Betula* into the area.

From 1.94 m to 1.91 m the local environment became wetter, the sand accumulation almost stopped, and water plants appeared. During this time *Betula* came nearer to the site or may have immigrated into it, and humic matter accumulated (V1).

FIG. 4. — Pollen diagram from the Langelede locality. The scale under the main diagram is valid for all curves.

The vegetational development was interrupted by new sand accumulations (from 1.91 m) and *Betula* only remained for a short time. Thereafter, *Salix* probably grew fairly densely at the site or the nearest vicinity for a while. It was then partly succeeded by *Scorpidium turgescens* and an abundance of *Drepanocladus sendtneri*, which suggests that the site was situated at the edge of, or possibly in the lake at intervals. The spectra from 1.80 m to 1.75 m indicate an association of plants dominated by annuals where trees can only have made up a minor part of the vegetation cover. As this interval probably represents a part of the Allerod which was warm enough for the growth of birch trees as well as willows (see e.g. VAN DER HAMMEN *et al.*, 1967 ; USINGER, 1975 ; CLEVERINGA *et al.*, 1977), the association of plants presumably reflects an environment dominated by sand accumulation and erosion in which plants with a short life cycle could become dominant.

The sand accumulation stopped once more and the sand became fixated by a vegetation cover (1.01 m to 0.98 m, V2). The local environment may have been moist to damp, but *Salix* did not come back, nor did *Betula*.

The surroundings then underwent a phase of aeolian activity again (0.98 m to 0.67 m) and the coversand built up microridges which buried parts of the depression. The surrounding area may gradually have become inhabited by *Pinus*, which, being in the locality for a while (0.67 m to 0.63 m), seems to have managed to suppress the sand drift.

A last coversand layer again buried the vegetation in the depression and formed the final coversand topography. Dunes developed later only on the highest and driest areas.

Conclusions.

It has previously been mentioned in this paper that the transition from the Earlier Dryas to the Allerod should probably be found around or just below the spectra at 1.80 m and 1.83 m's depth. Furthermore, a comparison to other areas reveals that the presence of charcoal, together with the high *Pinus* percentages in the uppermost peat layer (V3), may represent the upper part of the Allerod (compare VAN DER HAMMEN, 1951). This means that the whole sequence between 1.83 m and 0.63 m is of Allerod age. A comparison to other pollen diagrams shows that the present one is different from these, especially by the low percentages of *Betula* pollen. As tree birch was present in other, more northern parts of Europe during this time (IVERSEN, 1954 ; USINGER, 1975 ; CLEVERINGA *et al.*, 1977), the reason for the low *Betula* percentages at Langelede can not be attributed to a cold climate or a more southern tree-line, but is attributed to instability of the surface layers due to aeolian activity.

In the Allerod part of the section, the shifts between coversand and organic material results in at least one (between V2 and V3), maybe more gaps in the pollen record. This may also be the case with the lower part of the diagram (from 2.25 m to 1.86 m). This possibility of hiati, together with the dissimilarities between this and other diagrams makes it impossible from the pollen composition to tell which spectra represent the Earlier Dryas and which the Bolling. A comparison between the lithostratigraphy in the present locality and that generally found in the Netherlands of Older Coversand II underlying, and Younger Coversand I overlying deposits of Bolling age (VAN DER HAMMEN *et al.*, 1967) might provide some help. It might be suggested that the older coversand deposit between 2.36 m and 1.94 m is equivalent to the Older Coversand II in the Netherlands and is consequently of pre-Bolling age. The peat layer between 1.94 m and 1.91 m might, if this interpretation is correct, consequently represent the Bolling ; and the Earlier Dryas may either be lacking in the pollen record or is only represented by the spectrum at 1.86 m. The younger coversand type of deposit from 1.91 m to 1.86 m or to 1.80 m should consequently be equivalent to the Younger Coversand I in the Netherlands.

Extensive deposits of Late-Glacial coversands are found in Belgium (MARÉCHAL and MAARLEVELD, 1955 ; PAEPE and VANHOORNE, 1967), the Netherlands (MARÉCHAL and MAARLEVELD, 1955 ; DÜCKER and MAARLEVELD, 1957), northern Germany (DÜCKER and MAARLEVELD, 1957), and Poland (KOZARSKI, 1978). They generally build up the typical Late-Glacial lithological sequence in these areas, and peat development could only take place in relatively small areas where moist conditions prevailed. The pollen diagrams known today are, with a few exceptions (see e.g. VANHOORNE and VERBRUGGEN, 1975), from such wet or moist localities. The Langelede locality may to a larger extent reflect the vegetation in a conversand environment than that of a permanently moist or wet depression due to its situation at the transition between a coversand ridge and a depression together with the repeated changes in the local geomorphology. Therefore it is suggested that the Langelede pollen diagram to a larger degree than most reflects the vegetation as it was in the coversand areas during the Late-Glacial.

Abstract.

A discontinuous pollen diagram from a locality near Langelede in northwestern Belgium is presented which due to lithostratigraphy and

^{14}C dates must be of Weichselian Late-Glacial age. The composition of the pollen is different from that of other Late-Glacial diagrams due to low percentages of tree pollen, especially *Betula*, and high percentages of herbs. The vegetational development is seen in connection with the instability of the surface layers due to aeolian activity in the area. It is tentatively suggested that the vegetation reflected in the present diagram may represent the vegetation commonly found in the coversand ridges during the Late-Glacial.

Samenvatting.

Een discontinu pollendiagram van Langelede in noordwest België wordt op basis van de lokale lithostratigrafie en C 14 bepalingen gedateerd als Weichsel Laat-Glaciaal. De pollensamenstelling is verschillend van andere klassieke laat-glaciale diagrammen omwille van lage boompollenpercentages, voornamelijk *Betula*, en hoge kruidenpercentages. De vegetatieontwikkeling wordt in verband gebracht met de instabiliteit van oppervlakkige lagen als gevolg van lokale eolische aktiviteit. Het hier voorgesteld pollendiagram wordt beschouwd als representerend het vegetatiebeeld in de dekzandruggen gedurende het Laat-Glaciaal.

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REFERENCES.

ALBERTSON, N. (1940). — *Scorpidium turgescens* (Th. JENS.) MOENKEM. In . Växtgeografiska studier. *Acta Phytogeographica Suecica.* XIII. p. 7-26.

BEHRE, K. E. (1966). — Untersuchungen zur Spätglazialen und frühpostglazialen Vegetationsgeschichte Ostfrieslands. *Eiszeitalter und Gegenwart,* 17, p. 69-84.

BIRKS, H. J. B. and DRANSFIELD, J. (1970). — A note on the habitat of *Scorpidium turgescens* (T. JENS.) LOESKE in Scotland. *Transactions of the British Bryological Society.* 6, 1, p. 129-132.

CLEVERINGA, P., DE GANS, W., KOLSTRUP, E. and PARIS, F. P. (1977). — Vegetational and climatic developments during the Late Glacial and the early Holocene and aeolian sedimentation as recorded in the Uteringsveen (Drente, The Netherlands). *Geol. Mijnbouw,* 56, p. 234-242.

DE MOOR, G. and HEYSE, I. (1972). — Geomorfologisch onderzoek en kartering in vlakke gebieden. Nation. Centr. Geomorf. Onderzoek, Werkdocumenten 12, p. 61-80.

De Moor, G. and Heyse, I. (1974). — Litostratigrafie van de kwartaire afzettingen in de overgangszone tussen de Kustvlakte en de Vlaamse Vallei in Noordwest-België. *Natuurwet. Tijdschr.*, 56, p. 85-109.

De Moor, G. and Heyse, I. (1978). — De morfologische evolutie van de Vlaamse Vallei. *De Aardrijkskunde*, 4, p. 343-375.

Dickson, J. H. (1973). — Bryophytes of the Pleistocene. Cambridge University Press. 256 p.

Dücker, A. and Maarleveld, G. C. (1957). — Hoch- und spätglaziale äolische Sande in Nordwestdeutschland und in den Niederlanden. *Geol. Jb.*, 73, p. 215-234.

Heyse, I. (1979 a). — Bijdrage tot de geomorfologische kennis van het noordwesten van Oost-Vlaanderen (België). *Verhand. Kon. Acad. Wet. Letteren Sch. Kunsten België, Kl. Wet.*, XLI, 155, 257 p.

Heyse, I. (1979 b, in press). — Geomorphological mapping of flat regions in Flanders (Belgium) : the morphology and evolution of the coversands in the Flemish Valley. Proc. 15th Plenary Meeting of the Commission on Geomorphological Survey and Mapping (IGU - UNESCO) Modena Italy.

Heyse, I. and De Moor, G. (1979). — Morphology of Würm Lateglacial and Holocene deposits in the Flemish valley (North Belgium). *Acta Univ. Oul.* A. 82, Geol. 3, p. 121-131.

Iversen, J. (1954). — The Late-Glacial flora of Denmark and its relation to climate and soil. In : Studies in Vegetational History. *Danm. geol. Unders.*, II, 80, p. 87-119.

Jensen, C. (1923). — Danmarks mosser. Gyldendal. Kobenhavn. 569 p.

Kozarski, S. (1978). — Das Alter der Binnendünen in Mittelwestpolen. Beiträge zur Quartär- und Landschaftsforschung. Festschrift zum 60. Geburtstag von Julius Fink. F. Hirt, Wien, p. 291-305.

Maréchal, R. and Maarleveld, G. C. (1955). — L'extension des phénomènes périglaciaires en Belgique et aux Pays-Bas. *Meded. geol. Sticht.*, N. S., 8, p. 77-86.

Nyholm, E. (1974). — Musci. In : Illustrated Moss Flora of Fennoscandia. Vol. 2. Gotab, Kungälv. p. 405-647.

Paepe, R. and Vanhoorne, R. (1967). — The Stratigraphy and Palaeobotany of the Late Pleistocene in Belgium. Toelicht. Verhand. Geologische Kaart en Mijnkaart van België. 95 p.

Smith, A. J. E. (1978). — The Moss Flora of Britain and Ireland. Cambridge University Press. 706 p.

Tavernier, R. and De Moor, G. (1974). — L'évolution du bassin de l'Escaut. Soc. Géol. Belg. Colloque du Centenaire (Liège). 9-13 sept. 1974. Colloque sur l'évolution quaternaire des bassins fluviaux de la Mer du Nord méridionale.

Usinger, H. (1975). — Pollenanalytische und stratigraphische Untersuchungen an zwei Spätglazial-Vorkommen in Schleswig-Holstein. *Mitteilungen der Arbeitsgemeinschaft Geobotanik in Schleswig-Holstein und Hamburg*. 25, 183 p.

Van der Hammen, T. (1951). — Late-Glacial flora and periglacial phenomena in The Netherlands. *Leidse geol. Meded.*, 17, p. 71-183.

Van der Hammen, T., Maarleveld, G. C., Vogel, J. C. and Zagwijn, W. H. (1967). — Stratigraphy, climatic succession and radiocarbon datings of the last glacial in The Netherlands. *Geol. Mijnbouw*, 46, p. 79-95.

Vanhoorne, R. (1954). — L'Oscillation d'Allerod en Belgique. Vol. jub. Victor Van Straelen, I, Bruxelles, p. 141-147.

VANHOORNE, R. and VERBRUGGEN, C. (1975). — Problèmes de subdivision du Tardiglaciaire dans la région sablonneuse du nord de la Flandre en Belgique. *Pollen et Spores*, XVII, 4, p. 525-543.

VERBRUGGEN, C. L. H. (1979). — Vegetational and palaeoecological history of the Lateglacial period in Sandy Flanders (Belgium). *Acta Univ. Oul.*, A, 82, *Geol.* 3, p. 133-142.