THE STOKERSDOBBE: GEOLOGY AND PALYNOLOGY OF A DEEP PINGO REMNANT IN FRIESLAND (THE NETHERLANDS)[1]

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ABSTRACT

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This paper describes the results of geological and palynological investigations of a pingo remnant in Friesland. The remnant is situated in a small, former tributary valley of the Boorne river. As contrasted with other pingo remnants in The Netherlands, the Stokersdobbe is at its base filled with sand and gravel overlaid by a loam deposit of Bølling age. The decay of the pingo could be dated between 13,000 (Bølling) and 18,000 radiocarbon years B.P. The period of growth of the pingo is correlated with the Brandenburger Phase and the Upper Pleniglacial level of ice-wedge casts. An attempt is made to correlate the Friesland and Rammelbeek phases at the transition of Weichselian to Holocene with local changes in the hydrological situation.

INTRODUCTION

This study forms the continuation of our pollen analytical and geological investigations of closed topographic depressions (dobben) on the Drente plateau in the northern part of the Netherlands (DE GANS, 1976; CLEVERINGA ET AL., 1977). Subject of research this time was an about 100 m wide and 8 m deep dobbe filled with organic and inorganic sediments. This Stokersdobbe is situated at the western fringe of the plateau about 6 km south-east of Drachten (Fig. 1). At this site the plateau is drained by the Boorne river which runs to the west. The valley sides of the Boorne have slopes of less than 1° and are dissected by small tributaries. The Stokersdobbe is situated on the northern slope of the Boorne in such a tributary. This tributary does not take part in the present-day surface drainage (Fig. 2). The distance from the dobbe to the Boorne river is approximately one kilometre.

The detailed investigation of the Stokersdobbe enabled us to formulate some new ideas about pingo formation and about the Late Glacial and early Holocene vegetational history of The Netherlands.

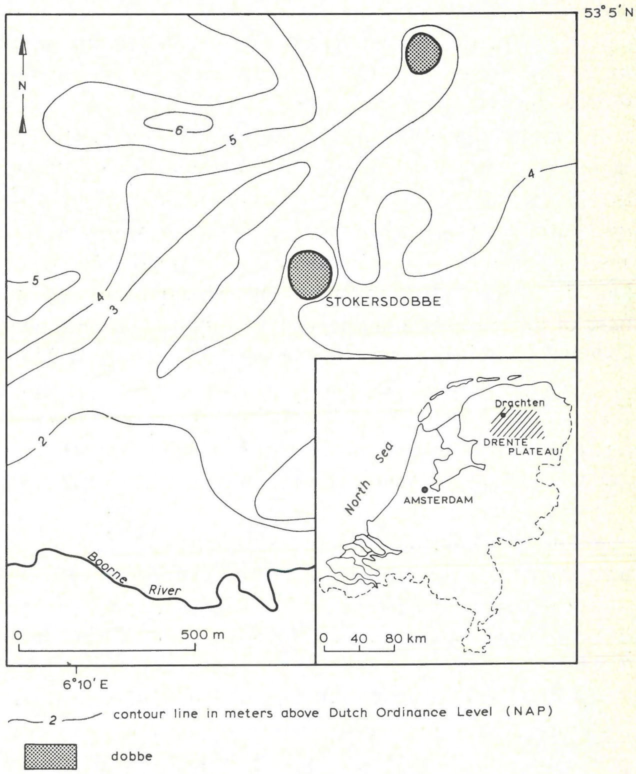

Fig. 1
Location of the Stokersdobbe area.

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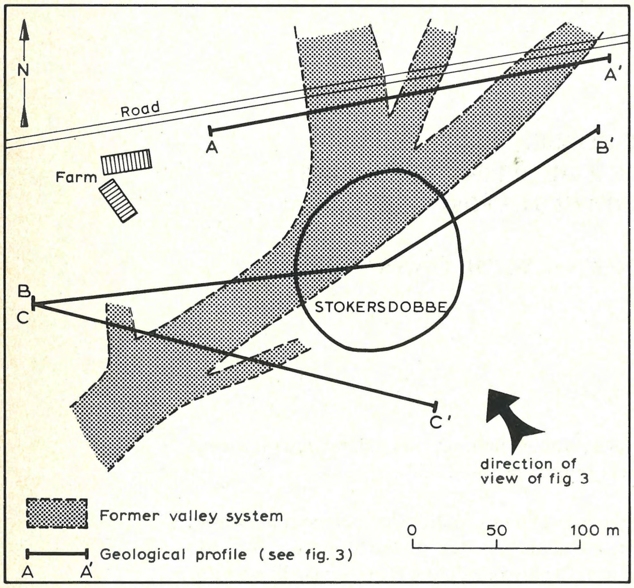


Fig. 2
The investigated area.

Table I
Lithology and stratigraphy of the investigated area (modified after Van der Hammen & Wijmstra, 1971 and Zagwijn & Van Staalduinen, 1976).

CHRONOSTRATIGRAPHY				LITHOLOGY (IN STOKERSDOBBE)	LITHOLOGY	LITHOSTRATIGRAPHY
HOLOCENE			SUBATLANTIC	PEAT		GRIENDTSVEEN FORMATION
			SUBBOREAL			
			ATLANTIC			
			BOREAL			
			PREBOREAL (R. / F.)			
WEICHSELIAN	LATE GLACIAL		LATE DRYAS	DETRITUS GYTTJA	YOUNGER COVERSANDS	
			ALLERØD *			
			EARLY DRYAS	GYTTJA		
			BØLLING *	LOAM	OLDER COVERSANDS	TWENTE FORMATION
	PLENIGLACIAL	UPPER		GRAVEL SAND / GRAVEL BED		
			PINGO DECAY	GELIFLUCTION DEP.		
			PINGO GROWTH	SANDY GYTTJA		
		MIDDLE	DENEKAMP *	FLUVIAL DEPOSITS IN BOORNE AND TRIBUTARY VALLEY		
			HENGELO *			
			MOERSHOOFD *			
		LOWER				
	EARLY GLACIAL		ODDERADE *			
			BRØRUP *			
			AMERSFOORT *			
EEMIAN						
SAALIAN				TILL		DRENTE FORMATION
				FLUVIAL AND AEOLIAN GREY SANDS		EINDHOVEN FORMATION

* = INTERSTADIAL
R = RAMMELBEEK PHASE
F = FRIESLAND PHASE

GEOLOGY OF THE STOKERSDOBBE

The geology of the Stokersdobbe has been studied on the basis of hand drilled sections.

A sticky lodgement till underlies the surroundings of the dobbe. The till has a thickness of 3 to 4 m (Fig. 3). The till is part of the Drente Formation (Table I). The underlying strata were reached only in a few borings due to the thickness of the till. The greyish, well sorted, fine, fluvial and aeolian sands found under the till belong to the Eindhoven Formation (ZAGWIJN & VAN STAALDUINEN, 1975; STIBOKA, 1971). Cut into the till a stratum of fluvial sands was found, that belongs to a former tributary of the Boorne (Fig. 2). The fluvial deposit is about 2.5 m thick and consists of coarse, angular, multicoloured loamy sands with fining upward sequences. At the base of these sands a lag deposit was found. These fluvial sediments have been deposited during the Weichselian. They belong to the Twente Formation (CNOSSEN & ZANDSTRA, 1965; TER WEE, 1976). Also to the Twente Formation belongs a thin layer of well-sorted fine sands which overlies the Stokersdobbe area. These sands of aeolian origin commonly are called coversands (Fig. 3).

A rampart surrounds the Stokersdobbe and consists of unstratified, coarse, angular sands mixed with till fragments. These sediments are interpreted as gelifluction deposits. A cryoturbated sandy gyttja was found under the rampart (Fig. 3-AA').

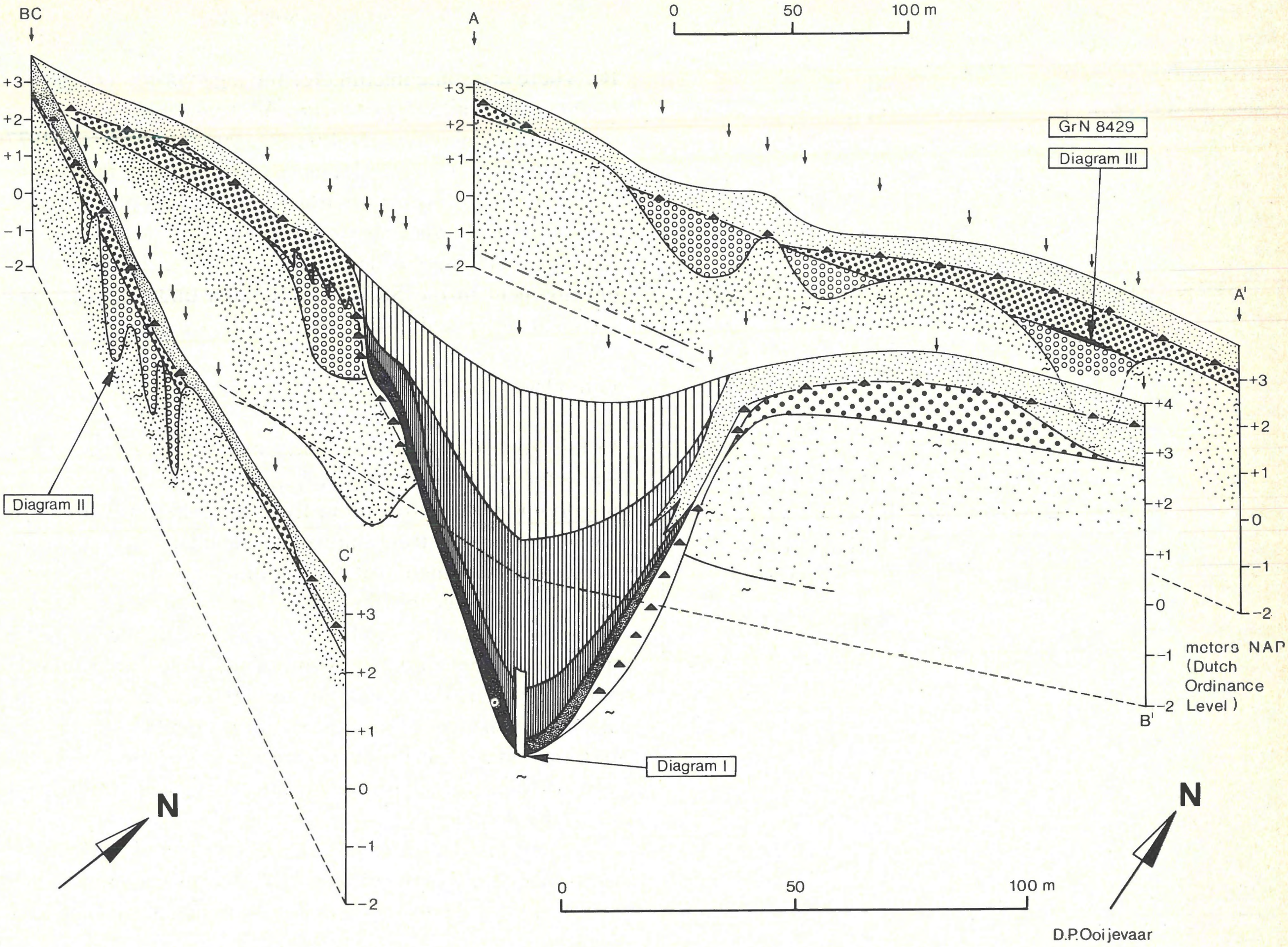
A gravel bed is located around the dobbe, but especially on top of the gelifluction deposits. It consists mainly of angular gravels (diameter less than 2 cm), is less than 10 cm thick and was formed before the deposition of coversands.

Stratified sands and gravels form the oldest sediments in the Stokersdobbe. They reach a maximum thickness of 50 cm and are situated on the slopes in the dobbe. They are followed by a loam which covers the whole basal part of the dobbe. This loam deposit underlies the organic sediments. The lowest part of the organic sediments consists of a 50 cm thick gyttja layer. This gyttja changes gradually into a detritus gyttja which contains thin peat intercalations. Aeolian sands are found intercalated within these organic sediments at the eastern side of the dobbe. A maximally 3 m thick peat layer forms the top of the organic material in the dobbe.

LABORATORY METHODS

Three cores were taken from the Stokersdobbe area for pollen analysis. The cores were sampled with a sampling auger (ø 50 mm). Pollen-slides were prepared from each 5 mm segment from the gyttjas of the Stokersdobbe core (Fig. 3-BB'). The underlying loam deposit was sampled every 40 mm. The cores from the till (Fig. 3-CC') and the sandy gyttja (Fig. 3-AA') were sampled every centimetre. The samples were treated according to ERDTMAN (1933) and FAEGRI & IVERSEN (1966). The results of the pollen analysis are represented in Iversen-diagrams (IVERSEN, 1942). A pollensum of 300 has been used.

In Table II a description and zonation is given for the pollen diagram of the Stokersdobbe Encl. I (Stokersdobbe I). No attempt is made to describe the diagrams Stokersdobbe II



and III, which show the pollen content of the till and of the sandy gyttja underlying the gelifluction deposit respectively.

INTERPRETATION OF POLLEN DIAGRAM STOKERSDOBBE I

Bølling (subzone IB)

Subzone IB is considered to represent the Bølling Interstadial. The pollen content differs from other sections (CASPARIE & VAN ZEIST, 1960; VAN DER HAMMEN, 1951; PLOEGER & GROENMAN-VAN WAATERINGE, 1964; POLAK, 1959) due to secondary pollen influx into the dobbe. These thermophilous elements (*Alnus, Quercus, Corylus* and *Picea)* have been derived from the till which surrounds the dobbe. The pollen content of the till is represented on Encl. II (Stokersdobbe II). After subtraction of the secondary pollen, the pollen content of this subzone appears to consist of Cyperaceae, Gramineae and *Betula*.

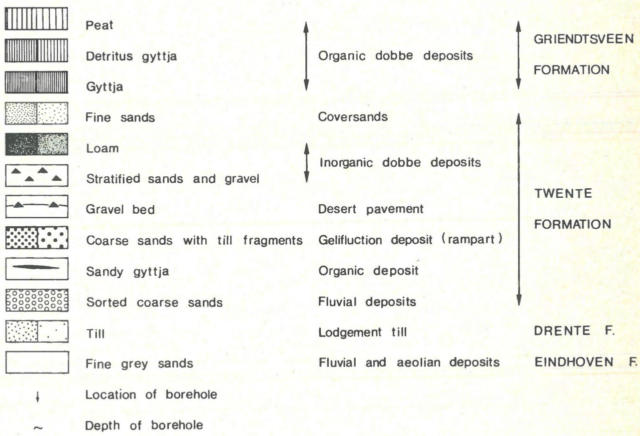


Fig. 3
Perspective fance diagram of Stokersdobbe.

Table II
Description and zonation of pollen diagram Stokersdobbe I.

Zone IV (441-397) Rise of AP curve. Alnus, Corylus and Quercus important. Nymphea alba and Typhaceae frequent. Artemisia scarce.		
Zone III (517-441) Pinus lower. At the top of the zone some fluctuations of Betula and Pinus. Scattered occurrences of Alnus, Corylus and Q.M. For the first time Empetrum. A continuous curve of Monoleet psilaat.	*Subzone III D (457-441)* Curves of Myriophyllum alt., Equisetum, Pediastrum, Botryococcus, Gramineae and Cyperaceae rise. *Subzone III C (467-457)* Rise of Pinus. Low frequencies of Myriophyllum alt., Botryococcus and Pediastrum. Artemisia and Ranunculaceae more frequent. *Subzone III B (486-467)* Myriophyllum alt., Sphagnum, Monoleet psilaat, Pediastrum and Botryococcus important. *Subzone III A (517-486)* Myriophyllum alt. and Botryococcus low. High frequencies of Type B.	
Zone II (550-517) Marked rise of Betula curve. Betula and Pinus predominant. Salix and Juniperus frequent. At the base of the zone a maximum of Juniperus. Herb species increase. Continuous curve of Artemisia. Well represented are the aquatics Myriophyllum alt., Equisetum, Isoëtes, Sphagnum, Stratoites aloides and Typha latifolia.	*Subzone II B (529-517)* Pinus rises at the expense of Betula. Continuous curves of Sphagnum and Isoëtes. *Subzone II A (550-529)* High frequencies of Betula.	*Subzone II B 2 (525-517)* High frequencies of Isoëtes. Low frequencies of Myriophyllum alt., Equisetum, Bryophyta and Type L. *Subzone II B 1 (529-525)* High frequencies of Myriophyllum alt., Equisetum, Bryophyta and Type L. *Subzone II A 2 (540-529)* Low frequencies of Myriophyllum alt., Equisetum, Pediastrum, Botryococcus, Bryophyta and Type L. *Subzone II A 1 (550-540)* High frequencies of Juniperus, Artemisia, Myriophyllum alt., Equisetum, Bryophyta, Pediastrum and Botryococcus.
Zone I (592-550) Pinus and Betula most important. Continuous curves of Alnus, Corylus, Picea and Quercus. Herbs almost exclusively Gramineae and Cyperaceae. Low frequencies of Ericales, Potamogeton and Sphagnum.	*Subzone I C (555-550)* A decrease of Pinus, Alnus, Corylus, Picea and Quercus. Betula and Salix increase. Gramineae and Cyperaceae important. A maximum of Potamogeton. First appearance of Equisetum, Pediastrum and Botryococcus. Tertiary pollen and spores scarce. *Subzone I B (592-555)* Pinus, Betula, Corylus, Alnus, Picea and Quercus the most conspicious trees. Gramineae and Cyperaceae the most important herbs. Tertiary pollen and spores frequent.	

Early Dryas (subzone IC)

The contamination with secondary pollen decreases. The dominance of herbs (Gramineae and Cyperaceae) and the lower percentages of *Betula* are interpreted as caused by a decrease in temperature. The maximum reached for *Potamogeton,* the first appearance of *Equisetum* and of the algae *Pediastrum* and *Botryococcus* indicate a fluctuation of the water-level. This phenomenon is also known from the Uteringsveen in the Drente area (CLEVERINGA ET AL., 1977).

Allerød (zone II)

The transition from the Early Dryas to the Allerød is indicated by the increase in amount of tree-pollen at the expense of herb-pollen. The appearance of the Pine is characteristic for the upper part of the Allerød (CASPARIE & VAN ZEIST, 1960; VAN DER HAMMEN, 1951; ZAGWIJN, 1969-a, b).

The lowermost subzone of zone II links up with subzone IC. There are some maxima for the algae *Botryococcus* and *Pediastrum,* while *Myriophyllum* alt. replaces *Potamogeton,* indicating a higher temperature (KOLSTRUP & WIJMSTRA, 1977; KOLSTRUP, in prep.). The fluctuation in aquatics reflects changes in the water level. Variations in the curves of *Myriophyllum* alt., *Sphagnum* and *Isoetes* point to an acidification of the water in the dobbe. This acidification may be due to a soil development in the Stokersdobbe area under a vegetation cover of *Pinus* and *Empetrum* (BERGLUND & MALMER, 1971).

Late Dryas (zone III)

In this zone the relative amount of *Pinus* becomes lower, while the Ericales – especially *Empetrum* – become more important. On the transition from the Allerød to the Late Dryas there is a strong influx of secondary pollen (*Alnus, Corylus* and elements of Quercetum mixtum) which may have been caused by the effect of aeolian sedimentation, connected with coversand deposition in the dobbe. This phenomenon is repeated at the end of the Late Dryas and the beginning of the Preboreal. Subzone IIIA does not show any significant changes in the curves of the aquatics. In subzone IIIB there is a rise in the curves for *Myriophyllum* alt., *sphagnum* and algae which again indicates changes in the hydrology of the dobbe.

A change in the water level may be reflected by the lowering of the aquatics in subzone IIIC. In this subzone we also see a rise of *Pinus, Artemisia,* Ranunculaceae and *Empetrum.*

Subzone IIID shows a re-establishment of the hydrology of the dobbe as described in subzone IIIB.

Preboreal (zone IV)

The beginning of the Preboreal is indicated by the gradual increase in *Pinus* and a decrease in *Betula, Empetrum* and *Artemisia.* During the Preboreal another influx of secondary pollen is observed (see zone III). Once again this is connected with important changes in the vegetation cover.

Some climatic oscillations are derived from pollen diagrams of Late Glacial and early Holocene deposits for the beginning of the Preboreal. These so-called Friesland (10.200-10.000 years B.P.) and Rammelbeek (10.000-9.800 years B.P.) phases have been described by BEHRE (1966, 1978), FLORIN (1977), VAN GEEL & KOLSTRUP (1978), VAN DER HAMMEN & WIJMSTRA (1971) and IVERSEN (1973). Striking changes in the relative amounts of aquatics can be seen in subzone IIIB, C and D versus slight fluctuations in tree-pollen (*Betula* and *Pinus*) and herb-pollen. The position of the boundary between the Late Dryas and the Preboreal becomes problematical if the fluctuations in subzone IIIC and D correspond with the Friesland and Rammelbeek oscillations. By absence of radiocarbon datings we are not yet able to solve that problem for the time being.

Discussion

Because of (1) the minimum age (Bølling) of the initial infill (pollen diagram Stokersdobbe I: Encl. I), (2) the existence of a rampart and (3) the depth of the depression, we conclude that the Stokersdobbe is a pingo remnant (DE GANS, 1976). Deformation structures due to the growth of the pingo ice core may be present but they could not be identified as such because of the thickness of the till.

The pingo out of which the Stokersdobbe developed was located in a small tributary valley of the Boorne river. MAARLEVELD & VAN DER TOORN (1955) and NOSSIN (1961) describe pingo remnants from comparably small valleys in this area. The valley in which the Stokersdobbe is situated was filled with fluvial sands before the pingo started to develop. Probably favourable hydrological conditions prevailed in this valley to develop the seepage which is considered necessary for the growth of pingos. If this holds true the Stokersdobbe pingo was formed as an open system or East Greenland type (MÜLLER, 1959).

The rampart of the pingo remnant is deposited on top of a sandy gyttja (Fig. 3-AA'). Pollen diagram Stokersdobbe III (Encl. III) is derived from this gyttja. These pollen spectra can be placed in the Pleniglacial of the Weichselian. In view of the high relative amounts of *Betula nana* and Cyperaceae, these spectra differ from Denekamp and other interstadial spectra (VAN DER HAMMEN & WIJMSTRA, 1971; KOLSTRUP & WIJMSTRA, 1977), but the amount of *Betula nana* in our opinion is too high for spectra derived from stadials. Local environmental conditions may be the cause for this deviating pattern of the pollen spectra. In an area with a tundra vegetation (mosses, sedges and low grasses) the (southern) slopes of pingos may allow for growth of shrubs (willow and birch) due to a different microclimate and hydrological circumstances (PIHLAINEN ET AL., 1956; HOLMES ET AL., 1968). A radiocarbon date for the sandy gyttja below the rampart (GrN 8429: 18,000 ± 200 years B.P.) indicates that the melting of the pingo took place between this date and the time of the initial filling of the pingo remnant (older than Bølling). This means that the growing of the pingo probably is simultaneous with the formation of large ice wedges known from the Upper Pleniglacial (VAN DER HAMMEN ET AL., 1967; PAEPE & PISSART, 1969; MAARLEVELD, 1976; VAN DEN BERGHE & GULLENTOPS, 1977), which are indicative for the presence of a permafrost (BLACK, 1975). This permafrost may be synchronous with the Brandenburger Phase of the ice advance (WOLSTEDT & DUPHORN, 1974).

The gravel bed on top of the rampart was formed by subsequent erosion after the melting of the pingo. Part of this eroded material was deposited in the dobbe before deposition of the loam (Bølling). This gravel bed may therefore be equivalent in time with the Beuningen gravel bed (VAN DER HAMMEN & WIJMSTRA, 1971). The coversand sedimentation into the dobbe continued at least until the Preboreal but probably even later (Fig. 3-BB' and Encl. I: Stokersdobbe I). This agrees with VEENENBOS (1954) and CLEVERINGA ET AL. (1977).

The sedimentation of this Young Coversand II is also responsible for the damming up of the Boorne river approximately 5 km west of the investigated area during the Late Dryas and the Preboreal (VEENENBOS, 1954; CNOSSEN & ZANDSTRA, 1965). This obstruction of the Boorne river possibly resulted in a rise of the ground-water level in the Stokersdobbe area.

CONCLUSIONS

From the pollen-analytical results, the radiocarbon dating and the geological survey it can be deduced that the pingo from which the Stokersdobbe originated, developed between the Denekamp and Bølling Interstadials.

The oldest infill of the dobbe consists of stratified sands and gravel which may be equivalent in time with the Beuningen gravel bed. The loam deposit on top of this was formed during the Bølling Interstadial. The secondary pollen content indicates that the loam was derived from the till surrounding the dobbe. The texture of the loam and the bowl-shape form of this deposit point to a lake environment.

Sedimentation of the Younger Coversand II in the dobbe continued untill the Preboreal and possibly even later. As a consequence the Twente Formation should not be confined to the Weichselian.

Though the initial filling of the Stokersdobbe and the Uteringsveen in Drente (CLEVERINGA ET AL., 1977) is of the same age, the sediments differ: gravel, sand and loam in the Stokersdobbe versus gyttja in the Uteringsveen. This distinction may be explained by the differences in depth and angle of slope of the dobbe, caused by a different till thickness and structure. The absence of organic filling material older than Early Dryas in dobben may also account for too young pollen analytical datings (Allerød) if the inorganic material is not analysed. If pollen zones IIIC and D (diagram Stokersdobbe I: Encl. I) are interpreted correctly as equivalent with the Friesland and Rammelbeek phases, there arise some problems with the zonation of the diagram. Zone IIIC and D should in that case belong to the Preboreal. Apart from this there seems to be a relation between the reflexions of these oscillations and a supposed rise of the groundwater level due to the damming up of the Boorne river caused by the sedimentation of coversand. Probably local environmental circumstances are responsible for the differences in registration of these oscillations.

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