IV CHRONOSTRATIGRAPHY

IVa INTRODUCTION

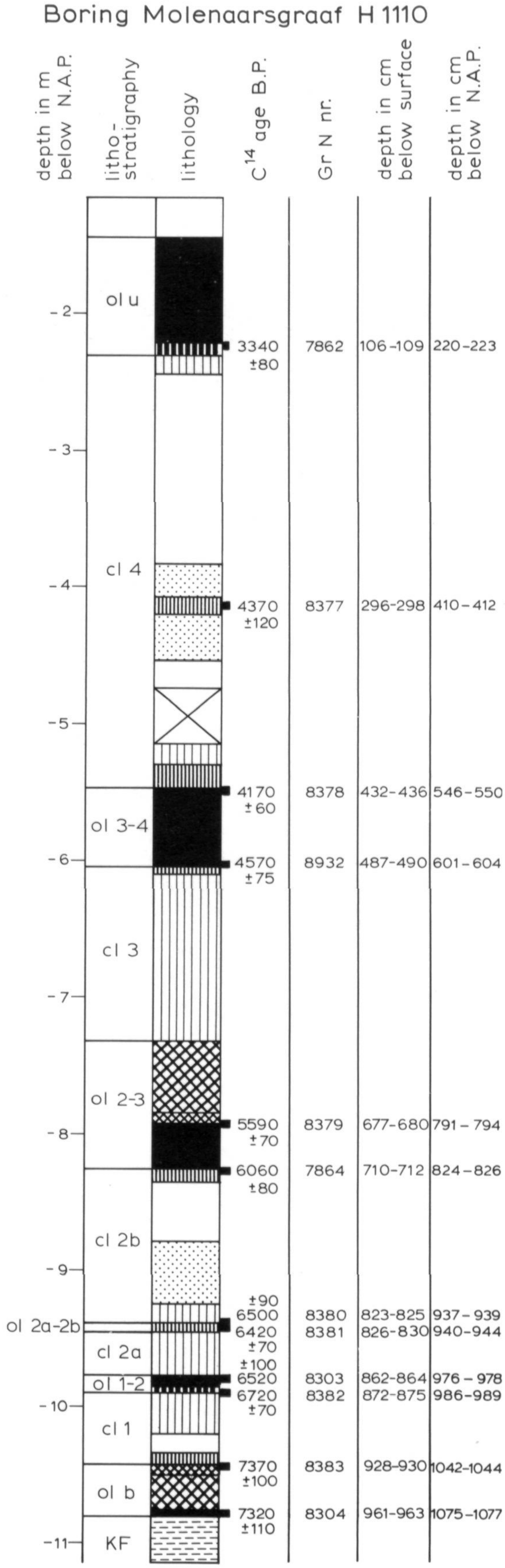
Chronostratigraphy is used here first to establish the chronology of the geological and paleoecological evolution in both study areas. Also, by chronostratigraphical comparisons of both study areas mutually and with the results of previous investigations in the river region, it may be possible to state the degree of regional isochrony (simultaneity) of the phases of geological evolution. This will involve the important question of whether the cyclicity in the clastic sedimentation, as expressed in the study areas in the alternation of clay- and peat beds, has only local significance (autocyclicity, e.g. by shifting of rivers; SELLEY 1978, p. 60) or also regional significance (allocyclicity; ibid.).
The chronostratigraphy of the deposits belonging to the upper part of the Kreftenheye Formation (*loam* and river dunes), as set forth tentatively in Ch. IVc, has been based largely on palynological results and geogenetical arguments (relating to the depositional conditions). The chronostratigraphy of the deposits belonging to the Westland Formation (mainly related to the cyclicity of clay- and peat beds) has been based largely on C-14 dates, but partly also on archeological data.

IVb DATINGS

IVb.1 C-14 dates

Most C-14 dates relate to samples taken at the base and top of peat layers. In the cyclic alternation of clay- and peat beds therefore, it is the peat beds that have been dated. Consequently, these dates are always before and after a period of clay deposition, in the case of peat samples at the base and top respectively of a clay bed. As the lithological transitions between the clay- and peat beds are generally rather gradual — at least in the basin environment, where the dates come from —, it is plausible that there are no important sedimentary hiatuses at the boundaries. This means that in general a date for the end of a period of peat formation may also serve as dating the start of the subsequent clay deposition; and that in general a date for the start of a period of peat formation may also serve as dating the end of the preceding period of clay deposition.
In dating the cyclic clay/peat stratigraphy, the litho- and biostratigraphical standard boring H1110 (Molenaarsgraaf study area) has naturally been given priority. In addition lithostratigraphical representative borings have been taken for the Leerdam study area. The importance of lithostratigraphical representativeness of the dated sections is stressed here, because e.g. at places where clay beds wedge out (especially at the river-dune flanks) C-14 dates might be less representative for the whole study area.
The sampled cores measure 5 cm in diameter; the (vertical) thickness of the samples varies (see Figs. 27-31) and amounts on an average to c. 3 cm. The outer layer of the cores was removed, but no rootlets or other possible contaminating material was removed from the remaining parts. This accords with existing practise in the C-14 sampling of peaty material. For a discussion of this possible source of error, see STREIF (1971), ROELEVELD (1974) and VAN DE PLASSCHE (1979-80). The samples have been dated at the State University Groningen, The Netherlands, under the supervision of Prof. Dr. W.G. Mook. The results are given in conventional C-14 years BP (before present, i.e. before A.D. 1950), with a standard deviation of one sigma; the half life used was 5570 years.
The results of all C-14 datings carried out for the present study are presented in Figs. 27-31. The topographic position of the borings concerned can be seen in Figs. 3 and 4. In Figs. 27-31, age, lithology and lithostratigraphy of all samples are indicated. Several of these figures can be compared directly to those indicating the pollen zones (Ch. III, Figs. 13, 16, 18, 19, 23 and 26); these relate to sections where both pollen analysis and C-14 datings have been carried out.
Some dates require further comment than shown in the figures. These dates are discussed here from oldest to youngest and for the two areas separately.

Fig. 27. C-14 dates in boring Molenaarsgraaf H1110 (standard boring). For lithological legend, see Fig. *9.



In the Molenaarsgraaf study area three datings have been carried out of the base of organic bed ol b (the 'basal peat'), forming also the base of the whole Westland Formation. The oldest date (9770 ± 100 BP) is from the base of the gyttja filling a depression in the surface of the Kreftenheye Formation (boring H1530, Fig. 28a; see also Ch. IIIe, Figs. 17 and 18). A C-14 date from the same depression infilling, but from slightly higher in the stratigraphy, gives a 2000 years younger date (7770 ± 80 BP, see Fig. 28b). The very base of the organic filling, below the latter sample, consists of strongly amorphous peat mixed with sand. In the stratigraphy of boring H1530 (with the age of 9770 BP at its base) the 2000 y. younger date should probably be related to the renewed gyttja sedimentation after the pollenanalytically (Ch. IIIe) established hiatus (in the middle of the gyttja layer, just above the intercalation of sandy clay, see Fig. 28a).
The basal-peat date in the standard boring (Fig. 27) shows an age of 7320 ± 110 BP for the base, and 7370 ± 100 BP for the top of the bed. The dates fall well within each others' standard deviation; arbitrarily, the start of organic accumulation here at this standard depth may be put at c. 7400 BP. Comparable to this, are the basal-peat dates of JELGERSMA (1961, p. 31) from the locality of Brandwijk, situated c. 3 km NW of the Molenaarsgraaf study area: 7540 ± 190 BP (GrN 201, 10.08 m below N.A.P.) and 7240 ± 230 BP (GrN 186, 11.98 m below N.A.P.).
The third date concerning the base of the basal peat in the Molenaarsgraaf study area, is on the charcoal occurring at 9.90 m below N.A.P. at the foot of the Hazendonk river dune (see Ch. IIIi). The age of this charcoal lying directly below the basal peat (see Fig. 28c; 6900 ± 100 BP) reveals a possibly water-level rise-induced difference from the date in the standard boring (7400 BP); the younger sample lies 80 cm higher than the older one. This would fit with the general picture of later basal-peat growth at higher localities because of the Holocene water-level rise (JELGERSMA 1961; see also Ch. Ia).
Two contiguous C-14 samples have been taken from the 7 cm thick peaty bed ol 2a-2b in the standard boring (Fig. 27). The ages obtained, 6420 ± 70 BP for the lower and 6500 ± 90 BP for the upper sample, are averaged here to c. 6450 BP for the whole bed.
The conflicting litho- and chronostratigraphy of the very thick gyttja layer (ol 2-3) in boring H2115 have been discussed in Ch. IIIk. Whereas in nearly the whole study area intensive fluviatile sedimentation occurred from c. 6450 to c. 6050 BP (bed cl 2b, see Fig. 27), lacustrine organic deposition occurred at boring H2115: the base of the gyttja layer dates from 6470 ± 150 BP, see Fig. 29).
During the sampling of the standard boring, the peaty clay intercalation in the sandy section of clay bed cl 4 (see Fig. 27) was supposed to belong lithostratigraphically to organic bed ol 4a-4b. However, the loose structure of the bed, the fact that the peaty clay also contains some sand, and the absence of the bed in the neighbouring borings make its lithostratigraphic interpretation uncertain. The age of the C-14 sample of the bed (4370 ± 120 BP; GrN 8377) is older than the top of the lower lying peat bed ol 3-4 (4170 ± 60 BP; GrN 8378). The lithology of peat bed ol 3-4 leaves no doubt as to the reliability of the latter date. The most probable solution to the problem of the former date (4370 ± 120 BP) is that it relates to reworked organic material, derived by erosion from peat bed ol 3-4.

In the Leerdam study area a piece of wood from the top of the Kreftenheye Formation has been dated as 9400 ± 120 BP (see Fig. 30a). The sample comes from the same depression as the pollen section discussed in Ch. IIIf. The position of the wood is such (in the sand below the gyttja infilling), that the date need not relate to the start of the gyttja deposition. This is in agreement with the palynological dating of the base of the gyttja, namely Boreal.
In the Leerdam area peat bed ip forms the separation between the two main clastic beds, lcp and up (see e.g. profile IV, Fig.*10). The base of this peat bed in a normal situation (i.e. outside stream ridges and river dunes) dates from 6090 ± 70 BP (boring S322; see profile IV and Fig. 30b). A dating from the base of the same lithostratigraphical unit ip in an extremely high position, namely on

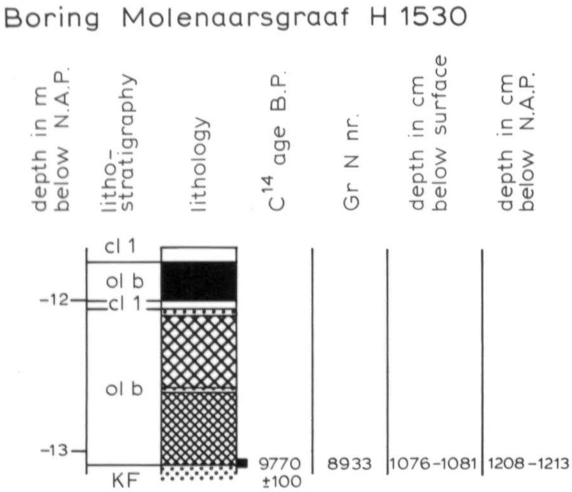


Fig. 28a. C-14 date in boring Molenaarsgraaf H1530.
For lithological legend, see Fig. *9.

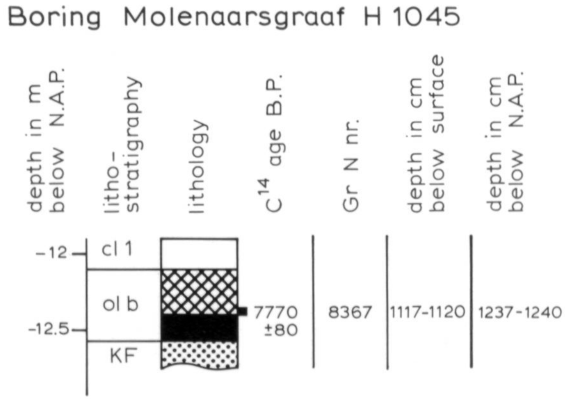


Fig. 28b. C-14 date in boring Molenaarsgraaf H1045.
For lithological legend, see Fig. *9.

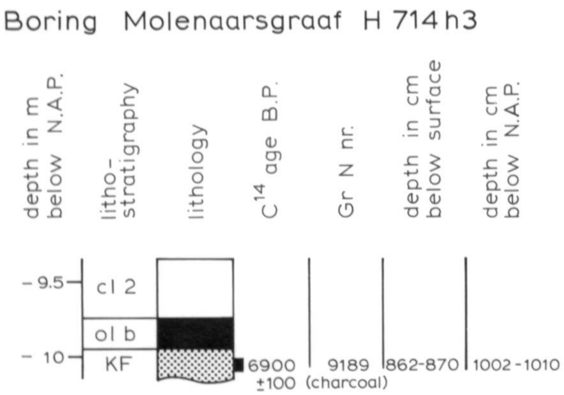


Fig. 28c. C-14 date in boring Molenaarsgraaf H714h3.
For lithological legend, see Fig. *9.

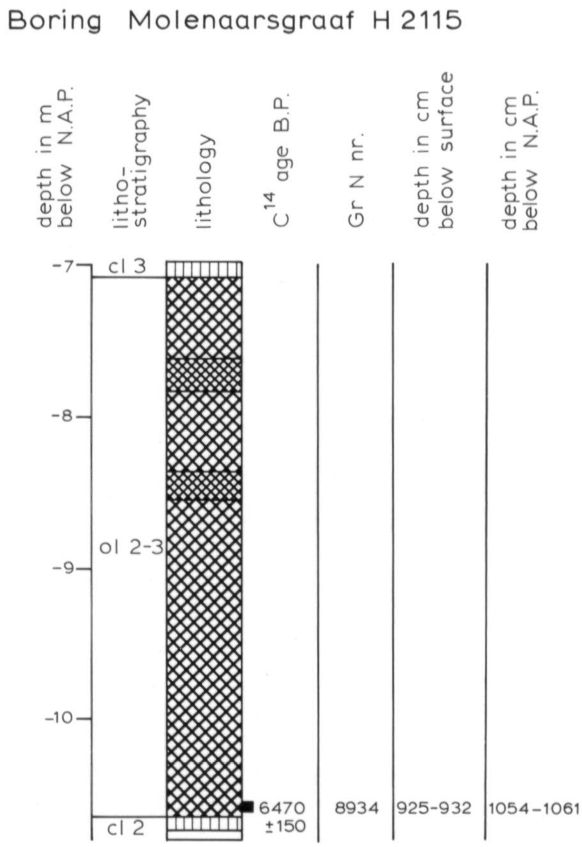


Fig. 29. C-14 date in boring Molenaarsgraaf H2115.
For lithological legend, see Fig. *9.

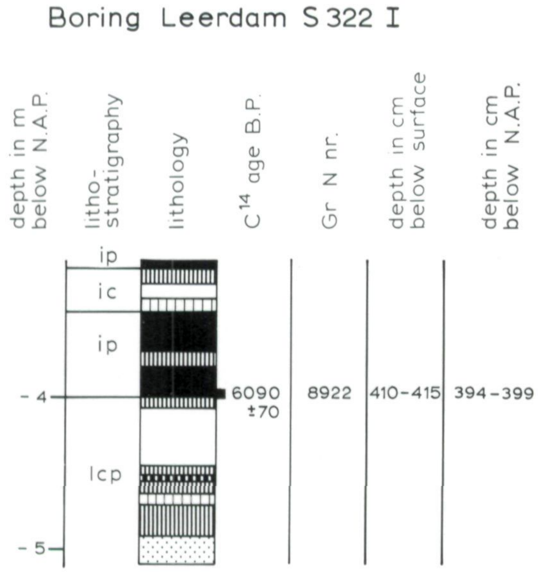


Fig. 30a. C-14 date in boring Leerdam S322 I. For lithological legend, see Fig. *9.

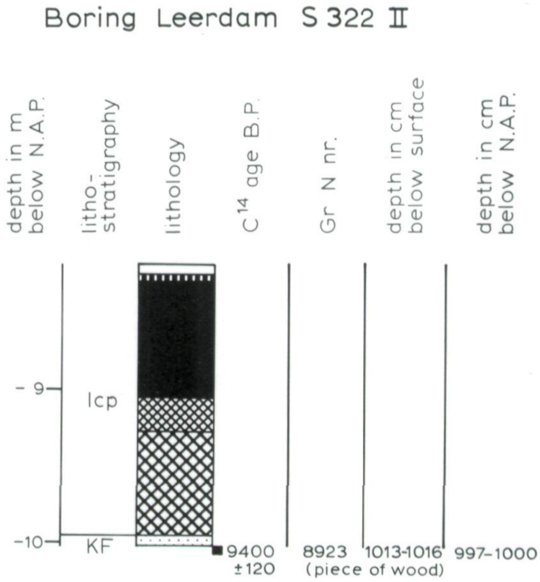


Fig. 30b. C-14 date in boring Leerdam S322 II. For lithological legend, see Fig. *9.

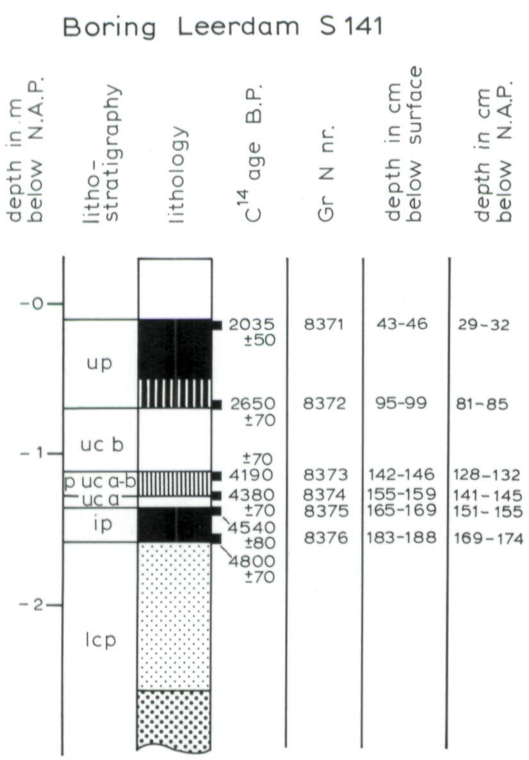


Fig. 30c. C-14 dates in boring Leerdam S141. For lithological legend, see Fig. *9.

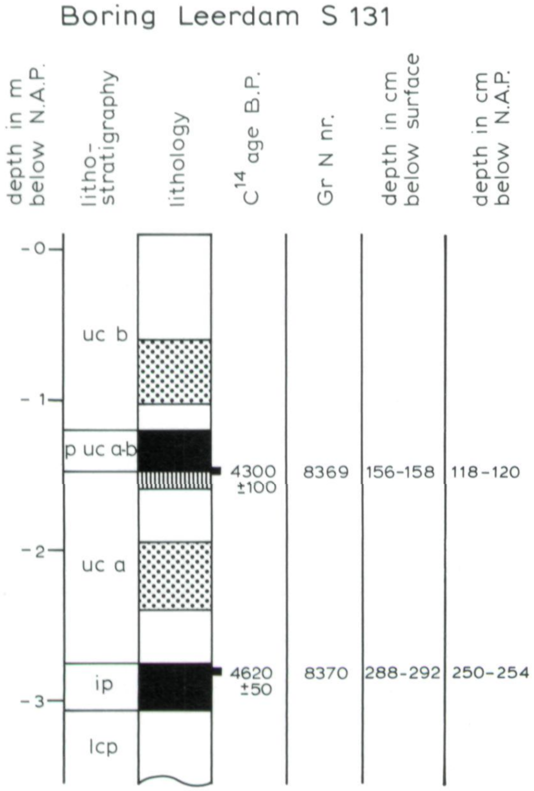


Fig. 31a. C-14 dates in boring Leerdam S131.
For lithological legend, see Fig. *9.

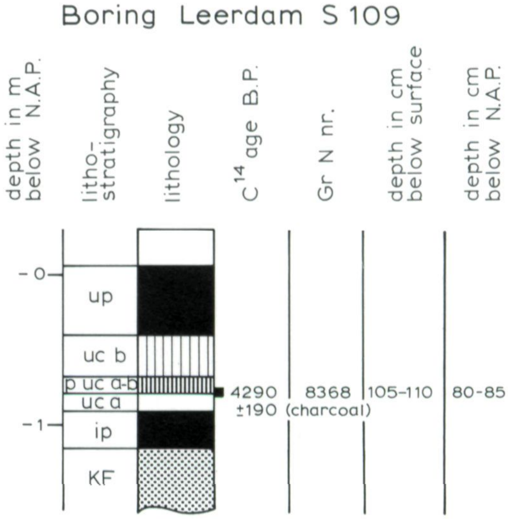


Fig. 31b. C-14 date in boring Leerdam S109.
For lithological legend, see Fig. *9.

top of the highly rising Middelkoop stream ridge, resulted in a much younger age: 4800 ± 70 BP (see Fig. 30c). The lithostratigraphical position of the boring concerned, S141 (see Fig. 4 for location), is about midway between that of boring S357 and that of boring S358 in profile IV (Fig.*10). The diachrony (differences of age within a lithostratigraphic plane) demonstrated indicates that peat growth on the highest parts of the stream ridge started much later than in the basins. Thus, these highest parts of the Middelkoop stream ridge should have remained dry from c. 6100 BP (after the period of intensive fluvial clastic sedimentation of bed lcp) up to c. 4800 BP. Palynological support for this can be found in zone III of section S322 I (Ch. IIId). There are of course interesting implications of this for the archeology of the region.
Partly for the sake of cross-checking, five C-14 samples from three borings have been taken with reference to clay bed uc a (Figs. 30c, 31a and 31b). The resulting ages support each other satisfactorily.

IVb.2 Indirect datings via archeological levels

The very detailed mapping (by means of borings) of archeological levels along the perimeter of the Hazendonk river dune (see Ch. Ic) may be used not only to give a picture of the areal extension of the levels (not published here), but also for slotting the clay/peat stratigraphy into the archeological chronology based on C-14- and typological datings. The levels can be observed in the auger core because they contain charcoal, fish-bone fragments and some dune sand (probably shifted by anthropogenic erosion). The levels could be interpreted archeologically by starting the rows of borings at the excavation pits. By following the archeological levels from the dune flanks to where the thickness and lithology of the clay-and peat beds have been developed normally, these levels could be fitted in the lithostratigraphy. From this special investigation carried out by VAN DIJK et al. (1976, internal report) the following correlations can be concluded:

archeological level (according to LOUWE KOOIJMANS 1976, fig. 2; 1980, pers. comm.)	age in C-14 years	lithostratigraphic position
Vlaardingen 2b	c. 4000 BP	organic bed ol 4a-4b
Vlaardingen 1b	c. 4400 BP	organic bed ol 3-4
Hazendonk 3	c. 4800 to 4900 BP	clay bed cl 3
Hazendonk 1	c. 5300 BP	organic bed ol 2-3

The indirect dates for the lithostratigraphic units mentioned on the right of the above table agree with the C-14 dates discussed in Ch. IVb.1 (cf. esp. Fig. 27). The Vlaardingen-1b level (c. 4400 BP) is situated mostly in the upper part of peat bed ol 3-4. The top of this bed has been dated as 4170 ± 60 BP in the standard boring (Fig. 27). So locally (especially in the area directly surrounding the river dune?) the formation of peat bed ol 3-4 stopped possibly earlier than at the standard boring; this is discussed further in Ch. IVd in connection with C-14 dates published by LOUWE KOOIJMANS (1974).
The locally occurring thin organic bed ol 4a-4b — see the discussion in Ch. IVb.1 in connection with date GrN 8377 — can now be dated indirectly via the Vlaardingen-2b level at c. 4000 BP.

IVb.3 Pollenanalytical datings

In three pollen sections of organic deposits in depressions in the Kreftenheye Formation-surface, an early-Holocene sequence has been found (Preboreal, Boreal, early-Atlantic). These sections have been discussed in Chs. IIIe, -f and -g; they provide important additions to the chronostratigraphic information treated above, which mainly concerns the Atlantic and Subboreal. The results are incorporated in Ch. IVc.
The limitations of pollenanalytical dating of river clay deposits in the Westland Formation have been discussed in Ch. IIIc.6. Nevertheless, taking an overall view of the pollen diagram of the standard boring (Fig.*12), the transition from Atlantic to Subboreal can most probably be placed, on the basis of the gradual decline of the *Ulmus* curve, about midway in zone 13, that is during the deposition of clay bed cl 3. This is in agreement with the C-14 dates concerning this clay bed (see Fig. 27).

The *Carpinus* curve of the standard section (Fig.*12) shows significant values only in wood-peat bed ol u (the Upper Peat). This points to a late-Subboreal/Subatlantic age for this peat bed, and this is in agreement with the C-14 date of the base of the bed (see Fig. 27).

IVc GENESIS AND AGE OF THE *LOAM* AND THE RIVER DUNES

The only absolute certainty about the age of the river dunes at the top of the Kreftenheye Formation, to be concluded on the basis of this study, is that they were formed before the middle-Atlantic — when the covering clay- and peat beds started to be deposited.

As mentioned in Ch. Ia, the published dates of river dunes in the top of the Kreftenheye Formation are not identical for the whole Dutch river area. Limiting the discussion to the stream area of Rhine and Meuse from the Eastern to the Western Netherlands, the older literature might be summarized in the words of DE JONG (1967, p. 396): 'A Pleistocene age [of the river dunes] for the eastern area seems to be based on better evidence than a Holocene age for the western area'. This statement refers mainly to publications by SCHELLING (1951) and PONS (1957) for the Eastern Netherlands, and PONS & BENNEMA (1958; with a pollenanalytical dating by FLORSCHÜTZ) for the Western Netherlands. We shall not discuss these sources in any more detail, but shall limit ourselves instead to the later publications by VERBRAECK (1974) and VAN DE MEENE (1980). VERBRAECK studied river dunes in the Alblasserwaard, the region in which also our main study area (Molenaarsgraaf) is situated; the Alblasserwaard is the most prominent river-dune area of the Western Netherlands. VAN DE MEENE studied a river-dune complex near Arnhem (Eastern Netherlands). On the basis of pollenanalytical results both authors could limit the date of the river dunes to the period from the Younger Dryas (the last phase of the Late-Weichselian) to the Atlantic. Both conclude a Younger Dryas age, mainly on the basis of the argument that the river dunes are likely to have been formed in a practically barren landscape. The validity of this argument should be questioned: the main factor controlling river-dune formation is the availability of channel sand for wind erosion, e.g. by a lowering of the water level; the area where this material is to be deposited need not be barren.

Nevertheless we endorse the legitimacy of geogenetical arguments in discussions on the age of the river dunes, where more direct dates are not available. To that end, we shall stress here a probable genetic relation between the *loam* and the river dunes.

The *loam* is a diamicton of clay and sand with a large lateral uniformity. The usual genetic interpretation of the *loam* as a purely fluvial sediment does not explain this uniform diamictic nature. A clear discrimination between sandier and more clayey parts would be expected. In our opinion, the eolian genesis ascribed by SCHELLING (1951, p. 94) and by PONS (1957, p. 15) to the coarse sand they found locally in the topmost part of the *loam* should be attributed to most if not all the sand in the *loam*. Sand that periodically during or after (also periodical, perhaps seasonal?) fluvial basin-clay deposition was blown on to these clay surfaces might have mixed there with the clay (syn- or postsedimentary) to form the diamicton *loam*. This hypothetical mixed genetic nature of the *loam* might make the name **fluvio-eolian** appropriate. According to this view, the formation of the river dunes may be seen as contemporaneous with the *loam* formation, namely as locally more dominant sand accumulation, especially near to the presumed source of the eolian transported sand, i.e. the channels. The grain-size composition of the sand fraction in the *loam*, as analysed in just one sample, is not in contradiction with the above assumed genetic relationship between the *loam* and the river dunes. There is a remarkable similarity to the average grain-size composition given by VERBRAECK (1974, p. 4) for the river-dune sand in the Alblasserwaard:

	16-50 mu	50-75 mu	75-105 mu	105-150 mu	150-210 mu	210-300 mu	300-420 mu	420-600 mu	600-850 mu	850-1200 mu	1200-1700 mu
Average grain-size composition of river-dune sand in the Alblasserwaard (VERBRAECK 1974, p. 4)	0.4	0.2	0.8	2.9	17.5	27.7	30.1	15.0	4.6	0.5	0.3%
										850-1400 mu	1400-2000 mu
Grain-size composition of sand in 'loam' in Molenaarsgraaf study area (one sample)	9.1	2.0	2.7	4.4	10.7	27.6	22.9	14.5	4.7	1.3	0.1%

The fluvio-eolian hypothesis of *loam* formation still requires to be thoroughly tested. Nevertheless we shall use it here in a consideration of various data from Chs. II, III and IV concerning the *loam* and the river dunes, in order to make a contribution, albeit a speculative one, to the discussion about the age of the river dunes.

Outside the river dunes the *loam* layer shows a differentiation into a light-grey, calcareous lower part and a dark-grey, noncalcareous upper part. Although the pedogenesis of the *loam* has not been studied here, it may be assumed on the basis of the locally considerable thickness of the dark-grey noncalcareous part (up to 1 m) that this vertical differentiation has not been brought about by postsedimentary pedogenetic processes. So, the lithological transition from the lower to the upper part of the *loam* should point to a change in the depositional environment. HAGEMAN (1970a) considers this to be the transition from the sparsely vegetated environment during the Late-Weichselian to the more densely vegetated environment during the early-Holocene.

On the few occasions when was gouged almost completely through the high, thick river-dune sand deposits, the sand appeared to be somewhat calcareous in its lowermost part; all the rest of the river-dune sand is noncalcareous. If postsedimentary decalcification — so many meters deep — may be excluded, this vertical differentiation of calcareous content may be viewed as a parallel development to that in the *loam*. This would mean that the river-dune formation also initially took place in the sparsely vegetated environment during the Late-Weichselian, and subsequently in the more densely vegetated environment during the early-Holocene. In agreement with this (but not supporting it especially) is the fact that, where low river dunes have been gouged through into the underlying *loam*, this *loam* shows the light-grey calcareous facies.

In the gyttja infilling of the depression in the Kreftenheye Formation surface (pollen section Molenaarsgraaf H1530, see Ch. IIIe), in the lower part dating from Preboreal and Boreal (zones I and II) some clay beds, up to 1 cm thick, have been found that show strong similarity in colour and structure to the dark-grey *loam*. This may support the above-mentioned dating of the dark-grey *loam* as early-Holocene. In the same section a hiatus is situated at the transition from zone II to zone III, which points to non-deposition (of the gyttja) during the later part of the Boreal and the very beginning of the Atlantic. This non-deposition may have been caused by a temporary fall of the water table in connection with possible drying out of shallow channels leading to more intensive eolian erosion and river-dune accumulation.

Some observations that by themselves have little diagnostic value, nevertheless agree with the more intensive dune-sand accumulation during the Boreal supposed above. In the above-mentioned section H1530, a 1 cm thick layer of sand showing the characteristics of river-dune sand is situated just at the hiatus. Primary eolian deposition of this sand during the Boreal is plausible. The uppermost part of the river-dune sand in pollen section H2178 (Ch. IIIg) shows Atlantic spectra; from this it was concluded that accumulation of this dune sand during the (late-)Boreal is not unlikely. Finally, the locally greater sandiness of the topmost part of the dark-grey *loam* (see Ch. IIa) possibly indicates more intensive eolian sedimentation towards the end of the early-Holocene *loam* deposition (or just after it, in the case of postsedimentary mixing).

The above speculative argument for a Late-Weichselian *cum* early-Holocene age of the river dunes at Molenaarsgraaf (with a possibly more intensive dune-sand accumulation during the Boreal) may serve mainly as stimulus to a more elaborate study specially aimed at these matters. Apart from the desirability of more direct dating, the depositional environment should be an important issue.

One important aspect of the *loam* has been left out of consideration above. This concerns the high, thick occurrence of the light-grey calcareous *loam* in the river-dune field, c. 300 m W of the Hazendonk (see Figs. 36 and 37). The *loam* occurring usually at a depth of c. 10.5 m below N.A.P. and with a thickness of some dm up to 1 m, here attains heights up to c. 8 m below N.A.P. and was found to be locally at least 2.5 m thick. Rejecting the explanation of this high, thick *loam* as being of purely eolian origin, or as natural levee, the explanation as an erosional terrace seems unavoidable. If so, this *loam* would have been deposited earlier and at a higher water level than the normal *loam*. In this connection, reference should be made to PONS' (1957, p. 24) reconstruction of a Late-Weichselian incision of Rhine and Meuse in the Eastern Netherlands, and to his supposition (ibid., fig. 16) of an extension of this incision into the Western Netherlands area. If the high, thick *loam* is explained as an erosional terrace — which presupposes Late-Weichselian erosion on a very large scale in this region! —, it is conceivable that this erosional terrace might have served as a nucleus for dune-sand accumulation (on the lee side?), and that possibly in other river-dune fields in this region other such erosional terraces might also be found. If this hypothesis should be confirmed, VINK's (1954) explanation of the *donken* (the regional descriptive term for the river-dune outcrops) as erosional terraces would after all in a way have some validity.

IVd CHRONOLOGY OF THE FLUVIATILE DEPOSITIONAL PHASES

Correlation between the Molenaarsgraaf and Leerdam study areas

The dating results related to the cyclicity of the fluvial clay beds and the peat beds in both study areas, as discussed separately in Ch. IVb, have been brought together in a chronological scheme (Fig. 32). The lithostratigraphical correlation brought about in Ch. IIb.3 between the main clastic and organic beds of both areas appears to be largely also a chronostratigraphic correlation. One of the most important lithostratigraphic levels, namely the top of clastic bed cl 2 (Molenaarsgraaf)/ lcp (Leerdam) has the same age in both areas (c. 6100 BP). The period of deposition of clastic bed cl 4 in the Molenaarsgraaf area falls within the period of deposition of the lithostratigraphically correlative clastic bed uc at Leerdam. The deposition of this bed appears to have started earlier and ended later in the upstream area (Leerdam) than in the downstream area (Molenaarsgraaf). However, the start of the main sedimentation was at about the same time, namely 4100 BP, in both areas.
The phases of clastic fluviatile deposition have, for their primary subdivision, been named after the BLYTT/SERNANDER terminology (see the right part of Fig. 32). This has been done on the basis of the presently accepted radiocarbon calibration of these periods (Atlantic and Subboreal) in the Netherlands (see ZAGWIJN & VAN STAALDUINEN 1975).

Comparison with other dates from the perimarine fluviatile coastal plain

The phases of the fluviatile depositional activity outlined above for both study areas (Fig. 32) agree in general with previously published dates for the fluviatile depositional phases during Atlantic and Subboreal in this region (Alblasserwaard and Vijfheerenlanden, see for location Fig. 1).

Mainly on the basis of prehistoric occupation on stream ridges and of pollen analysis of peat beds beside the stream ridges, DE BOER & PONS (1960, p. 23 f.) concluded that there were separate phases of increased fluviatile depositional activity in the Vijfheerenlanden. For the period of Atlantic and Subboreal they place these phases roughly in the second half of the Atlantic (before the end of the Atlantic), in the transition from Atlantic to Subboreal, and in the middle-Subboreal. Although the datings are not precise, they give about the same phasing as depicted in Fig. 32.

The C-14 dates published by VERBRAECK (1970) in connection with a phasing of fluviatile depositional activity in the area of sheet 38 Oost of the Geological map of the Netherlands (i.e. the Vijfheerenlanden and the eastern part of the Alblasserwaard) derive from the section at Goudriaan (op. cit., fig. *43). The location of this boring is midway between the Molenaarsgraaf and Leerdam study areas. On the basis of the lithology of this section and the depth of the various clay- and peat beds in it, the lithostratigraphical position of the C-14 dates may be indicated in terms of the local lithostratigraphy of our both study areas:

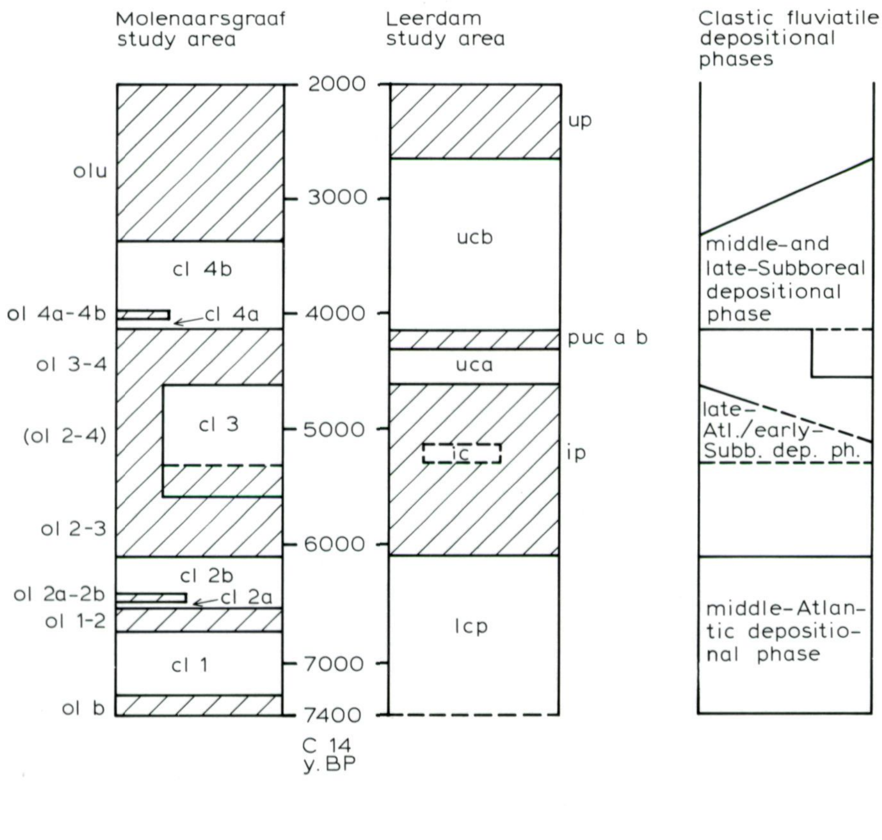


Fig. 32. Scheme of the chronostratigraphy in both study areas. Compare with Figs. 5 and 11, and Table 2.

2820 ± 75 BP (GrN 787) ~ base of peat bed up (Leerdam)
4095 ± 90 BP (GrN 784) ~ peaty level p uc a-b (Leerdam)
4650 ± 95 BP (GrN 785) ~ top of peat bed ip (Leerdam)
5340 ± 90 BP (GrN 786) ~ in organic bed ol 2-3 (Molenaarsgraaf)

The first three dates give good support for the middle- and late-Subboreal depositional phase distinguished in Fig. 32. The fourth date (GrN 786: 5340 ± 90 BP) falls within the late-Atlantic period of organic accumulation in the chronologic scheme of Fig. 32, but on account of the lithostratigraphical position of the sample concerned (in the lower part of the peat bed) it is rather young. The discrepancy might be explained by a locally later start of the peat formation after the middle-Atlantic depositional phase. Such a local hiatus in deposition is not unlikely, as the underlying clastic bed — as shown in fig. 43 by VERBRAECK (op. cit.) — consists of (channel) sand and so possibly has been developed as a stream ridge. A comparable situation has been discussed in Ch. IVb.1 in connection with the C-14 dates GrN 8922: 6090 ± 70 BP and GrN 8376 : 4800 ± 70 BP in the Leerdam study area.
A more regional approach to the dating of fluviatile depositional phases in the Alblasserwaard and Vijfheerenlanden was used by LOUWE KOOIJMANS (1974, see especially tables 5 and 6). It concerns mainly datings of archeological finds on stream ridges. These of course always only give a terminus ante quem for the depositional phase in which the stream ridge concerned was formed. The oldest phase dated in this way concerns the one in which the so-called Gorkum stream was active; a find on top of its stream ridge dates from the period 6000-5400 BP, so possibly the depositional phase ended before 6000 BP. Interpreted in this way, the dating would support the middle-Atlantic depositional phase distinguished in Fig. 32. A comparable date (c. 6050 BP) has also been mentioned by LOUWE KOOIJMANS (op. cit., p. 134) as a possible date (on account of the depth) for the top of a clay bed on the flank of the Hazendonk river dune — the so-called bed clay 1. This bed is the same as bed cl 2 distinguished in this study, the top of which has been dated as 6060 ± 80 BP (see Fig. 27).
In connection with the late-Atlantic/early-Subboreal depositional phase distinguished in Fig. 32, reference should be made to a similar phase mentioned by DE BOER & PONS (1960; see also above) as well as LOUWE KOOIJMANS (1974, table 6). In both sources this phase has been based mainly on archeological finds on and near the so-called Zijderveld stream ridge. However, according to the Geological map of the Netherlands, sheet 38 Oost (VERBRAECK 1970, map and p. 85), this stream ridge belongs to the same pattern to which the Schaik stream and the (western continuation of the) Schoonrewoerd stream also belong. The clay deposits connected with these stream ridges have been dated in the Leerdam study area as middle-Subboreal (see Ch. IVb.1, lithostratigraphic unit uc). This is in agreement with DE JONG's (1970-71, figs. 1 and 13) indication of the Zijderveld stream ridge — in its type locality — as 'Gorkum IV'. The archeological finds, on the basis of which an older age had been concluded, also come from this type locality (see LOUWE KOOIJMANS 1974, fig. 18). However, at this point the Zijderveld stream ridge lies partly on, and directly next to a stratigraphically deeper stream ridge (VERBRAECK 1970, geological map; DE JONG 1970-71, fig. 1). It may be assumed that the older archeological finds mentioned by LOUWE KOOIJMANS do not so much relate to the Zijderveld as to this deeper, older stream ridge. DE JONG (op. cit.) concludes that a late-Atlantic/early-Subboreal age is appropriate for this deeper stream ridge, on the basis of a C-14 dating and pollen analysis of overlying material, and thus on the basis of a terminus ante quem. Comparing the situation here to that in the Leerdam study area we presume that this deeper stream ridge had already been formed long before this terminus ante quem, namely not in the late-Atlantic/early-Subboreal but in the middle-Atlantic. According to the geological map 38 Oost cited above (VERBRAECK 1970), the stream ridge belongs to the same system to which the Middelkoop

stream ridge in the Leerdam area also belongs (see also DE JONG 1970-71, fig. 1). The depth of the top of both stream ridges is the same (c. 2 m below N.A.P., cf. e.g. Fig.*10 with DE JONG's fig. 13; we suppose the sand at the base of DE JONG's section 4A — Zijderveld R.O.B. excavation — to belong to the Zijderveld stream ridge, see also his fig. 1). The formation of the Middelkoop stream ridge was placed in the middle-Atlantic (namely before 6100 BP; see Ch. IVb.1) by means of a C-14 dating of peat on top of the basin-clay bed connected laterally to the stream ridge in the Leerdam area. Organic material on top of the stream ridge itself in our study area also appeared to be much younger than this 6100 BP, namely 4800 BP (see discussion in Ch. IVb.1). It should be stressed again that in dating stream ridges C-14 dates on peat overlying a basin-clay bed are more useful than C-14 dates on peat on top of the stream ridges themselves. In the latter case, considerable depositional hiatuses should be reckoned with. Summarizing, with regard to the late-Atlantic/early-Subboreal depositional phase it may be concluded that at Zijderveld — just as at Leerdam and Molenaarsgraaf — no stream ridges from this phase occur.

The greater part of the clastic sediment of the middle- and late-Subboreal depositional phase has been brought into both study areas by the Schoonrewoerd stream. The start of the clay deposition from this river on the Hazendonk river dune flank was estimated by LOUWE KOOIJMANS (1974, table 8) at c. 4050 BP (2100 BC); this estimation was based on presumed water-level heights connected with the Holocene sea-level rise. Our dating of c. 4100 BP (see Ch. IVb.1) agrees well with this. However, two C-14 dates on peat samples at the base of this clay bed, one on the flank of the river dune and another just outside it, give an older date, namely 4480 ± 40 BP (GrN 6213), and 4290 ± 40 BP (GrN 5175; ibid., p. 140) respectively. So, as noted in Ch. IVb.2, the possibility that at least locally in the Molenaarsgraaf area clay deposition occurred some centuries before 4100 BP should not be excluded. This would then partly correspond to the deposition of clay bed uc a at Leerdam (see Figs. 30c, 31a and 31b).
Archeological finds (C-14 dated) on the stream ridge itself indicate that the Schoonrewoerd stream at Molenaarsgraaf had already been filled up and become a stream ridge in the middle-Subboreal, namely c. 3800 BP (LOUWE KOOIJMANS 1974, p. 97 and table 6). From the position of the finds on the depth-contour maps of the stream ridge (ibid., figs. 57, 58 and 60), it appears that these finds do not just relate to the natural levees of the formerly active river, but definitely to the whole stream ridge (which comprises both the sanded up channel and the former levees).
The sedimentation in the remaining part of the middle- and late-Subboreal depositional phase may be related to the inundations supposed by LOUWE KOOIJMANS as explanations for the 'break-through channels' in the Schoonrewoerd stream ridge (ibid., p. 100 f.). These inundations must have been brought about by rivers situated outside the study area. The fluvial activity in these break-through channels ends at Molenaarsgraaf c. 3350 BP and at Culemborg (c. 5 km NE of the Leerdam study area) c. 2350 BP at the latest (ibid., p. 111, see also fig. 18). Agreeing with these dates are our dates for the end of the middle- and late-Subboreal depositional phase (3340 ± 80 BP at Molenaarsgraaf and 2650 ± 70 BP at Leerdam; see Figs. 27 and 30b). LOUWE KOOIJMANS' dating GrN 6212: 3630 ± 35 BP for the end of the clay deposition on the flank of the Hazendonk river dune (ibid., p. 140) relates in our opinion to just this inundation and clay deposition, after the filling of the Schoonrewoerd stream; in this marginal location near the river dune the sedimentation ended earlier than at the standard boring. The dates GrN 5219: 2880 ± 35 BP at Zijderveld (DE JONG 1970-71, p. 83) and GrN 787: 2820 ± 75 BP at Goudriaan (VERBRAECK 1970, fig. 43; see also above) also refer to the end of this phase. Moreover, all these dates make it clear that there is an important diachrony with regard to the end of the middle- and late-Subboreal depositional phase: in the western part of the region the deposition ended c. six centuries earlier than in the eastern part.

Some relations to upstream regions

In the Betuwe, part of the central-Netherlands river-clay area and situated c. 40 km upstream of Leerdam, HAVINGA (1969) distinguished a vertical sequence of four clastic (clay) deposits. On the basis of archeological dates (op. cit., p. 27) he concluded that the lower two deposits were formed before c. 3800 BP, possibly before 3300 BP in part of the study area. These dates can be related to the middle- and late-Subboreal depositional phase distinguished here. Moreover, the 3800 BP date coincides with the filling of the Schoonrewoerd stream at Molenaarsgraaf (see above).

In the 'Land van Maas en Waal' situated further upstream, PONS (1957) has practically no dates on Atlantic and Subboreal clay deposits. But in a general discussion of the deposits in the central Netherlands river-clay area, he concludes, with reference to MODDERMAN's (1955) archeological dates, that the period of rather intensive occupation from c. 3800 to c. 2800 BP (Bronze age mainly) was a period of decreased fluviatile activity. So again the date 3800 BP is mentioned here as the end of a period of intensive fluviatile sedimentation. Comparison with LOUWE KOOIJMANS' (1974) figs. 7 and 8 also shows that the central Netherlands river-clay area was occupied in the Bronze age more intensively than in the preceding period.

The only study known to us of a phasing of Holocene fluviatile activity in the far hinterland is by BECKER & SCHIRMER (1977) on the paleoecology of the Main valley (Southern Germany). On the basis of among others C-14 dates on oak trunks occurring in the fluvial deposits they established increased fluviatile activity in the middle-Atlantic, the Subboreal and another four periods starting from the Iron/Roman age. The Main represents only a small part of the fluvial hinterland, and according to BECKER (1980, p. 35) various aspects of several river systems should be compared in order to be able to reconstruct the Holocene fluvial activity in the broader region. Nevertheless, a preliminary comparison with at least the middle-Atlantic depositional phase discerned in our study can be made. Thus, notwithstanding the uncertainty attached to correlating over so large a distance, the strong fluviatile depositional activity in our study areas during the middle-Atlantic might somehow be connected to increased fluvial activity in the hinterland (see also Ch. Ve).

IVe CORRELATIONS BETWEEN FLUVIATILE AND MARINE DEPOSITIONAL PHASES

Several of the authors referred to in Ch. IVd in connection with the chronology of the fluviatile depositional phases, assume or conclude a certain synchrony of these phases with the marine transgressive phases. As these transgressive phases have been distinguished on the basis of deposits — namely the alternation of clay- and peat beds —, they may be called marine depositional phases as well. Because of the assumed synchrony, HAGEMAN (1963, p. 219) extrapolated the marine depositional phases Calais I, II, III and IV and Dunkerque 0, I, II and III to the perimarine fluviatile area, and distinguished there as fluviatile equivalents the phases Gorkum I, II, III and IV and Tiel 0, I, II and III. In a later publication a hypothesis was given regarding the mechanism that could have caused this synchrony (HAGEMAN 1969, p. 380 f.); we shall return to this in Ch. Ve.

The Gorkum-/Tiel-terminology has also been used by VERBRAECK (1970) and ZAGWIJN & VAN STAALDUINEN (1975). In a purely geochronological respect it involves only a renaming of the Calais-/Dunkerque-terminology, and thus one might confine oneself only to the latter (as LOUWE KOOIJMANS, 1974, did), in a discussion on the perimarine fluviatile depositional phases.

The marine depositional (transgressive) phases in the period of the Atlantic, Subboreal and early-Subatlantic, to which the fluviatile depositional phases shown in Fig. 32 should be compared, are as follows:

2050-2550 BP: Dunkerque I
2950-3450 BP: Dunkerque 0
3750-4550 BP: Calais IV
4750-5250 BP: Calais III
5250-6250 BP: Calais II
6450-7950 BP: Calais I

The chronology has been established by HAGEMAN (1969) for the Western Netherlands coastal plain. ZAGWIJN & VAN STAALDUINEN (1975, p. 111) suggested some minor alterations to this scheme; however these are not essential for a comparison of the marine and fluviatile depositional phases. No publications have appeared which incorporate an important revision of the chronological scheme for the Western Netherlands. It should be noted that the Calais IV phase is often subdivided into IVa and IVb; the regressive interval between them can be placed in the period 4300-4100 BP (cf. LOUWE KOOIJMANS 1974, fig. 10, summarized from various sources).
As already established in a preliminary publication of C-14 dates from our study at Molenaarsgraaf (VAN DER WOUDE 1979, p. 283), the older Calais phases in particular do not correlate well with the fluviatile depositional phases. During the middle-Atlantic depositional phase (see Fig. 32) the stronger clastic sedimentation occurred in the later part of the phase, namely from c. 6450-6100 BP. This is the very period in which the marine regressive phase between the transgressive phases Calais I and II has been observed. The subsequent period of organic deposition in the fluviatile area (c. 6100-5300 BP, see Fig. 32) coincides with the marine transgressive phase Calais II.
On the other hand HAGEMAN's scheme of the marine transgressive and regressive phases may of course show regional variations; hence the depositional chronology of the perimarine fluviatile region distinguished here might mirror such a regional variant. To check this possibility, all published C-14 dates that refer to the marine depositional chronology up to 2500 BP in the seaward foreland of our study area have been collated in Table 11. This foreland area has been defined rather broadly, namely from the island of Schouwen (prov. of Zeeland) up to Haarlem (prov. of Noord-Holland). All the dates relate to samples from peat beds between or on top of marine clay beds and therefore should fall in the regressive phases (at least the phases of non-clastic sedimentation) of HAGEMAN's scheme. Basal-peat samples are left out of consideration. To a certain extent groups of dates can be discerned in the table. The first group of only three dates comprises the period from c. 6400 to c. 6300 BP and may confirm the regressive interval between the transgressive phases Calais I and II. The second group, from c. 5500 to c. 5200 BP indicates the end of the Calais II phase. The third group, from c. 4900 to 4700 BP, will largely relate to the end of the Calais III phase, and the fourth group (c. 4400-4200 BP) might relate to the regressive interval Calais IVa/IVb. The younger dates show less clear groupings.
It may be concluded that the marine depositional phases in the foreland of our study area fit reasonably well with HAGEMAN's scheme of the Calais transgressive phases. This confirms that a comparison of the fluviatile depositional phases with the Calais phases is valid.
In connection with the negative correlation of the marine depositional phase Calais II and the fluviatile depositional phases, it is interesting to examine in some detail mapping results published by VERBRAECK & BISSCHOPS (1971) on a transitional area between the marine and the perimarine areas (sheet 43 Oost of the Geological map of the Netherlands 1:50000, its centre lying c. 35 km SW of Molenaarsgraaf). In the western part of this area, at about 5-6 m below N.A.P., they found deposits everywhere of marine clay and sand many meters thick. At the top, these deposits were dated as

Table 11. C-14 dates published of peat beds intercalated between or situated on top of marine clay beds in the Western Netherlands coastal plain, between Schouwen island and Haarlem.

GrN No.	C-14 age BP	Locality	Reference	Lithology/ Stratigraphy
6501	6410 ± 65	Schipluiden II	Van Staalduinen 1979	peat bed
639	6330 ± 150	Honselersdijk	Jelgersma 1961	peat bed
1620	6320 ± 70	Nieuwe Wetering	ibid.	peat bed
2268	5930 ± 80	Nootdorp	Zagwijn 1965	peat bed
6497	5470 ± 60	Schipluiden I	Van Staalduinen 1979	base of peat bed
2849	5460 ± 50	Mijdrecht	Riezebos & Du Saar 1969	peat bed
5918	5435 ± 60	Zuid-Beyerland	Verbraeck & Bisschops 1971	base of gyttja bed
1143	5420 ± 60	Zuidland	Jelgersma 1961	base of peat bed
6500	5270 ± 60	Schipluiden II	Van Staalduinen 1979	base of peat bed
222	5200 ± 120	Willemstad I	Jelgersma 1961	base of Upper Peat
3566	4970 ± 75	Vijfhuizerpolder	Riezebos & Du Saar 1969	peat bed
1622	4880 ± 80	Alphen	Jelgersma 1961	base of Upper Peat
3563	4820 ± 100	Beinsdorp	Riezebos & Du Saar 1969	peat bed
2852	4805 ± 60	Bovenkerkerpolder	ibid.	base of Upper Peat
2857	4800 ± 75	Duivendrechterpolder	ibid.	base of Upper Peat
1139	4780 ± 80	Zuidland	Jelgersma 1961	top of peat bed
238	4765 ± 130	Willemstad II	ibid.	base of Upper Peat
1648	4740 ± 60	Nieuwerkerk	Van Rummelen 1970	base of peat bed
6495	4685 ± 60	Schipluiden I	Van Staalduinen 1979	base of peat bed
2267	4670 ± 65	Rijswijk	Zagwijn 1965	base of Upper Peat
3565	4530 ± 90	Vijfhuizerpolder	Riezebos & Du Saar 1969	base of Upper Peat
2119	4515 ± 45	Nieuwe Wetering	Jelgersma 1961	base of Upper Peat
5016	4490 ± 55	Aalsmeer	Riezebos & Du Saar 1969	base of Upper Peat
6499	4405 ± 65	Schipluiden II	Van Staalduinen 1979	base of peat bed
1142	4400 ± 80	Zuidland	Jelgersma 1961	base of Upper Peat
2858	4390 ± 60	Tolhuis Bilderdam	Riezebos & Du Saar 1969	base of Upper Peat
1098	4380 ± 75	Lodderland	Jelgersma 1961	base of peat bed
1646	4360 ± 60	Nieuwerkerk	Van Rummelen 1970	base of peat bed
633	4350 ± 130	Honselersdijk	Jelgersma 1961	base of Upper Peat
3552	4300 ± 80	Beinsdorp	Riezebos & Du Saar 1969	base of Upper Peat
1036	4295 ± 55	Prunjepolder I	Jelgersma 1961	base of Upper Peat
6494	4290 ± 60	Schipluiden I	Van Staalduinen 1979	base of Upper Peat
1035	4280 ± 55	Prunjepolder II	Jelgersma 1961	base of Upper Peat
256	4250 ± 150	Willemstad III	ibid.	base of Upper Peat
1136	4195 ± 55	Renesse	ibid.	base of Upper Peat
315	4130 ± 130	Heenvliet	ibid.	base of Upper Peat
310	4085 ± 150	St. Philipsland	ibid.	base of Upper Peat
202	3985 ± 170	Schiedam	ibid.	base of Upper Peat
286	3820 ± 180	Hekelingen	ibid.	base of Upper Peat
4935	3680 ± 40	Overveen	Jelgersma et al. 1970	base of peat bed
159	3145 ± 150	Vredenheim	Jelgersma 1961	base of peat bed
4933	3010 ± 80	Beverwijk	Jelgersma et al. 1970	base of peat bed
1095	2900 ± 60	Lodderland	Jelgersma 1961	base of peat bed
6498	2795 ± 50	Schipluiden II	Van Staalduinen 1979	base of peat bed
1094	2645 ± 65	Lodderland	Jelgersma 1961	top of peat bed

Calais II. The marine clay- and sand deposits pass eastwards into 'mudclay', regarded by them as fluviatile. The authors conclude from this that during the marine transgressive phase Calais II increased deposition also occurred in the perimarine fluviatile area, in agreement with HAGEMAN's scheme and extrapolation (see above). This would be in contradiction to our negative correlation between the marine Calais II and the fluviatile depositional phases. However, in the NE part of the mapped area, within this mudclay (described lithologically as peaty clay and even clayey peat) sandy channel fills of rivers whose activity had stopped before the end of the marine Calais sedimentation (ibid., p. 55) occur. In our opinion it is not unlikely that these channel fills belong to the same fluvial system as the middle-Atlantic ones (lithostratigraphic unit cl 2) at Molenaarsgraaf. If the channel fills occurring within the (peaty!) mudclay do indeed indicate a middle-Atlantic period of increased fluvial activity, then this would contradict to some extent the positive correlation, as put forward by the authors, between increased marine (Calais II) and increased perimarine fluviatile sedimentation.

The late-Atlantic/early-Subboreal fluviatile depositional phase in both study areas (Molenaarsgraaf and Leerdam) involves a generally discontinuous, strongly organic clay deposit, without clear stream ridges. This phase, in its later part, coincides with the marine transgressive (depositional) phase Calais III.

During the middle- and late-Subboreal fluviatile depositional phase, the strongest sedimentation in both study areas occurred from c. 4100 BP (see Ch. IVb.1) to c. 3800 BP (see Ch. IVd). This period is practically synchronous with the marine transgressive phase Calais IVb. The preceding sedimentation of clastic bed uc a at Leerdam, from c. 4600 to c. 4300 BP (see Fig. 32) coincides with the Calais IVa phase.
Thus there is a positive correlation between certain parts of the late-Atlantic/early-Subboreal and the middle- and late-Subboreal fluviatile depositional phases on the one hand and the marine transgressive (depositional) phases Calais III and IV on the other. Yet there is also a complication. During the period of the marine transgressive phases Calais III, IVa and IVb, the strongest sedimentation in our fluviatile study areas occurred during the phase Calais IVb. In the marine foreland this is reversed: there the phases Calais III and IVa were the most important sedimentation phases (see e.g. RIEZEBOS & DU SAAR 1969, figs, 1 and 2; BOSCH & PRUISSERS 1978, fig. 1).
As mentioned before, the end of the middle- and late-Subboreal fluviatile depositional phase is highly diachronous throughout the perimarine area, at least from the Molenaarsgraaf up to the Leerdam study area. So here a comparison with the marine transgressive phases (the late-Subboreal Dunkerque phases) may be of limited value only. A more extensive evaluation of dates in this younger period in the fluviatile perimarine regional history may be expected from BERENDSEN (in prep.).
Some of the observations and conclusions made in this chapter about the regional chronostratigraphy are briefly discussed in a paleoenvironmental context in Ch. Ve.