I Introduction

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I INTRODUCTION

Ia THE PERIMARINE FLUVIATILE COASTAL PLAIN OF THE WESTERN NETHERLANDS

The Holocene geology of the Western Netherlands coastal plain (for location, see Fig. 1) has been studied for many decades. As well as its beach barrier-, dune- and lagoonal/estuarine/tidal flat deposits, research has included its fluvial and organic deposits. Literature reviews have been given by among others DE JONG (1971), LOUWE KOOIJMANS (1974) and ZAGWIJN (1974). Traditionally, the emphasis in the research has been on the marine deposits, but increasing attention has been paid to the fluvial (and related organic) deposits. This study aims to contribute to the last-mentioned development. Before discussing the detailed aims of this study (see Ch. Ib), a short outline of the geological history of the fluvial part of the Western Netherlands coastal plain is given here with reference to the most relevant literature (PONS & BENNEMA 1958, HAGEMAN 1969, VERBRAECK 1970, 1974 and LOUWE KOOIJMANS 1974; older sources, like STEENHUIS, VINK and PANNEKOEK VAN RHEDEN have been largely quoted herein). Most subjects in this outline will be dealt with in more detail in subsequent chapters.

The sedimentary basin

The Western Netherlands coastal plain forms part of the Quaternary sedimentary North Sea basin. During the Weichselian glacial age coarse sands were deposited in this area by the then braided rivers Rhine and Meuse. Where, towards the end of the Weichselian, the rivers Rhine and Meuse were still active — and this roughly coincides with their present-day position — a thin, nearly continuous bed of clayey material was deposited on top of these coarse sands. This top layer varies texturally from clayey sand to sandy clay and is often referred to as (the) *loam* (see e.g. ZAGWIJN & VAN STAALDUINEN 1975, p. 25). On top of this substratum of coarse sands and *loam* many river dunes have been found; where these have not been completely buried by younger sediments, the outcropping, topmost parts of them are locally known as *donken*. For the *loam* and the river dunes in the Western Netherlands coastal plain, the Late-Weichselian as well as the early-Holocene are mentioned as periods of deposition (see also Ch. IVc).
From the beginning of the Atlantic period, extensive clastic and organic accumulation occurred in this fluvial sedimentary basin, as well as in the whole coastal plain. The vertical space for this was offered by the rise of the water table under the influence of the Holocene sea-level rise.

Depositional cyclicity

In the fluvial part of the Western Netherlands coastal plain — mostly in the central part of it, in the region of the lower courses of the rivers Rhine and Meuse —, a pronounced cyclicity in the Holocene deposits has been observed. There is a manifold vertical repetition of river-clay beds and peat- (and gyttja-)beds. The clay beds are connected laterally to many sandy channel fills. These, together with their natural levees, are situated at a less lower depth than the corresponding clay beds, partly as a consequence of differential compaction; they are hence called 'stream ridges'. This morphological term refers equally to those channel fills that are visible as low ridges in the present-day scenery as to the completely buried ones (see among others VERBRAECK 1970, p. 59).
The cyclic sequence of river-clay- and peat beds is supposed by most authors to be litho- and chronostratigraphically largely the same throughout the region and to be correlative with the sequence of clay- and peat beds in the marine part of the coastal plain. The phases of increased marine depositional activity (mostly referred to in the literature as the transgressive phases) are thought to

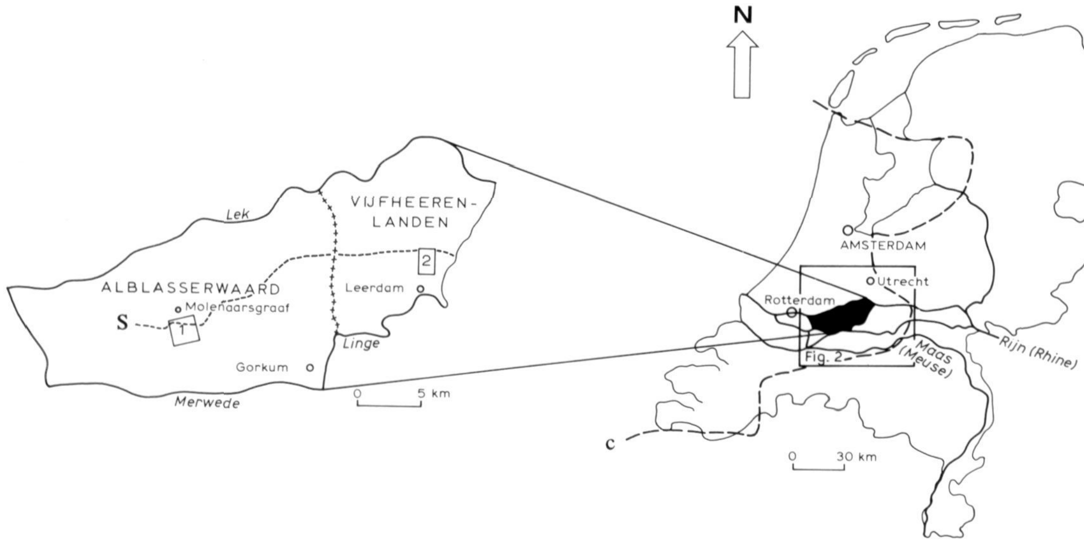

Fig. 1. Location of study areas. 1 = Molenaarsgraaf study area, 2 = Leerdam study area. Line c = schematic landward boundary of Western Netherlands coastal plain. Line S = approximate course of Schoonrewoerd stream ridge.

correspond to phases of increased fluvial deposition in the coastal plain, either as a consequence of a direct or of an indirect causal relationship. In the latter case a climate effect is envisaged, e.g. increased cyclonic activity. In the case of a direct relationship a mechanism involving damming up of river water as a result of shortening of the lower river courses by marine transgression is proposed by HAGEMAN (1969).

The relation of the depositional history in the marine part of the coastal plain to that in the fluvial part of it deserves in our opinion considerable research and discussion (see e.g. Ch. IVe). The earlier mentioned general relation, namely the Holocene sea-level rise as the cause of the general rise of the water table and so the increase of the vertical depositional space in the fluvial part of the coastal plain, is however unquestionable. In the filling of this vertical space not only fluvial sediment but also peat is involved, and beyond the depositional reach of the rivers and the sea peat alone may occur. HAGEMAN (1969) introduced the term 'perimarine area' for the inland part of the coastal plains incurring this deposition of fluvial sediment and peat under the influence of the Holocene sea-level rise. His definition of the term ('the area where the sedimentation or sedentation took place under the direct influence of the relative sea-level movements but where marine or brackish sediments themselves are absent', op. cit., p. 377) mirrors not only the general relation to the Holocene sea-level rise but also the more specific direct relation to marine transgressions. This last notion puts, to our opinion, too much interpretation in the definition. For the time being, we would restrict the term 'perimarine (area)' to the more general relation, and, for the region of this study, combine it with the more descriptive term 'fluviatile coastal plain' (SELLEY 1978, p. 13). The **perimarine fluviatile coastal plain** is therefore that part of the Holocene coastal plain, where, because of the sea-level rise, extensive accumulation of fluviatile clastic and related organic material could occur.

The term perimarine fluviatile coastal plain refers to genetic aspects. The thus defined area is not simply outlined in the present embanked and cultivated landscape. Its seaward boundary may have been subject to shifts during the Holocene. The term also includes the so-called river clay/wood peat region discerned by LOUWE KOOIJMANS (1974). Fig. 2 outlines its surface geology.

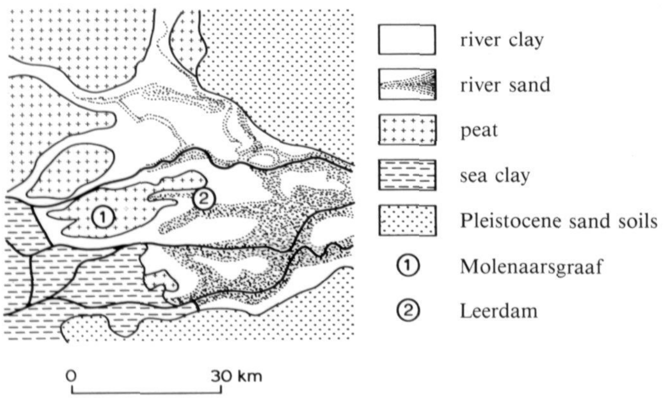

Fig. 2. Fragment of Soil map of the Netherlands, scale 1:200000 (simplified and greatly reduced in scale here). For location, see Fig. 1.

Prehistoric occupation and paleoecology

The river dunes (*donken*) and the stream ridges appear to have been suitable places for prehistoric occupation (LOUWE KOOIJMANS 1974). These high, dry sites amidst the swampy environment were often occupied during a large part of the Holocene. There seems to be a phasing in the prehistoric occupation, related to changes in the geological environment. As at the coast itself prehistoric occupation seems to have occurred mainly during phases of decreased marine depositional activity (mostly referred to in the literature as the regression phases), so in the perimarine fluviatile coastal plain the same seems to hold for phases of decreased fluvial activity.
Little is known about the paleoenvironments of the perimarine fluviatile coastal plain. Paleoecological studies of terrain surrounding archeological excavations have produced valuable information (see e.g. VAN REGTEREN ALTENA et al. 1962, 1963, DE JONG 1970-71, LOUWE KOOIJMANS 1974), but are restricted areally. The scarce, more regionally directed conclusions from these studies have not yet given a coherent picture of the paleoenvironments and their evolution during the Holocene.

Ib AIM AND FRAMEWORK OF THE INVESTIGATION

This study aims mainly at a relatively detailed reconstruction of the former Holocene landscapes of the area surrounding the Hazendonk, a small, almost completely buried river dune in the perimarine fluviatile coastal plain (for location, see Figs. 1 and 3). During the Atlantic and Subboreal periods this river dune had many phases of prehistoric occupation (LOUWE KOOIJMANS 1974, 1978); a request to supply the archeological investigators at the Hazendonk with a detailed geological map of the area, formed the direct inducement for this study, undertaken by the present author at the Institute of Earth Sciences, Free University, Amsterdam, from 1977 (after a preparatory field work in 1976 by others, see below). The study has been directed in such a way that this mapping around the Hazendonk is the basis of a case-study of the geological and paleoenvironmental evolution of the perimarine fluviatile coastal plain in a more regional sense. The Hazendonk river dune is situated in the centre of the region called the Alblasserwaard (prov. of Zuid-Holland; see Fig. 1). The geology of the Alblasserwaard may be regarded as representative of a large part of the perimarine fluviatile coastal plain; consistent with this is the fact that the Geological Survey has named the Alblasserwaard as the type area of the Holocene perimarine deposits (ZAGWIJN & VAN STAALDUINEN 1975, p. 47). In view of the strong differentiation in the geological structure of the

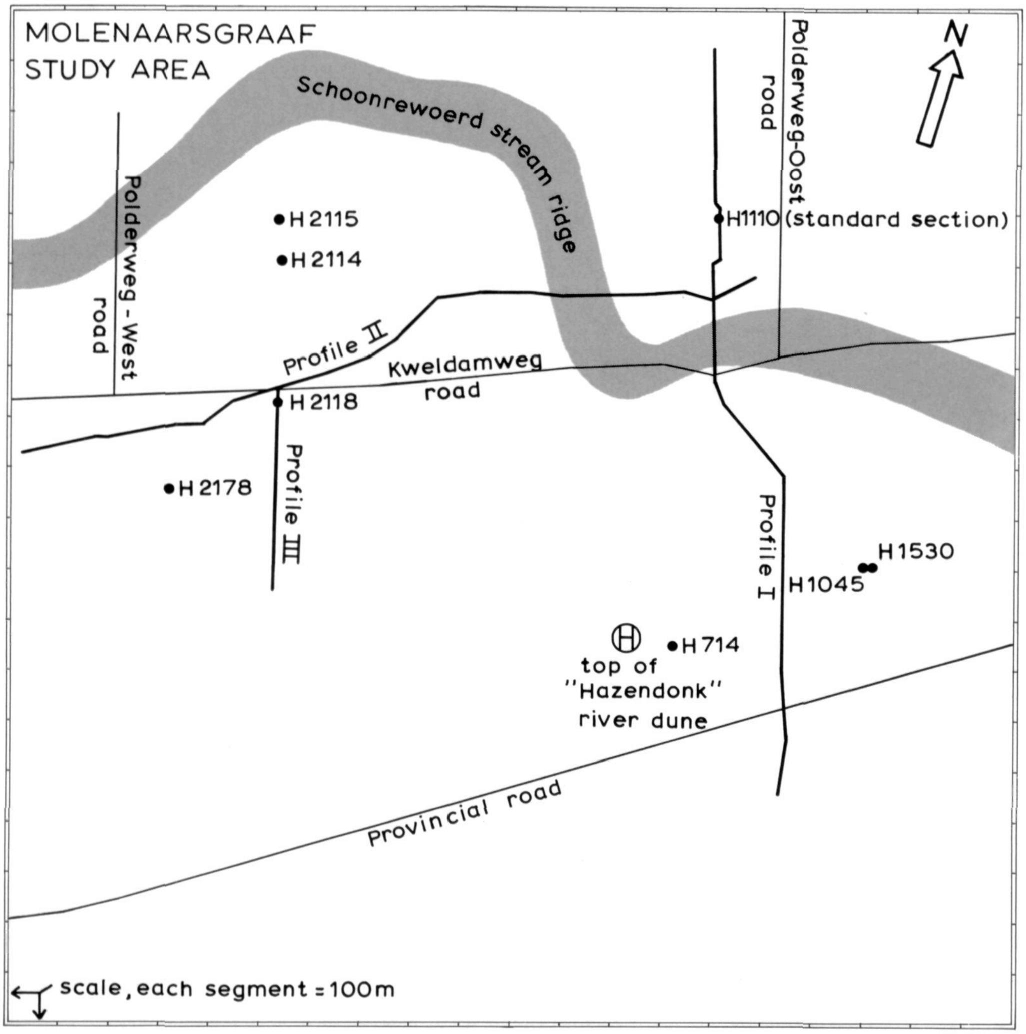

Fig. 3. Location of pollen- and C-14 borings and of selected profiles, Molenaarsgraaf study area.

perimarine fluviatile coastal plain, the detailed mapping facilitates a more fundamental reconstruction of the former landscapes and insight in their genesis than could formerly be achieved for this specific environment. For thematical problems concerning the litho- and chronostratigraphy, this detailed case-study may be regarded as complementary to the more regional approach as used among others by the Geological Survey for the preparation of the Geological map of the Netherlands, scale 1:50000 (see e.g. VERBRAECK 1970). The case-study area at the Hazendonk is referred to in the text as the Molenaarsgraaf study area (after the nearest community, see Fig. 1); in the figures in Ch. V it is also indicated as csa 1.

To facilitate the reconstruction of the former landscapes, the aim is to integrate the detailed geological mapping with elaborate paleobotanical research. This integration facilitates the use of the term **paleoenvironment** for the former landscape, mainly with respect to its geological-sedimentological environment and its vegetation. This combined, paleoecological approach is the main aspect of the framework of this study. Another important aspect is the establishment of the detailed chronology of the evolution of the paleoenvironment. This has been done for the sake of comparison with the

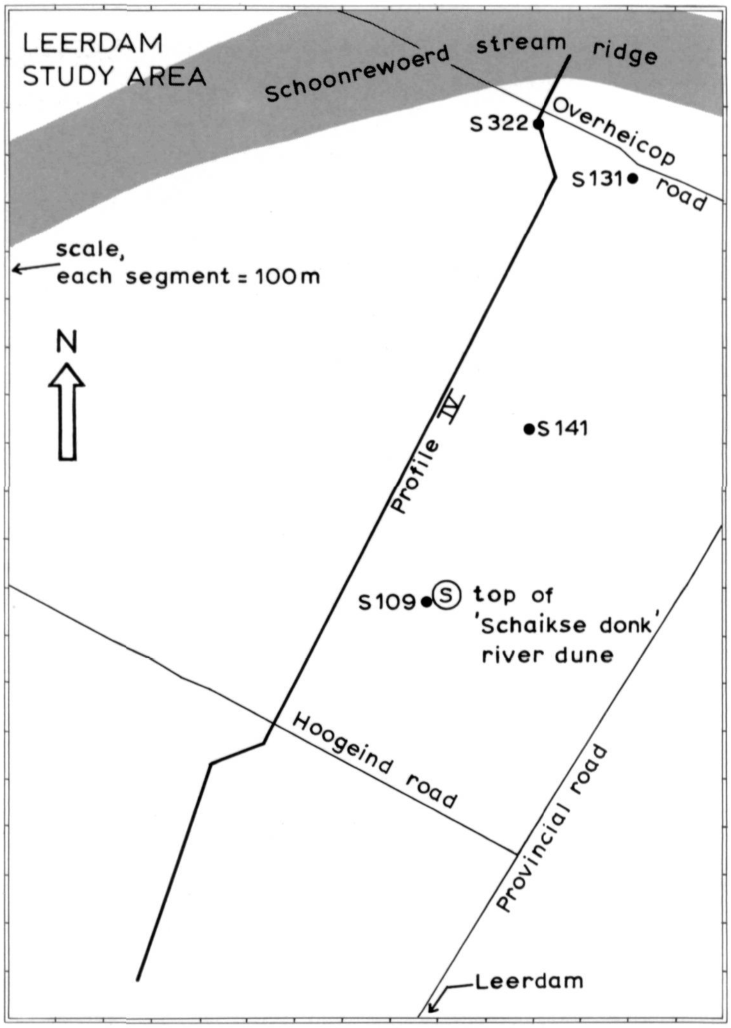

Fig. 4. Location of pollen- and C-14 borings and of selected profiles, Leerdam study area.

prehistoric occupation of the area as well as with the geological history of other parts of the coastal plain and of upstream areas.

Apart from the main case-study area (the Molenaarsgraaf study area), a second one has been chosen, mainly to give a broader regional scope to the geological history and partly also to the paleoenvironmental evolution. This second case-study area is situated near Leerdam (prov. of Zuid-Holland, see Fig. 1), c. 20 km to the east of Molenaarsgraaf, and thus upstream in the fluviatile coastal plain. The choice of this area (called the Leerdam study area, or csa 2) was determined in the first place by the presence of a river dune (the 'Schaikse donk'; see Fig. 4), comparable to the Hazendonk. In the second place, the new geological map 1:50000 that is available for this particular region (sheet 38 Oost; VERBRAECK 1970) shows in the immediate vicinity of the Schaikse donk river dune three stream ridges of partly different age. One of these, the so-called Schoonrewoerd stream ridge, is traceable down to the Molenaarsgraaf study area (see Fig. 1). Presumably, the Schaikse donk river dune also underwent some phases of prehistoric occupation (LOUWE KOOIJMANS 1974, fig. 18).

The study of this second area is less comprehensive than that of the Molenaarsgraaf area, as regards both the geological mapping and the paleobotanical research. In all respects, the emphasis in this study is on the Molenaarsgraaf area.

Ic METHODS

Detailed geological mapping

The geological field data were all obtained by means of hand borings, with the use of gouge-augers measuring c. 3 cm in diameter. Because the groundwater surface is only some dm deep, generally the whole boring profile could be gouged in undisturbed state.
In the larger part of both areas the borings have been placed at intervals of c. 80 m and in parallel rows; also the distance between the rows is usually c. 80 m (see Figs. 33 and 34). The resulting large density of this general boring grid (c. 150 borings per square km) became apparent early in the field study because of the complex stratigraphy and the short distances of the lateral facies changes. For several specific problems the distances between the borings were considerably smaller, especially so along the rather steep flanks of the central river dunes in both areas. Thus, along the border of the Hazendonk river dune c. 500, mostly shallow borings were placed at intervals of 2 to 5 m during the preparatory field work in 1976, mainly for the sake of pursuing stratigraphically the archeological levels (VAN DIJK et al. 1976).
The mapped surface amounts to c. 3 square km in the Molenaarsgraaf area and to c. 2 square km in the Leerdam area. The boring numbers have the prefixes H- and S- for both areas respectively. The total number of borings amounts to c. 1350 at Molenaarsgraaf (including c. 800 borings of the preparatory field work in 1976) and to c. 500 at Leerdam.
Where possible, the borings have been gouged down to the sand- and *loam*-subsoil that forms the basement of the Holocene sequence of clay- and peat layers. In most cases where this could not be achieved, the borings ended in a sandy Holocene channel fill. Outside the river dunes, the sand-subsoil lies on the average c. 9 to 9.5 m below the surface in the Molenaarsgraaf area and c. 5 to 7 m in the Leerdam area.
The aim of the investigations required not only a relatively large boring density, but also a detailed description of the stratigraphy of the bores. Most of the features discerned in the bored material appear in the legend units in Figs.* 9 (Ch. II) and*35 (Ch. V). The discrimination between the various units listed therein, and the quantitative indication of some features all proceeded in the field, without laboratory methods. For example, the discrimination between peaty clay and clayey peat was established by visual estimation of the relative abundance of clay and of plant remains and also by rubbing the material between the fingers. In processing the bore descriptions in order to construct the profiles and maps, a lower level of precision than present in the field descriptions was selected; this increases the reliability of the profiles and maps.
Discerned features that area not listed in Figs.*9 and*35 but nonetheless have played a role in the processing and interpretation of the boring results include among others colour, calcium carbonate content, occurrence of charcoal, occurrence of snail shell remains, and degree of gradualness of vertical lithological changes.

Paleobotanical analysis and C-14 dating

In both case-study areas a number of borings has been selected for paleobotanical analysis and C-14 dating (for location, see Figs. 3 and 4). These borings have been sampled by means of a gouge-auger, 5 cm in diameter. Among them, the standard boring of the Molenaarsgraaf study area (boring H1110) is one of primary interest. In this boring all distinguished lithostratigraphic units (see

Ch. II) are present with the exception of the river-dune sand. The complete section (over 9 m) has been sampled for pollen analysis, and for the larger part of it fruit analysis has also been undertaken. The organic deposits have been sampled continuously per cm, the clay deposits with sample intervals of 5 cm. At all important lithostratigraphic transitions in this boring C-14 samples have been taken.

The other selected borings are intended mainly as support for and supply to this standard boring and therefore have been sampled only partially for pollen analysis and C-14 dating.

The preparation of the pollen-, fruit- and C-14 samples is discussed in the relevant chapters (IIIb and IVb.1). The full pollenanalytic results of the standard boring (Molenaarsgraaf H1110) and of a boring in the Leerdam study area are presented in diagrams (Figs. *12 and *15), drawn by a computer-directed laser plotter; see VELDKAMP et al. for an explanation of this technique. The results of some of the remaining pollenanalytically investigated borings are presented in somewhat simplified diagrams, drawn by a conventional computer-directed ink plotter (see App.). Moreover, the results of all pollen sections have been presented in simplified tables.

Computer maps and landscape-reconstruction drawings

All boring data have been processed for computerized map constitution of thickness and several other characteristics of most of the distinguished lithostratigraphic units (see e.g. Figs. 41 and 42). For this purpose, the boring data were lithostratigraphically interpreted and uniformly coded as regards the diverse characteristics distinguished. Where boring sites occur in very dense concentrations, as at the foot of the Hazendonk river dune, for the sake of clarity only a limited number of them has been presented on the computer maps. These maps have been drawn, as were the main pollen diagrams (see above), by a laser plotter at the Mathematical Centre, Amsterdam. The computer has been involved not so much in computations, but more for the directing of the plotter.

The ultimate integration of the geological and paleobotanical results and the resultant reconstruction of the paleoenvironments, has been visualised in three-dimensional landscape pictures (drawn by drs. D. P. Ooijevaar) for four times in the Holocene history of the Molenaarsgraaf study area (see e.g. Fig.*43).