C17

SOUTHERN SHORES OF THE NORTH SEA (CONTINENTAL EXCURSION)

R.Paepe

1977

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Guidebook for Excursion C17

SOUTHERN SHORES OF THE NORTH SEA (CONTINENTAL EXCURSION)

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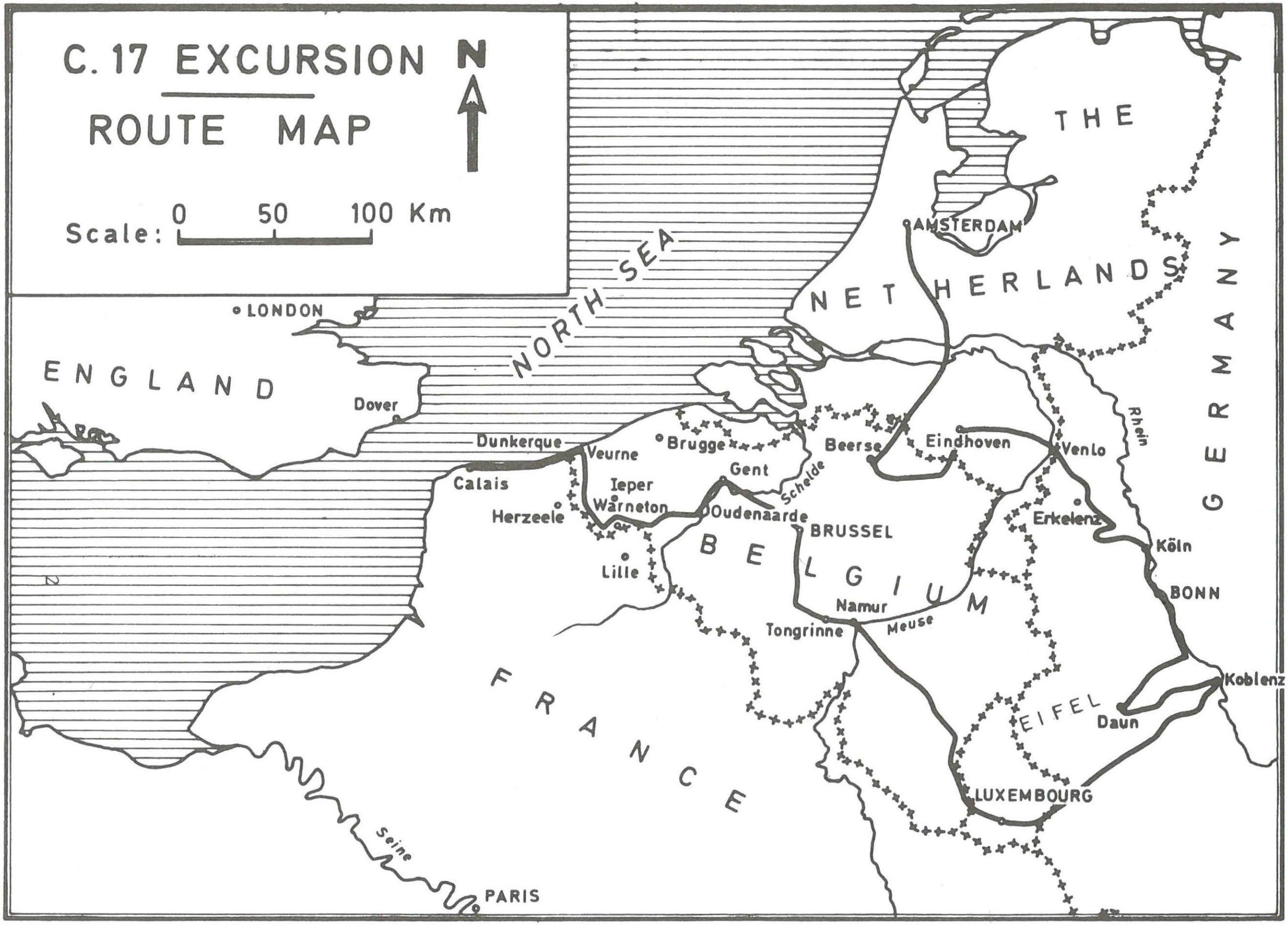

Fig. 1 MAP (Route and Sites)

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GENERAL INTRODUCTION TO THE QUATERNARY OF THE EXCURSION AREA

During this excursion the southern part of the North Sea Basin and its surroundings will be studied on the European continent from the point of view of the Quaternary.

The southern North Sea Basin which coincides in part with the Netherlands, contains Quaternary sediments which range up to several hundreds of meters in thickness. It was an area of subsidence, whereas its surroundings were rising. Such was the case with the 'Rheinisches Schiefergebirge' between Koblenz and Bonn, the Ardennes and the Artesois-Downs area in the south. Consequently the stratigraphic equivalents of horizons deeply buried in the central part of the basin may be found as river terraces in the uplifted areas.

The Quaternary sediments were for the greater part laid down in a coastal area. They were deposited either in a shallow sea or in coastal swamps, lagoons and lower river reaches: that is, slightly below or above sea level. At present, however, they are often found at a considerable depth, e.g. as deep as 400 to 600 m. Since the beginning of the Quaternary such sedimentation has kept pace with the rate of downwarping.

On the other hand, the surrounding areas which were close to sea level at the end of the Tertiary have subsequently been uplifted by several hundred metres.

To some extent the basin was filled by sediments brought in from the North Sea but most, however, came from the land by rivers. Heavy mineral and gravel analyses show that the rivers Rhine and Meuse provided a substantial supply of sediments. Moreover, in the northern half of The Netherlands substantial amounts of Lower Pleistocene and Lower Middle Pleistocene sediments were deposited by rivers of North German provenance. These also had tributaries from the Scandinavian Shield and their courses differed from present ones. In general they flowed west to the North Sea in the area presently occupied by the northern Netherlands. In the lower part of the Lower Pleistocene, marine sedimentation was still wide-spread in this part of the basin. Later on, however, both in the Lower Pleistocene and greater parts of the Middle Pleistocene the sea regressed and fluviatile sedimentation took over. After the later part of the Middle Pleistocene the sea invaded the present coastal areas of The Netherlands during interglacial high stands of sea level, but during glacial low sea level stages the greater part of the present North Sea floor was land.

During these interglacials, and the Holocene, the coastal areas of the Netherlands, Belgium and northern France (probably by way of the Straits of Dover) were inundated by marine transgressions.

Other sediments in the basin were deposited on several occasions by the Scandinavian Ice Sheet although during the Weichselian it failed to reach the area.

A characteristic feature of the southern part of the North Sea basin is that it is crossed by a system of SE-NW running faults, which continue towards the SE into the Lower Rhine embayment to the vicinity of Bonn. The Lower Rhine embayment, bordered by areas where Mesozoic and Palaeozoic rocks occur at or near the surface has subsided during the Tertiary, since Oligocene times, and has continued this subsidence in the Quaternary. The most striking tectonic feature of the basin is the Peel Horst extending from Erkelenz (Germany) in the south-east to Utrecht in the north-west. It is flanked by two Graben areas, the Central Graben in the south and the Venlo Graben in the north. The latter extends towards the Zuiderzee Basin. In the Lower Rhine district of Germany a deep Graben, the Roer Valley Graben is situated in the continuation of the Central Graben of The Netherlands. To the east it is flanked by the 'Erftscholle', an inclined tectonic block filled by substantial thicknesses of Upper Tertiary and Quaternary sediments. This tectonic block is bordered by another horst-like structure, the Ville-block.

As to the areas surrounding the southern part of the North Sea basin, several other features are of special interest during the Quaternary. In the first place the cutting of river valleys, bordered by terrace systems should be mentioned. In particular the valleys of the rivers Rhine and Meuse are of importance, the first mentioned one forming a link between the Alpine area of glaciation and the Scandinavian one. The study of the terrace deposits of the river Rhine therefore is of particular interest to Quaternary stratigraphy.

Secondly the volcanic activity of the Eifel area, bordering the Rhine Valley to the west, during the upper half of the Quaternary is a special feature of this region. The study of the volcanic rocks produced during these times and the presence of volcanic materials in fluvial and eolian deposits of Quaternary age offers possibilities of correlation over long distances and radiometric dating. An example is the eruption of the Laachersee during Lateglacial time, not more than about 11,000 years ago, the volcanic ash of which has been found in many places, in particular in lake deposits, over a very large area to the north-east and south-west of the eruption point.

Thirdly the loess deposits and their stratigraphy are of particular interest. The study of their stratigraphy may also serve as a link between the stratigraphy established in the North Sea Basin area and that of the glaciated area of the Alps and Central Europe.

Finally the coastal deposits of Holocene age are of particular interest. As they have been preserved more completely than those of previous transgressions, their study permits insight into the problems of sea level change and related climatic changes. In particular knowledge of Holocene sea level change is of utmost importance to man, as many of the densely populated areas of the world are now in coastal areas. Knowledge of sea level change in the recent past may help to understand the mechanisms controlling sea level in more detail and perhaps in future to allow prediction.

(R.P. and W.H.Z.)

DAY 1 THE COASTAL PLAIN OF NORTHERN FRANCE

Introduction

The coastal plain of northern France forms the extreme south-west part of the Holocene coastal area which extends along the southern North Sea through Belgium, The Netherlands and Germany well into Denmark. The French sector of this area deserves special attention since it is considered the type of region for the stratigraphical subdivision of the coastal sequence (Calais deposits, Dunkerque deposits; cf. G. Dubois, 1924) and since the Calais region, with a shingle spit system, is the beginning of the North Sea coastal plain after the chalk and head cliff coast of the Pas de Calais (Strait of Dover).

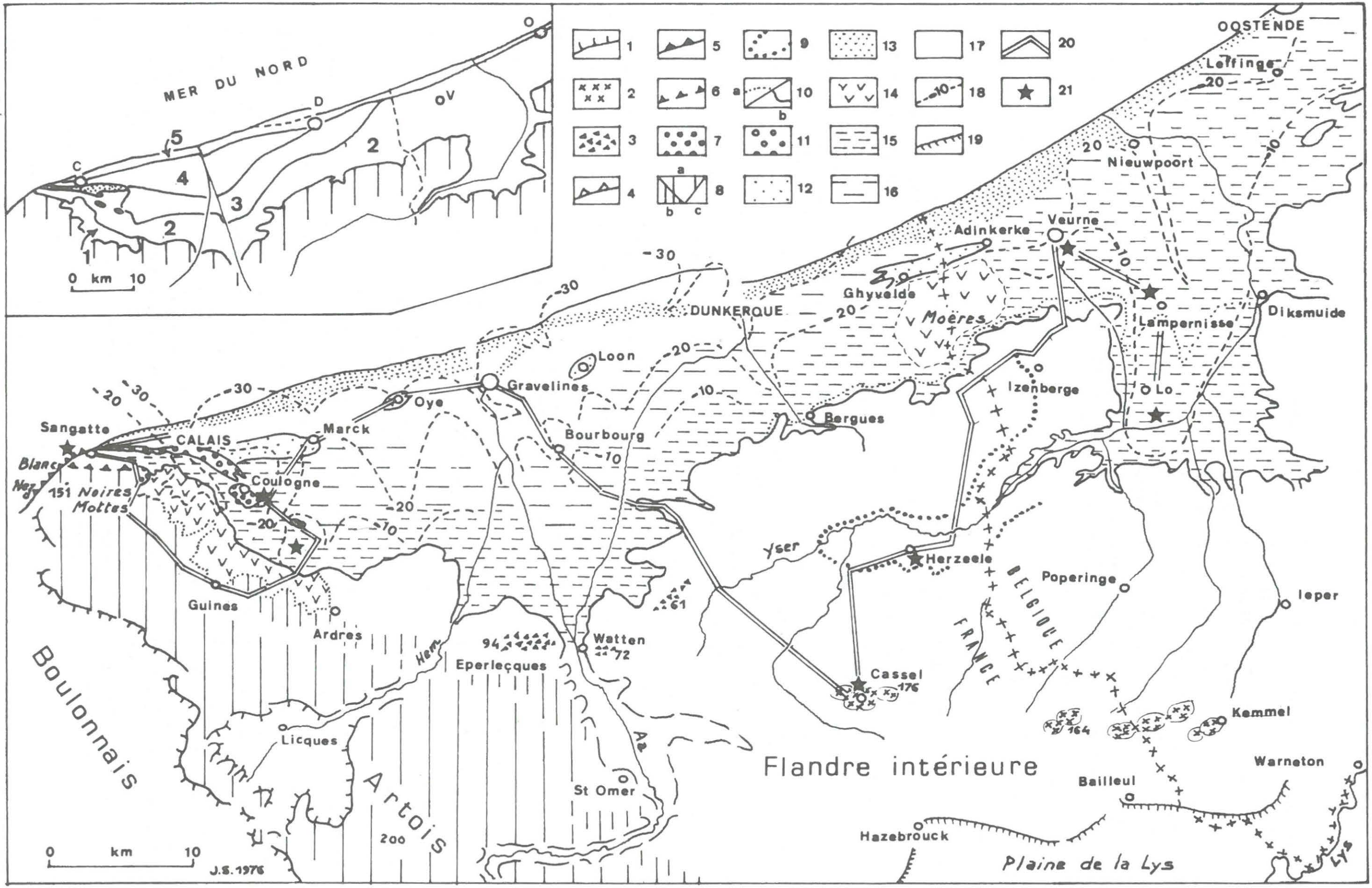
A recent survey of the area has been conducted by J. Sommé of Lille University. Special investigations in which universities of The Netherlands and Belgium participate are in progress.

The coastal plain of Northern France occupies a roughly triangularly shaped area which extends over some 60 km from Sangatte, west of Calais, to the Belgian frontier in the east. It attains a maximal width of about 20 km in its central part near Gravelines, in connection with the presence of former estuaries (Hem, Aa). To the west the plain wedges out against the Chalk hills of Artois, from which it is separated by continental Pleistocene head deposits which fossilize the ancient Pleistocene cliff of Sangatte. To the east it narrows to 10 km at the Belgian border. Along its southern margin the coastal plain is bordered by the hills of Artois and Flanders which consists of Cretaceous (in the west) and Tertiary (Landenian and Ypresian) largely covered by predominantly eolian Pleistocene deposits. (figure 2 on page 7).

Fig. 2 - GENERAL MAP OF THE COASTAL REGION OF NORTHERN FRANCE AND WESTERN BELGIUM

1: escarpment of chalk; 2: Diestian (Neogene) deposits; 3: Lower Pleistocene fluviatile gravels (flint); 4: Present-day chalk cliff; 5: Cliff developed in Pleistocene formations; 6: Fossil Middle Pleistocene cliff; 7: Pleistocene spit related to fossil cliff of Sangatte; 8: Pleistocene loess on: a. chalk; b. Landenian sands; c. Ypresian clay; 9: Extension of the Herzeele Formation (marine and continental Middle Pleistocene deposits); 10: Limit of the Holocene coastal plain: a. Calais deposits; b. Dunkerque deposits; 11: Holocene spit; 12: Ancient Holocene barriers and dunes; 13: Recent dunes; 14: Outcropping upper peat (excavated in Moëres); 15: Zone with essentially continuous presence of the upper peat under Dunkerque deposits; 16: Zone where the upper peat is sporadic; 17: Zone without upper peat: Dunkerque deposits resting directly on Calais deposits; 18: Isobaths of the prequaternary subsoil; 19: Border slope of the Lys Plain; 20: Excursion road; 21: Excursion point.

INSET : Zones distinguished in the text.


MER DU NORD
OOSTENDE
Leffinge
Nieuwpoort
Diksmuide
Veurne
Adinkerke
Lampernisse
Lo
Ghyvelde
Moëres
DUNKERQUE
Izenberge
Loon
Gravelines
Oye
Bergues
Bourbourg
Marck
Sangatte
CALAIS
Coulogne
Blanc Nez
151 Noires Mottes
Guines
Ardres
Eperlecques
Watten
Herzeele
Yser
Poperinge
Ieper
BELGIQUE
FRANCE
Cassel
176
Kemmel
164
Warneton
Bailleul
Hazebrouck
Plaine de la Lys
Lys
Flandre intérieure
St Omer
Aa
Licques
Artois
200
Hem
Boulonnais
0 km 10
J.S. 1976

The coastal plain is essentially flat, although very slightly sloping down towards the interior: from about 3 m N.G.F. * near the coast to 0.5 - 1 m inland. The deepest depressions are encountered in the drained lakes (the result of peat excavation) of the Moëres near the Belgian frontier: about - 2 m N.G.F. Along the coast several barrier systems and coastal dunes form higher elements in the landscape. The pebbly "Blanc des Pierrettes" which extends from Sangatte to Calais and its sandy eastern prolongation towards Marck should be especially noted along with the barrier of Ghyvelde-Adinkerke at the Belgian border. Furthermore, some isolated "massifs", remnants of a Pleistocene barrier, rise a few metres above the general level of the plain in the vicinity of Calais.

THE CALAIS DISTRICT

Pleistocene Geology

The area west of Calais is one of recent coastal erosion. Consequently the coast-line obliquely intersects: 1. Cretaceous Chalk (Cap Blanc Nez), 2. the Pleistocene cliff of Sangatte and its head formation, 3. the Holocene coastal spit system (Blanc des Pierrettes) (figure 3 on page 9).

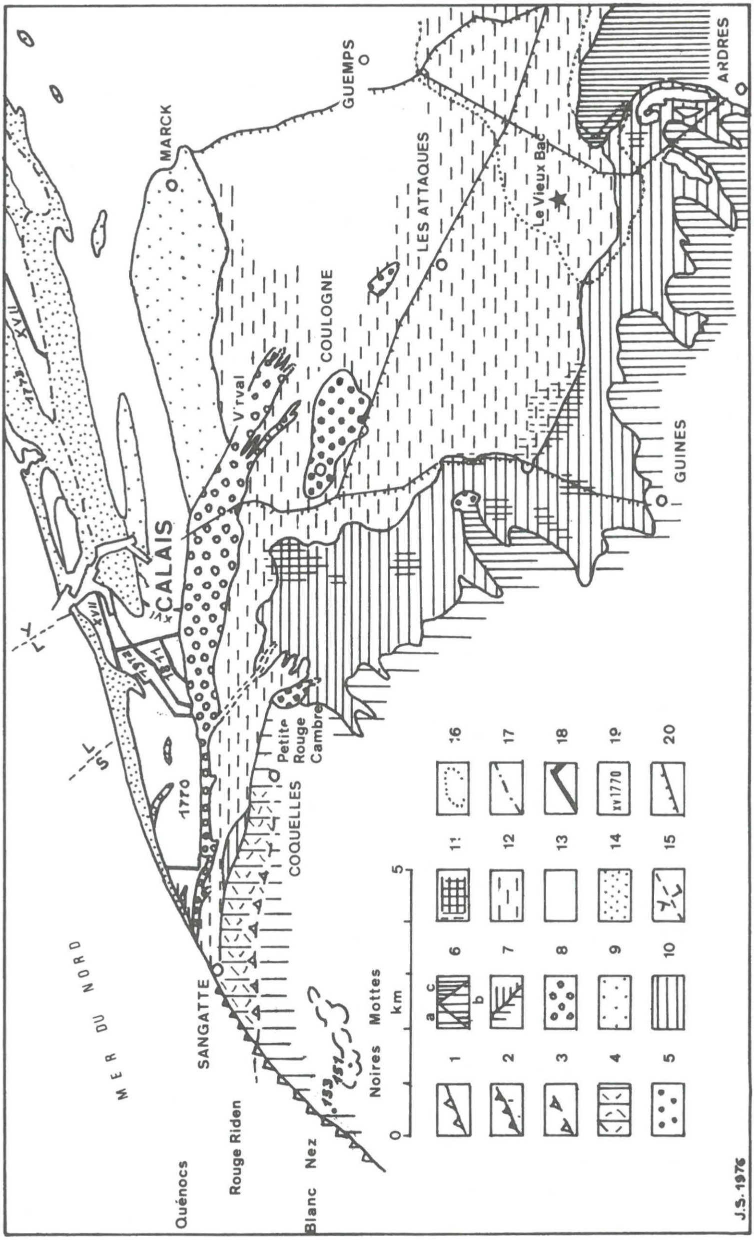
The fossil cliff and 'raised beach' of Sangatte correspond to an interglacial high sea level (relative level of 5 m; alt. about 10 m N.G.F.) (figure 4 on page 11). Several remnants of shingle (flint) spits ("massifs" of Petite-Rouge-Cambre, Coulogne, Attaques) are related to this ancient shore line which had a NW-SE direction. Many authors, after Dubois, considered this Pleistocene shore line to be of Eemian age (Monastirian). Opposed to this interpretation was the one which ascribed, after Briquet, the Sangatte cliff to an earlier interglacial, notably Mindel-Riss or Holsteinian (Bourdier). A Middle Pleistocene age accords better with the stratigraphic evidence of the cliff and of the coastal plain formations. It is also supported by the conclusions drawn from the study of the Herzeele Formation (see below).

A continental Weichselian sequence is found as the fill of deep valleys which separate the remnants of the Pleistocene spit on the plain. This implies considerable erosion prior to the Late Pleistocene; also a feature of the valleys of the interior region.

* French datum level. 0 (NGF) = about 0 (NAP) = about + 2.3 m (OP)

Fig. 3 - MAP OF THE COASTAL PLAIN IN THE CALAIS REGION (FRANCE);

1: Present-day chalk cliff; 2: Cliff developed in Pleistocene formations of Sangatte; 3: Fossil Middle Pleistocene cliff; 4: Pleistocene head formations of Sangatte; 5: Pleistocene spits (pebbles); 6: Pleistocene Loess on: a. chalk; b. Landenian sands; c. Ypresian clay; 7: Limit of the Holocene coastal plain; 8: Holocene spits (pebbles); 9: Ancient Holocene barriers and dunes; 10: Outcropping upper peat; 11: Freshwater marl with *Limnea*; 12: Zone with essentially continuous presence of the upper peat (Tourbe de surface) under Dunkerque deposits; 13: Zone where the upper peat is essentially absent: Dunkerque deposits resting directly on Calais deposits; 14: Recent dunes (Middle and modern ages); 15: Boundaries of prequaternary formations in the subsoil: S. Senonian; L. Landenian; Y. Ypresian; 16: Extension of the Gallo-Roman site of Ardres; 17: Coast-line at the end of middle ages; 18: Dike; 19: Date of embankment; 20: Canal.


MER DU NORD
CALAIS
MARCK
GUEMPS
COULOGNE
LES ATTAQUES
Le Vieux Bac
GUINES
ARDRES
SANGATTE
COQUELLES
Petite Rouge Cambre
Quénocs
Rouge Riden
Blanc Nez
Noires Mottes
km
0
5
1770
J.S. 1976

Holocene Geology

The depositional basin of the coastal plain attains a maximum depth of over 30 m at the present-day shore. It is infilled essentially by marine deposits with peat layers interspersed in the sequence, notably in the upper part: 'Tourbe de Surface' (surface peat complex).

Stratigraphically the Holocene sediments are grouped in the Flandrian. Dubois (1924) defined the subdivisions of the Flandrian which was understood by this author to be the complete sequence deposited during the last great sedimentary cycle known in Flanders. Consequently he labelled as Lower Flandrian (end of the last Glacial) the 'Assise d'Ostende' the lower part of which was afterwards proven to be of Eemian age (R. Tavernier). Dubois proposed the term of 'Assise de Calais' (Middle Flandrian) for the thick marine grey-blue sandy deposits underlying the upper peat and for the shingle spit of Pierrettes -and the term of 'Assise de Dunkerque' for the historical beds which contain, especially near Dunkerque, *Mya arenaria*.

The 'Assise de Calais' is composed of tidal sediments which occur below the (uppermost bed of the) 'Tourbe de Surface'. The sediments are predominantly sandy ('sables pissards'), but the upper part may contain heavier textured elements. In the inner reaches of the plain the sediments are significantly more clayey. A lower peat layer ('Tourbe profonde') is occasionally present at the base of the 'Assise de Calais'; in other cases, however, the 'Tourbe profonde' applies to peat layers which are contained in sediments of Weichselian or older age ('Assise d'Ostende'). The 'Assise de Calais' is found at the surface in the reclaimed lakes of the Moëresin the extreme east. Elsewhere its sediments are overlain by the 'Assise de Dunkerque' and/or the 'Tourbe de Surface'.

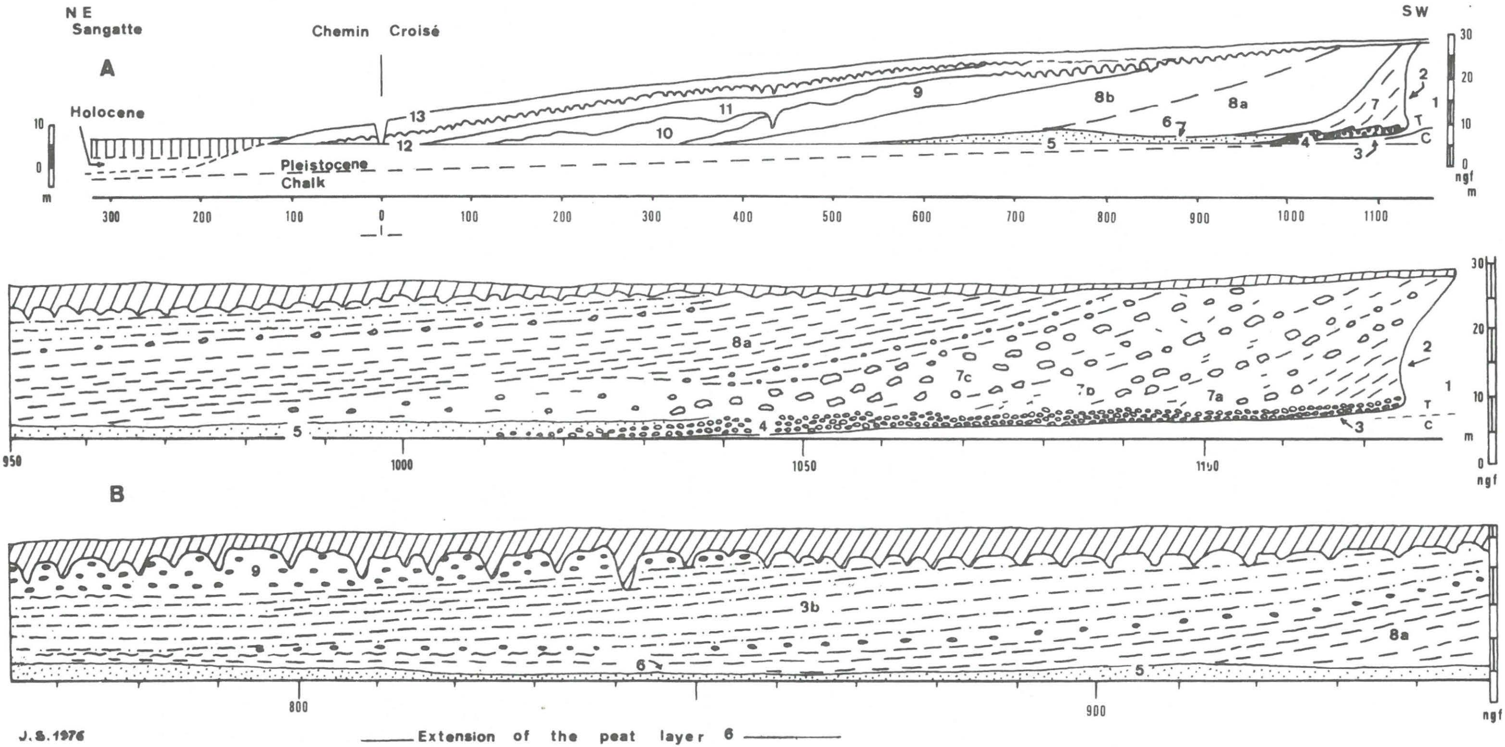
Fig. 4 - THE CLIFF OF SANGATTE (NORTHERN FRANCE)

A - General profile of the cliff.

B - Detailed profile of the south-western part of the cliff.

Description of stratigraphic units: Marine forms and formations: 1. Chalk (C: Cenomanian; T: Turonian); 2: Ancient cliff; 3: Fossil shore-platform; 4: Flint shingle; 5: Sandy beach with shells (*Cardium edule, Tellina balthica*, etc). These marine deposits are corresponding to an interglacial high sea-level (relative level of 5 m; altitude: c. 10 m N.G.F.).
Continential formations: 6. Thin peaty layer (0,20 m) with *Pinus* pollen (R.Vanhoorne) extending only in a small depression of the fossil beach (14 C GrN-5868 : older than 50,300 y BP); 7: Chalky slide deposits at the bottom of the ancient cliff. These first continental deposits can be chiefly considered of the end of the interglacial.
Lower complex of calcareous regularly bedded formations: 8: chiefly composed of chalky material; 9: with more important flint layers; 10: with loess layers.
Upper complex composed of irregular beds of flint pebble, sands and loams:
11: non calcareous; 12: calcareous.
13: sandy-loamy cover.

SANGATTE (NORTHERN FRANCE)



The 'Assise de Calais' includes a shingle spit system (flint and chalk) the main element of which is the 'Banc de Pierrettes' prolongated by the Virval digitations and the sandy barrier of Marck. Several phases of spit growth are found: (1) at about - 20 m in the surface of the town of Calais, (2) at about - 15 m in a more southern position; (3) reaching from - 10 m to the surface which is at + 4 m.

The marine deposits which occur stratigraphically above the 'Tourbe de Surface' form the 'Assise de Dunkerque'; their litho-facies in general is very sandy. The 'Assise de Dunkerque' occurs at the surface practically everywhere in the coastal plain, except for the narrow zone between Ardres and Calais in the south-west (the so-called 'Marais'), where the 'Tourbe de Surface' crops out. In the latter area a few isolated patches of lacustrine marl occur. This material is found on the top of the peat and is at some places possibly covered by sediments of the 'Assise de Dunkerque'.

The 'Tourbe de Surface' is generally present in the southern marginal belt of the coastal plain, but only in the 'Marais' near Ardres is it found at the surface. In this southern zone the peat attains its maximal thickness of over 1 m. Seawards its occurrence is more scattered and overall thickness, although varying greatly, diminishes. It has long been known that the 'Tourbe de Surface' may consist of a number of separate peat beds which interfinger with the 'Assise de Calais'. Recent investigations in the area to the south-east of Calais have clarified this. Consisting of a single major peat layer in the interior zone of the plain, the 'Tourbe de Surface' splits up into a number of beds in a seaward direction. In general the tendency is for the number of individual peat beds, which in places may amount to seven, to decrease seawards. As a rule, stratigraphically higher beds extend farther seaward than lower ones.

Obviously, the seaward decrease of the number of peat beds reflects a less effective depositional environment for a record of regressions. From this there is no particular reason why the complete absence of peat in the northern part of the coastal plain should not be regarded as a primary feature. Certainly, the absence should not necessarily be attributed to later erosion.

Chronology

Until recently the chronology of the Holocene evolution of the coastal plain of northern France could be indicated only in a very rough way. During the last few years a number of radiocarbon datings have been carried out which enable us to define more precisely the chronological framework of the evolution in this type region.

It appears that the 'Assise de Calais' was formed during the Atlantic (8,000 - 5,000 BP) and probably even earlier, and during the greater part of the Subboreal, until 3,500 BP. The lower beds of the 'Tourbe de Surface' developed as early as the Late Atlantic, but peat formation was especially significant during the Subboreal (5,000 - 2,750 C^{14} BP). The 'Assise de Dunkerque' was formed during several phases from 2,500 BP onward.

The formation of the interior elements of the coastal barrier systems (Banc de Pierrettes, Marck) took place during the Atlantic and Subboreal. The formation terminated, in places, as late as the Early Subatlantic. The outer barrier systems were formed predominantly during the Subatlantic.

The formation of the lacustrine marl in the south-western edge of the plain is related to the initial deposition of the 'Assise de Dunkerque', and may be dated from 2,500 BP onward.

The interfingering of the 'Tourbe de Surface' and the 'Assise de Calais' and the occurrence of discontinuities and vegetational horizons within the 'Assise de Dunkerque' point to the occurrence of transgressive and regressive oscillations. Available radiocarbon dates enable a first transgressive-regressive chronology for the area to be established. Parallels with the Netherlands are easily recognizable, notably for the Atlantic, Early Subboreal and Subatlantic. The Middle- and Late-Subboreal oscillations compare less well. The limit between the Calais deposits and the Dunkerque deposits (term from Dubois), determined by its stratigraphic relations with the main upper peat, corresponds to the basal part of the Dunkerque I transgression deposits.

Regional Subdivision

On the basis of the available stratigraphical and geomorphological information, concerning both the surface and subsurface, the following regional subdivision can be made (figure 5 on page 14).

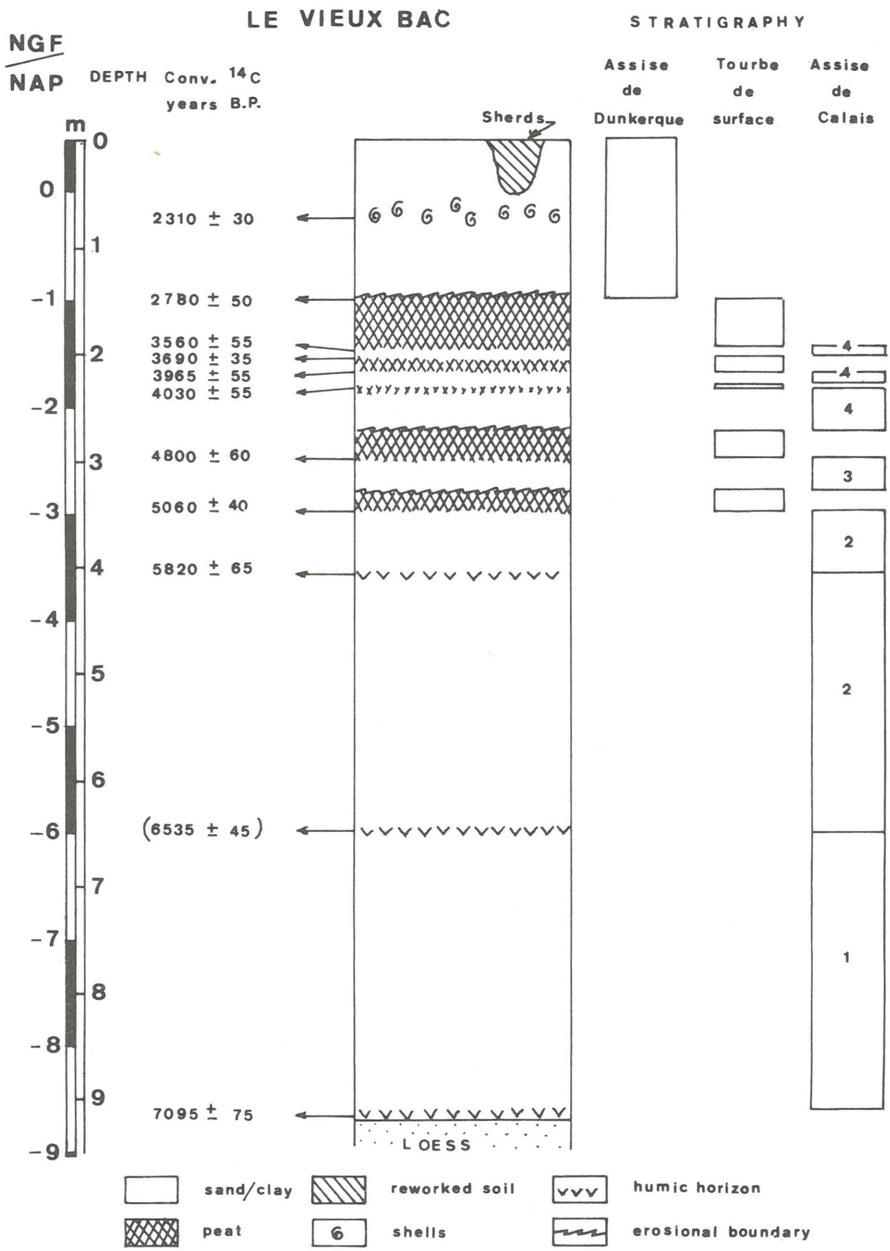
1. The 'Marais' near the interior limit of the coastal plain in the area south of Calais. Here the Subboreal 'Tourbe de Surface', overlying marine deposits of the 'Assise de Calais', crops out. At places a lacustrine marl, containing *Limnea*, is found on top of the peat.

2. The marsh where the 'Tourbe de Surface' is overlain by marine deposits of the Dunkerque I and II phases. In this zone the occurrence of transgressive oscillations during which the sea penetrated the area can be recognized most clearly (cf. Le Vieux Bac section).

3. Zone 3 marks the maximal extension towards the north of the 'Tourbe de Surface'. The peat is present in very few places, partly due to erosion in Dunkerquian channels. In places, chiefly in the Dunkerque region, these channels display inverted relief. The horizon between the marine deposits of the Dunkerque I and II phases tends to disappear in this zone. The Dunkerque III transgression was mainly active in the ancient Aa estuary. Zone 3 does not exist in the Calais region as a result of the presence of the protecting Pierrettes coastal barrier. Subsurface pebbles of this barrier system are found at depths down to - 10 m, which proves a permanent vertical growth and a constant position since the Early Atlantic or even earlier.

4. North of the Pierrettes-Marck axis, the 'Tourbe de Surface' is missing. Zone 4 is characterized by the presence of a series of older sandy barrier ridges, covered with low dunes which are now stabilized. The evolution of this system marks a change in the general orientation of the coast line (E-W to ENE-WSW).

5. The littoral zone represents the continuation of this evolution with a series of dune ridges which date from the Middle Ages and modern times. East of Dunkerque a different coastal sector begins where the coast has retreated and where, as a consequence, older and younger dunes form a single system; also the 'Tourbe de Surface' crops out on the present-day beach such as in the region of Sangatte.


LE VIEUX BAC
STRATIGRAPHY
NGF
NAP
DEPTH
Conv. 14C years B.P.
m
Assise de Dunkerque
Tourbe de surface
Assise de Calais
Sherds
2310 ± 30
2780 ± 50
3560 ± 55
3690 ± 35
3965 ± 55
4030 ± 55
4800 ± 60
5060 ± 40
5820 ± 65
(6535 ± 45)
7095 ± 75
LOESS
4
4
4
3
2
2
1
sand/clay
reworked soil
humic horizon
peat
shells
erosional boundary

HERZEELE

A few kilometres from the Belgian boundary the HERZEELE FORMATION is exposed at Brickyard Heem at Herzeele south of the Yser Valley on the gentle slope of a little adjacent valley (alt. 13 m N.G.F.) (figure 6 on page 16). The study of the section, started by J. Sommé in 1970, continues in collaboration with R. Paepe and members of the Centre for Quaternary Stratigraphy.

The complete profile consists of the following lithostratigraphic units (figure 6 on page 16), from top to bottom:

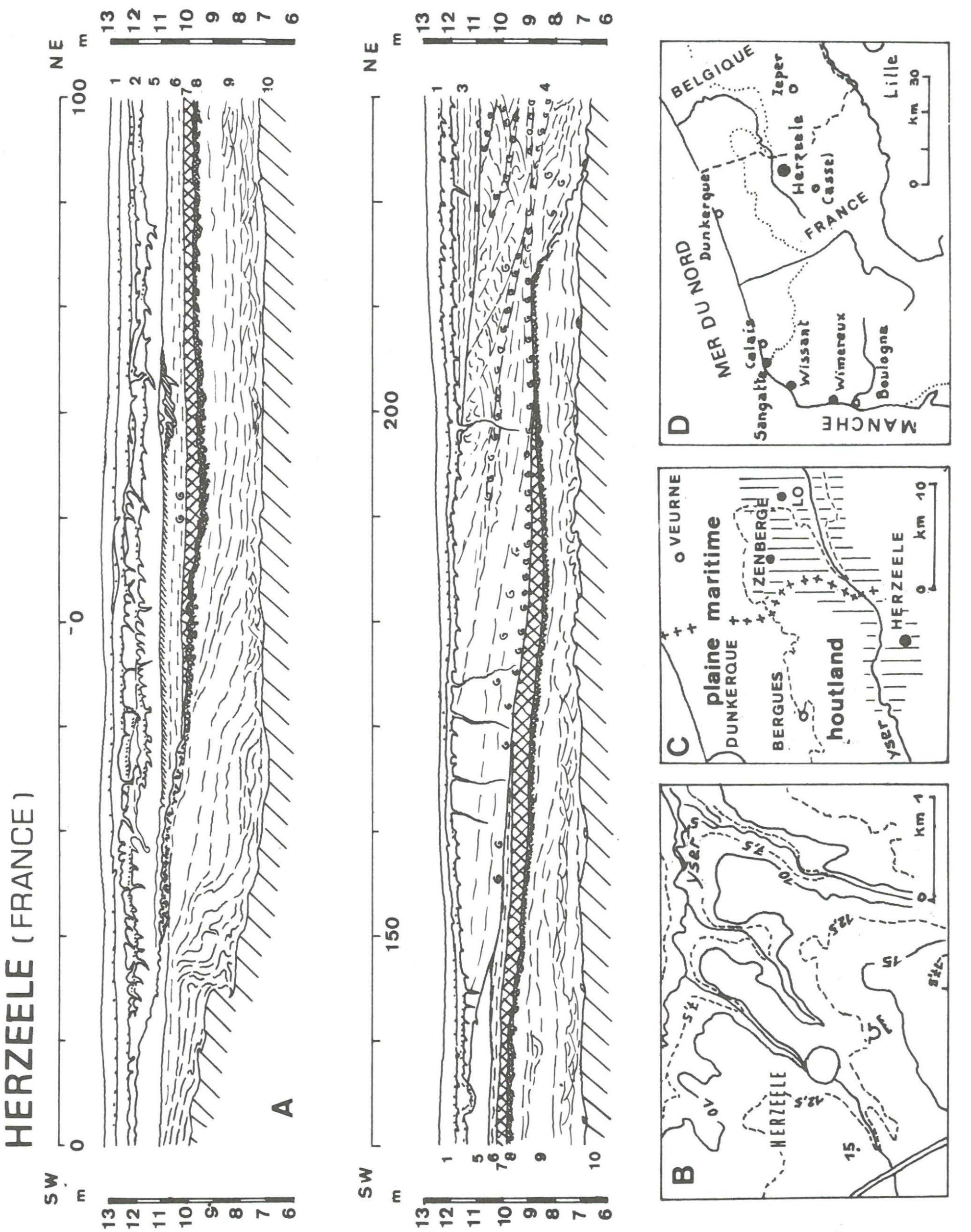
- a continental cover of eolian loams and loamy sands (1 and 2) with several soils (pseudogley to grey brown podzolic type) separated from each other by stone pavements with frost wedges. The whole is covered by a thin yellow-brown Weichselian cover-loess.
- an upper marine loamy-sandy complex (4) with numerous shells (*Cardium edule, Macoma balthica,* etc.) corresponding to a lagoonal sedimentation near the shore line. It is the so-called Izenberge crag which rapidly increases in thickness as a consequence of erosion of the underlying sediments down to the Ieper clay substratum (points 140 to 230 only). The whole is overlain by alternating clayey and sandy horizontal layers (3) which increase in thickness towards the NE.
- a loamy-clayey marine lagoonal marine series with sporadic shells and capped by a humic horizon (*Picea* pollen, R. Vanhoorne) showing in places traces of cryoturbatic perturbation (6 and 7).

Fig. 5 - Boring at Le Vieux Bac (N.W. Ardres; coastal plain of Northern France)

The complete Holocene sequence at the spot is slightly over 9 m thick, and is overlying Pleistocene loess. Initial peat formation on top of the loess was radiocarbon dated to c. 7100 BP. The final stage of Holocene deposition may be dated around the beginning of the Christian era: in the immediate surroundings pottery from the Gallo-Roman epoch was found at the surface.

From 9,15 to 3,5 m below the surface the sequence consists of silty-clayey tidal deposits of the Assise de Calais, interrupted only by two humic horizons. Between 3,5 and 1,4 m clastic beds of the Assise de Calais alternate with peat layers (Tourbe de Surface). This complex of peat and tidal deposits was formed, according to 14C dating, between c. 5000 and 2500 BP, i.e. during the Subboreal. The formation of the uppermost bed of the Assise de Calais ended around 3550 14C y.BP.

From 1,4 m upward sandy tidal deposits of the Assise de Dunkerque are encountered. They were formed between c. 2500 and 1900 y.BP at this spot. The definition of these deposits as a distinct stratigraphical unit has, in practice, to be based on their position relative to the Tourbe de Surface.


HERZEELE (FRANCE)
SW
NE
m
A
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C
D
HERZEELE
Yser
plaine maritime
houtland
DUNKERQUE
BERGUES
VEURNE
IZENBERGE
LO
MER DU NORD
BELGIQUE
FRANCE
MANCHE
Dunkerque
Calais
Sangatte
Wissant
Wimereux
Boulogne
Herzeele
Cassel
Ieper
Lille
km

- a cryoturbated peat horizon (main peat, 8) originally formed under warm climatical conditions in the same way as the humic horizon 7, but characterized by the abundance of *Taxus* pollen (R. Vanhoorne). The peat has been disturbed by cold activity after its development.

- a lower marine sandy tidal flat series (9) with characteristic point bar features, overlying immediately the Ieper clay substratum (Eocene) (10).

The whole of the sequence below the eolian sediments, from layer 3 and the crag down to the Tertiary substratum is called 'Herzeele Formation'. The Izenberge crag is at present considered to be of Holsteinian age on the basis of its fauna. The occurrence of the crag below a loess with fossil soil of the interglacial type supports this. To the peat which we provisionally locate at the same stratigraphical position as the Lo peat (taking into account the lithostratigraphic phases which separate it from the crag) a Cromerian age is most likely. This interpretation is not at odds with the palaeobotanical content of the peat. Because the peat is disturbed by frost action, it is provisionally proposed to place the middle and lower marine phases respectively into Cromerian III and II. However the first palaeomagnetic results (J. Hus and R. Geerarts) pose a problem because the whole of the profile, except for the uppermost part of the eolian cover and the lowermost sand complex, show a reversed inclination.

Provisionally we can offer the following conclusions. The section at Herzeele demonstrates marine conditions in the southern part of the North Sea from East Anglia to Flanders during several periods in the Middle Pleistocene. Sea level was probably little different from the present one (figure 6 on page 16). According to the distance from the present coast (approximately 40 km) at which these sediments are found, the former southernmost North Sea belt would have extended far beyond its present limits: it may be inferred that the Straits of Dover were open at this time. A sudden change seems to have occurred in the direction of the marine invasions at the beginning of the Middle Pleistocene. Belgium was so to speak the 'hub' of a transgression 'turn-table' which switched direction from the NE to SW, most probably during 'Cromerian' times. This evolution is related to tectonic movements known to have occurred during Tertiary times. The Herzeele Formation at the type-locality is evidence of a new and most important event in the Quaternary palaeogeography of the southern North Sea which probably relates to the opening of the Straits of Dover.

Fig. 6 - PROFILE OF THE BRICKYARD OF HERZEELE (FRANCE)

A. Detailed profile.

B. Map of the relief with contour lines and location of the brickyard.

C. Map of the French-Belgian region with the extension of the Herzeele Formation.

D. General map with marine Middle Pleistocene sites along the North Sea and Manche coast.

DAY 2 PLEISTOCENE DEPOSITS IN BELGIUM

MOVEMENTS OF THE SOUTHERN NORTH SEA IN BELGIUM DURING THE PLEISTOCENE

The Quaternary geology of Belgium is closely related to changes in configuration of the southern North Sea as well as to the marine transgressions and regressions which took place during that period. Clearly in studying these the geomorphological shaping of the landscape must be considered.

On the ridges of Artois and Downs, Upper Miocene deposits (Diestian - Lenham beds) occur generally and may be followed continuously along a series of inselbergs (Cassel, Kemmel, Ronse, Diest; figure 7 on page 19) N.E. into Germany. It is generally assumed that the line linking up these outcrops more or less represents the configuration of the coastline of the North Sea at that time (J. Van Voorthuizen, 1957). We believe that the Strait of Dover was not open at that time (J. de Heinzelin 1966), but others believe differently (J. Van Voorthuizen, 1957). Subsequent to the north-eastward withdrawal of the sea, in the reach of Cassel to Merksem (in the vicinity of Antwerpen) the present N.E. pattern of major Belgian streams originated. J. Cornet (1904) has named this the 'Pliocene regression', the Diest beds being classified as Pliocene at that time. M. Gulinck (1963) stated that this so-called Diestian might well belong to the Casterlee-sands which occupy a geometric position comparable to the Kattendijk-sands in the north, nearby Antwerpen.

It has long been known that a series of marine deposits are well developed in the Antwerpen area. North of the town they increase considerably in thickness towards the subsidence zone of The Netherlands.

Until recently the uppermost of them, the Merksem sands (Table on page 60), were considered to be Pliocene. P. Laga (1973) studied their foraminiferal content and concluded that a series of marine deposits with a benthonic fauna (Merksem, Kruisschans, Oorderen and Luchtbal sands) belongs to the Lillo Formation. The top of the Merksem sands would then correspond to part of the 'Icenian', the Merksem, Kruisschans and Oorderen sands to the 'Amstelian', and the Luchtbal sands to the 'Scaldisian-Poederlian'.

Neither on the basis of foraminifera nor on previously studied vertebrate remnants (A. Schreuder, 1944) may a definite age be assigned to these sediments. P. Laga therefore also proposes a Plio-Pleistocene age for the underlying Formation of Kattendijk. W.H. Zagwijn (1974), however, correlated the Merksem beds with the upper part of the Oosterhout Formation which is of Reuverian (Upper Pliocene) age.

From the foregoing the only firm conclusion to be drawn is that the coastline of the retreating North Sea had stabilized in the Antwerpen area during the Plio-Pleistocene transition. Indeed, the shallow-marine nature of most of the sediments endorses such an inference.

Though the coastline may have been situated more to the south-west at certain times, the withdrawal of the sea between the Upper Miocene and the beginning of the Pleistocene took place over ca. 150 km (distance from the Artesian ridge to the Antwerpen area). The drop in topographical level amounted to almost 200 m.

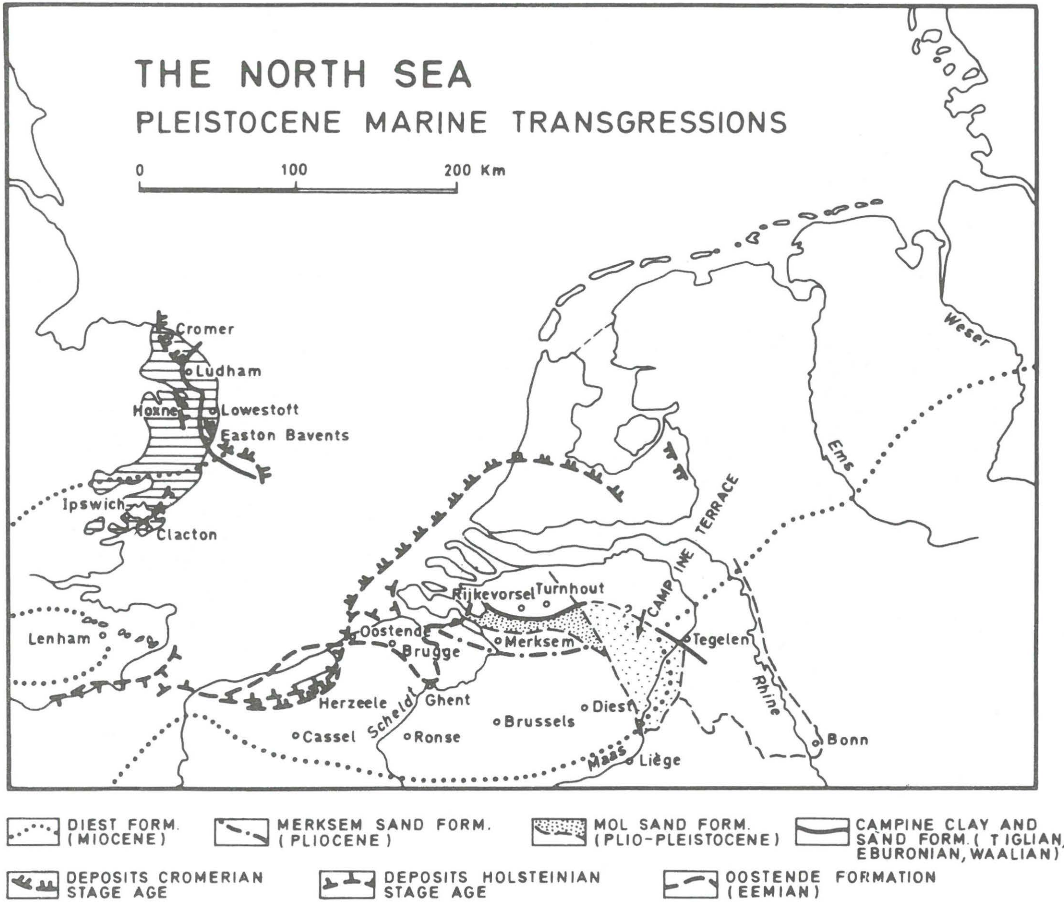

THE NORTH SEA
PLEISTOCENE MARINE TRANSGRESSIONS
0
100
200 Km
Cromer
Ludham
Hoxne
Lowestoft
Easton Bavents
Ipswich
Clacton
Lenham
Rijkevorsel
Turnhout
Merksem
Oostende
Brugge
Herzeele
Ghent
Cassel
Scheldt
Ronse
Brussels
Diest
Liège
Maas
Tegelen
Rhine
Bonn
CAMPINE TERRACE
Ems
Weser
DIEST FORM. (MIOCENE)
MERKSEM SAND FORM. (PLIOCENE)
MOL SAND FORM. (PLIO-PLEISTOCENE)
CAMPINE CLAY AND SAND FORM. (TIGLIAN, EBURONIAN, WAALIAN)
DEPOSITS CROMERIAN STAGE AGE
DEPOSITS HOLSTEINIAN STAGE AGE
OOSTENDE FORMATION (EEMIAN)

Fig. 7.

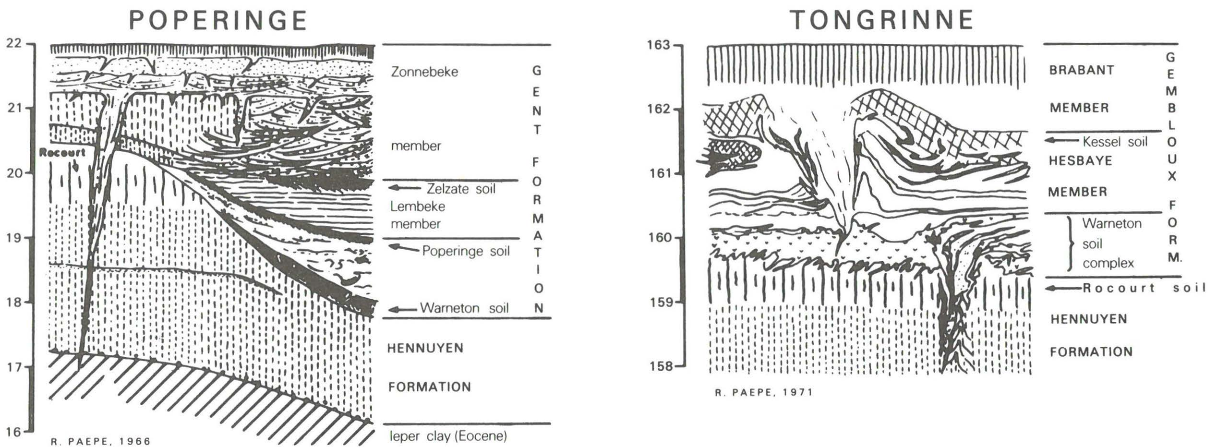

POPERINGE
22
21
20
19
18
17
16
Rocourt
R. PAEPE, 1966
Zonnebeke
member
Zelzate soil
Lembeke
member
Poperinge soil
Warneton soil
GENT FORMATION
HENNUYEN
FORMATION
Ieper clay (Eocene)
TONGRINNE
163
162
161
160
159
158
R. PAEPE, 1971
BRABANT
MEMBER
Kessel soil
HESBAYE
MEMBER
Warneton
soil
complex
Rocourt soil
GEMBLOUX FORM.
HENNUYEN
FORMATION

Fig. 8.

It is probable that this was not continuous, though any certainty is not possible in the absence of deposits between Artois and Antwerpen.

Furthermore, it is not clear whether the withdrawal of the sea was due to climatic change only or related to subsidence along a NW-SE extending flexure from Vlissingen to Antwerpen. Yet the recurrence of transgressions and regressions of the Plio-Pleistocene series which is covered by a Lower Pleistocene series of beds showing alternating continental and estuarine facies indicates that the effect of the subsidence was overshadowed by the climatic effects at certain stages; during other stages subsidence prevailed, resulting in beds of considerable thickness. The thick continental fluviatile Mol sands in the Campine area, east of Antwerpen, are also of Plio-Pleistocene age (R. Vanhoorne, 1961, 1971). The gravels below the Arendonk peat member are of Pliocene age, those above that member of Pre-Tiglian age. It is noticeable that the Mol sands are the eastward extension of the Merksem sands (M. Gulinck, 1963). On top of the Mol sands lie the Campine Formation marine-continental beds. The facies of these beds indicates again alternating regression and transgression of the sea and its shoreline, as a result of climatic changes. Generally a lower lithostratigraphic unit, the Rijkevorsel Clay Member (R. Paepe and R. Vanhoorne, 1971) is present in the area of northern Belgium. It is the continuation of the Tegelen Clay of The Netherlands. In the Campine area it has an estuarine facies proving that the shore-line was near during the Tiglian (W.H. Zagwijn, 1974).

It is overlain by a continental deposit consisting of eolian sands and peat layers, the Beerse Member (Dricot, 1962). The cold character of this formation is indicated by the pollen content of the peat beds and by frost wedges along deflation horizons. It is supposed to belong to the Eburonian glacial stage.

The Beerse Member is overlain by interglacial estuarine beds of the Turnhout Clay Member of Waalian age. (Paepe and Vanhoorne, 1971).

A period of intense cold followed after deposition of the Turnhout Member: deflation horizons and frost wedge levels truncate the topmost beds of the Campine Formation. This cold period is correlated with the Menapian glacial stage, when extensive pediplanation took place.

The prescence of the sea in northern Belgium caused considerable environmental changes in the southern hinterland. At present remnants of them are known to be preserved in the Ardennes.

At the end of the Early Pleistocene the marine influence in the north came to an end. The sea withdrew entirely to the north-east during 'Cromerian' times (W.H. Zagwijn, 1974), with the river Rhine building a large delta in a north-western direction. However there is good reason to assume that the sea was present in or shifted to the west during the Cromerian for deposits of 'Cromerian' age are believed to exist in the western part of Belgium and Northern France.

In south-west Flanders, along the French border, A. Rutot (1897) described Izenberge crag with *Cardium edule*. In more recent studies (Tavernier and de Heinzelin, 1962; Paepe and Sommé, 1975) an early Middle Pleistocene age and marine character of at least three groups of deposits were recognized at

Herzeele (France) and in the surrounding Belgian-French area. It seems that the whole of the southern North Sea was flooded as *Macoma balthica* is found amongst the fauna accompanying *Cardium edule*. P. Norton (1970) believes that the presence of this species indicates a connection with the Atlantic Ocean from the north.

The problem of the existence of the Straits of Dover at that time should now be discussed. The beds containing *Macoma balthica* date from the last phase of the 'Cromerian complex', but it is still not certain whether the Izenberge crag is 'Cromerian' or of Holsteinian age: we prefer the first interpretation.

W.H. Zagwijn (1974) infers a 'Late Cromerian' coastline running from north of Rotterdam to the south-west, thus avoiding the problem of linking it to 'Cromerian' deposits in Belgium and involving an irregular coastline. Indeed, Pre-Eemian marine deposits seem to exist in the 'Flemish Valley' ('Golfe de Gand' of Rutot) along the Belgian-Dutch border as far inland as Gent. None are found in the coastal plain between Brugge and the Yser; yet west of this river the 'Herzeele Formation' spreads out continuously under the Late Pleistocene and Holocene cover.

It is most likely that during the 'late Cromerian' most of the southern North Sea was flooded including deeply eroded river-mouths. This suggests that erosion during the Menapian and Glacial stages of the 'Cromerian', (sensu Zagwijn), was important. It is interesting to note the difference in absolute height between the highest marine deposits in the Campine area (± 30 m O.P.) and the Herzeele deposits (± 13 m O.P.). The southern North Sea had been limited hitherto to a line following roughly the Antwerpen-Vlissingen flexure line (perhaps continuing in the Easton Bavents-Ludham flexure) but the opening of the Straits of Dover resulted in water flowing into the North Sea directly from the Atlantic Ocean.

As a result of western marine transgressions landscape evolution underwent profound changes. In addition to the primary north-eastern direction of the rivers, E.-W, oriented erosion occurred in the Flemish Valley and to a minor extent in the Yser basin. However, retreat of the sea to the north was at the origin of continued erosional activity along the primary NE-SW fluvial pattern. The River Meuse developed a new drainage pattern which resulted in the Lesse terrace system, the gravel deposits of which belong to the Meuse (Maas) Gravel Formation: in the Campine High Terrace it finds its most striking expression.

Gravel deposits on the north-easterly oriented ridges in western Belgium, Schelde Gravel Formation (Paepe, 1963; Demoor, 1963), developed simultaneously with the Meuse Gravel Formation. Both formations show that erosion took place uninterruptedly from Menapian through Elsterian times.

After changes in the orientation of marine transgressions and adjustment in drainage pattern, sedimentation changes occurred.

Eolian sedimentation grew gradually since the beginning of the 'Cromerian' (Hainaut Formation) and became widespread at the beginning of the Saale. No matter whether we are dealing with loess sections underlain by the marine Herzeele Formation or Schelde-Meuse Gravel Formation, the Hainaut Formation covers and seals the newly shaped landscape. It was affected little, if any, by the next erosional phase of the Eemian interglacial.

During the course of the warm period the sea invaded the Flemish Valley again and tidal influence was felt in the hinterland. In the western part of the coastal plain, west of Oostende, none of the marine interglacial deposits, the Oostende Formation, are found. In our opinion it shows that the Eemian shore was located seawards of the present coastline. Farther west it is located in the substrata of the coastal plain west of Dunkerque (figure 7 on page 19).

Continental deposits of the same period are found in the Flemish Valley and tributaries as the Zemst Gravel Formation. Elsewhere this may be represented by peat layers (Rumbeke peat) or simply by a soil horizon (Rocourt Soil, Gullentops, 1954).

Finally during the Weichselian, aggradation was active and former large estuaries such as the Flemish Valley were infilled completely. This contributed greatly to the build-up of the coastal plain. Indeed in the subsurface of the Flemish Valley and the Yser estuary a well marked step on the threshold of the present coastal plain occurs. Therefore the role of continental erosion in shaping the present coastal plain was of considerable importance.

Further evolution during the Holocene is discussed later.

KEMMELBERG

This is the highest crest of a group of inselbergs (Flemish Hills) 15 km south of Ieper. Almost the entire Tertiary sequence is found with the Ieper clay (Lower Eocene) at the bottom and ending with the so-called Diestian (End Miocene), perhaps Casterlee sands (Pliocene) (Gulinck, 1963). During archaeological excavations, reworked flat beach pebbles were found in soliflucted layers recalling the 'Pseudo-Diestien' of the Catsberg in France (Bonte, Sommé).

This inselberg dominates the sand-loess area to the north and the Lys-plain to the south. The latter is a flat triangular plain (20 m O.P.) between Lille, St. Omer and Warneton ranging between 20 - 30 km in height.

The contact between Lys-plain and Flemish Hills zigzags along the steeper walls of asymmetric hill blocks. This pattern is inherited from a basement horst and graben structure in the Carboniferous.

WARNETON

The brickyard DEMOULIN (North side of Lys-plain; at 20 m O.P) produced in the last twenty years many good outcrops of which several have been recorded. It offers a good sequence of the Quaternary deposits of Lys-plain.

Most important is the Rocourt-Warneton soil sequence because it may readily be compared, litho-stratigraphically and pedo-stratigraphically, to other sections in both the sand-loam and loess belt (Tongrinne). Therefore it is an important marker horizon or better marker sequence.

Here, the Rocourt soil is truncated by the Warneton soil. Pedologically the Ruccourt soil belongs to the grey-brown podzolic type of soil developed under warm climatic conditions whereas the Warneton soil displays a humic horizon which probably developed under cold conditions.

As the Warneton soil splits up in gullies into several recurrent layers, it seems justified to use the connotation of 'soil complex'. One is dealing here with the entire sequence of Early Weichselian interstadial peat deposits which are telescoped together in one single layer outside the gullies. The first indication of marked coldness is the stone-line with small frost wedges above the Warneton soil. If compared to the classification established by Zagwijn and Paepe (1968), the cold marker bed should correspond to the Lower Pleniglacial. Actually the stone (deflation) horizon corresponds to the erosional phase at the end of it, erosion responsible for the lack of other deposits of that period.

The peaty loam formation is a typical litho-facies indicating a cold - humid run-off deposit. The humic layer at its base occupies an identical position to the Poperinge soil. At Poperinge it was dated 45,600 BP representing the Moershoofd-Poperinge interstadial phase. It thus supports the assumption of a Middle Pleniglacial Weichselian age for the peaty loam formation. (fig.8 p 20)

Finally the loam layers above it show cold-dry eolian conditions, thus pointing to an Upper Pleniglacial age. The row of large frost wedges and the sand-pebble band horizon correspond to the maximum cold which occurred between 24,000 and 16,000 BP (Zagwijn and Paepe, 1968). The second phase of the Upper Pleniglacial is not represented here.

The clayey cover above the eolian coverloam is fluvial in origin; the lower part dates from the Late Glacial, the upper part from the Holocene (T'Jonck, 1962; Paepe, 1967).

Similarity in lithological succession of the Flemish Hills and Lys-plain shows that the landscape was fashioned before the Saalian loess deposition.

OUDENAARDE (VOLKEGEM)

The brickyard 'De Steenberg' at Volkegem is a loess site located at the east side of the Schelde valley (Northern limit of the Loess belt; 73 m O.P.). Its sediments contrast with the sandloess area which terminates abruptly on the opposite (west) side of the Schelde valley. The composition clearly reveals also the importance of the Upper Pleniglacial loess cover which is one of the most typical in Belgium.

TONGRINNE (fig. 8 on page 20)

This is at the southern limit of the loess belt near Gembloux. The exposure is in the brickyard 'Point du Jour' where 6 m (total thickness 15 m) of loess is exposed. The area has undergone little erosion and lies on the ridge between the Schelde and Meuse basins. The loess area has long been the basic area for the study of the lithostratigraphical sequence of Weichselian and Saalian loess deposits. As early as 1946 Manil had recognized the existence of two reddish fossil textural-B-horizons in the Gembloux area below the uppermost loess cover. Later Gullentops (1954) gave the name ROCOURT soil to the uppermost of the two fossil soils which he believed to be of Eemian age. Tavernier (1954) stated that the base of the Weichselian (Würmian) was formed by a humic loess horizon. This was probably the layer which Gullentops had considered to be the A_1-horizon of the Rocourt soil. Mainly by comparison with similar sequences of the sand-loess area (Warneton) Paepe (1965) concluded that two superposed soil horizons occur. Bastin (1967) came to similar conclusions on the basis of the palaeobotanical evolution of this soil sequence. The humic horizon above the Rocourt soil is considered to belong to the Warneton soil complex of Early Weichselian age.

Higher up in the sequence Gullentops recognized a faintly developed brown soil which he called KESSELT soil. It occupies the same chronostratigraphical position as the Denekamp interstadial of The Netherlands which Paepe (1967) was able to date on a peat from the Zelzate tunnel pit (coversand area) : 28,200 ± 200 y. BP.

(R.P.)

THE BELGIAN COASTAL PLAIN: INTRODUCTION

Evolution during the Holocene

Since 1970 the Holocene of the Belgian coastal plain was studied anew. Subdivision of the Flandrian as introduced by Dubois (1924) in three 'assises' (Oostende, Calais and Dunkerque), is generally used, although these had not been studied in the same detail.

It is striking that little attention is given to the Calais member, while the Dunkerque member has been intensively investigated.

Until 1970 (Tavernier et al.) the following subdivision of the Holocene in the Belgian coastal plain was in use: Lower-, Middle- and Upper- Holocene. To the Lower- and Middle-Holocene belong:

1) 'assise van Kales' : deposited during the Atlantic as a result of the Flandrian transgression. The 'assise van Kales' (or Atlantic wadsediment) is mainly composed of sandy sediments.
2) the so-called surface peat.

The Upper-Holocene includes sediments of the Subatlantic including deposits of the Dunkerque 1, 2 and 3 transgression. Halet (1931) noticed the existence of peaty horizons in the sediments deposited during the Flandrian Transgression which indicate standstills during transgression. These observations were largely neglected; and there was little interest in the Calais member.

Lithostratigraphical Quaternary outline of the Belgian coastal plain

1. Pleistocene

With regard to the Pleistocene, distinction is made between an eastern and a western part, the boundary of which is situated near Oostende (Paepe, 1975).

1.1. The Eastern Area

At a level of - 7 m to - 1 m OP* sediments of Eem age occur (Oostende Formation) in the form of tidal flat deposits with at its base a crag (containing amongst others *Tapes senescens* spec.). These are overlain by coversands of Weichselian age which occur continuously towards the east, while to the west they wedge out between the Oostende Formation and the Flandrian Formation.

* OP : Oostends peil = 2.33 m beneath NAP

1.2. The Western Area

The western part of the plain is bordered in the south by the so-called 'Izenberge low plateau'. Here the Izenberge sands occur at levels ranging from 1.45 m to 12.20 m OP, containing amongst others *Cardium edule* in life position. The crag rests on a peat bed which is thought to belong to the Holsteinian or perhaps to the 'Cromerian' interglacial (Vanhoorne, 1962).

At Herzeele, Paepe and Sommé have described the same sequence. Furthermore the Pleistocene sediments of the western area may be differentiated into a northern and southern facies, the boundary of which extends along the Lampernisse-Diksmuide line.

1.2.1. In the southern part, Pleistocene sediments occur at a level of -5 m, to 1 m OP, and contain *Cardium edule* crag but ranging between 0 m and -3 m OP. The peat bed is found in some places.

1.2.2. In the northern part Pleistocene sediments dip north and finally disappear. Here Holocene sediments have overstepped on to the Tertiary.

2. Holocene

Thanks to the main peat layer (Holland Peat, 4,150 BP) generally situated at a level of -1 m to 2 m OP, a subdivision of the Flandrian Formation into three members is possible. From bottom to top they are: the Calais, Holland peat and Dunkerque members.

2.1. Calais member

A differentiation is made between the western and the eastern part of the coastal plain.

2.1.1. In the eastern part, the Calais sediments reach a maximum thickness of 5 m which is reduced to 1 or 2 m in areas where Weichselian sediments occur below it. It is remarkable that these deposits seem to occur as one sequence composed of sands and loamy sands, without any peaty horizon.

2.1.2. In the western part the situation is different. Three areas can be distinguished : (a) The area south of the Lampernisse-Diksmuide line is characterized by the virtual absence of the Calais member. Only in two N.-S. fossil gullies have sediments of Calais age been found.
(b) The area between the Lampernisse-Diksmuide line in the south and the Adinkerke - St. Joris line in the north. Here the Calais member (15 m) is represented by clastic clay and sandy clay with several peat layers. The principal peat layers are found nearly continuously at -2.50 m OP (dated as ca. 5,830 BP) and -6 m OP. Thus it may be concluded that different transgressive and regressive phases can be distinguished, particularly in the Calais member. (c) The area north of the Adinkerke - St. Joris line. Here the Calais member (20 - 25 m) is exclusively composed of sand containing *Cardium edule* and *Hydrobia*; peaty horizons are lacking. It would seem that this area was not exposed to erosion during the formation of the Calais deposits.

2.2. Dunkerque member

The Dunkerque member (mean thickness 1 m) is nearly everywhere at the surface. It outcrops more extensively than the Calais member. The distinction between Dunkerque 1, 2 and 3 beds is rather difficult to make because lithological differences and peat horizons are scarce.

VEURNE STOP 1

This is situated in the western part of the coastal plain where the 'Yser Gulf' (A. Rutot) merges into the coastal plain. To the west the Gulf is bordered by the Izenberge low plateau and to the east by an area where the Tertiary outcrops at 40 m OP. In the coastal plain the top of the Tertiary (consisting of Ieper clay) lies at about 0 m OP. It dips steeply towards the north and lies at a depth of about -30 m OP near the coast. A deep N-S running gully reaches a depth of -20 m OP. The Tertiary is covered by Pleistocene sediments consisting of mainly green subhorizontally bedded clayey sands containing reworked peat fragments. These sands overlie a shell layer containing amongst others *Cardium edule*.

At the base (ca. -4.5 m OP) sporadic humic horizons are found. This sequence is found in the Izenberge low plateau, though at a higher level. The Izenberge sands with *Cardium edule* and the peat layer underlying it are thought to belong to the Cromerian or Holsteinian stage (Paepe and Sommé, 1975). These are covered directly by the Flandrian Formation, which here consists exclusively of Dunkerque 2 and 3 phases on top of the Holland peat. However the peat thins, wedge-like towards the south where it is mostly found only as a faint vegetation horizon. In this area the Calais member is missing, except for the two gully occurrences.

VEURNE STOP 2

In the middle part of the coastal plain, north of the Lampernisse-Diksmuide line, a complete sequence of the Flandrian Formation is found. Pleistocene sediments are absent and the Flandrian directly overlies Tertiary clay.

In this part of the plain the Calais member consists mainly of clayey sediments gradually becoming more sandy towards the base. The Calais member is broken up by several peat layers, the most important of which are found at:

1) -6.0 m OP, separating the Calais I and Calais II

2) -2.5 m OP, dated elsewhere at 5,830 BP and which could be compared with the Holland Peat II separating the Calais II and Calais III.

Between -1 m and +2 m OP a peat layer is found which represents the principal peat bed of the Belgian coastal plain. This Holland peat member corresponds to the main peat layer in the sense of Dubois in the Calais area permitting the distinction of Calais and Dunkerque members. This peat has been dated elsewhere about 4,150 BP at the base and about 2,900 BP at the top. It may explain why several phases of Calais and Dunkerque (ranging in age between 4,500 and 2,900 BP) are lacking as compared to the Dutch stratigraphy. Near to the coast the Calais deposits become more sandy without any peaty horizon at all.

The Dunkerque member in this area may be subdivided into a Dunkerque II and III. Yet it is very difficult to make this distinction because of the scarcity of peaty or vegetation horizons separating these sediments. This is even more complicated due to numerous fossil gullies. (C.B.)

DAY 3 DIE RHEINLANDE (GERMANY) I

DAUNER MAARE

Volcanic activity occurred widely during the Upper Tertiary and Quaternary in the Rheinisches Schiefergebirge. Quaternary volcanism was limited to the Laacher See region and the western Eifel (maare), the Tertiary volcanism in the Westerwald, Hohen Eifel and in the Siebengebirge (figure 9 on page 29).

Quaternary volcanism of the Laacher See area is important in relation to the stratigraphy of the Middle and Lower Rhine area. According to Frechen (1971) the volcanism started before the main terraces were built up and lasted into the Late Glacial. The volcanism in the Laacher See region corresponds firstly with the strengthened development of the Rheinisches Schiefergebirge which was already uplifted during the Tertiary, and secondly with the collapse of the Neuwied Basin. The connection between volcanic activity and river terraces can be seen by the pyroclastics which are deposited in the Rhine terrace-deposits or in the covering loess layers.

Frechen (1971) differentiated between 3 main phases of the Laacher See volcanism on the basis of the composition of the ejected products. An older phonolitic-foiditic phase was followed by a second phase of mainly basaltic products. This was brought to an end by a third phase of basaltic and pumice products. During the youngest phase the volcanic activity reached its climax in the ejection and composition of the pyroclastics.

According to Razi Rad (1975), the older phase of the volcanic activity is characterised by heavy mineral association of pyroxene in the Rhine sediments, the second phase by the occurrence of brown hornblende and the youngest phase by pyroxene (tab. 1).

The volcanism of the Westeifel is characterised by a more limited variety of the volcanics (mainly alkalic, basaltic rocks), and by a more varied morphological volcanic development, maars and volcano-tectonic depressions are widely spread. Maars and volcano-tectonic depressions are evidence of the extremely strong explosivity of the Quaternary volcanism of the Westeifel. According to Noll (1967) the actual maars are volcano forms, due to an explosion of the alkalic-basaltic magma, which was blocked below the surface of the earth. Those craters in the Devonian sediments and 'Buntsandstein' are surrounded by pyroclastics and sometimes by a low wall.

The ash and slag eruptions in the Westeifel date from the lower part of the Quaternary whereas the maars date from the uppermost Quaternary. According to pollenanalytical data the latter are between 12,000 and 10,000 years old. In the Laacher See region the volcanic activity was brought to an end by the eruptions, during the Alleröd, of pumice which was spread over the whole of Middle Europe. (W.T.)

KÄRLICH CLAY WORKS MANNHEIM & CO. K.G.

The beds underlying the Quaternary in the Neuwied Basin (Middle Rhine) consist of Oligocene to Pliocene clays with occasional tuff levels. The Quaternary beds consist of river sediments and loess. This exposure, known for 60 years,

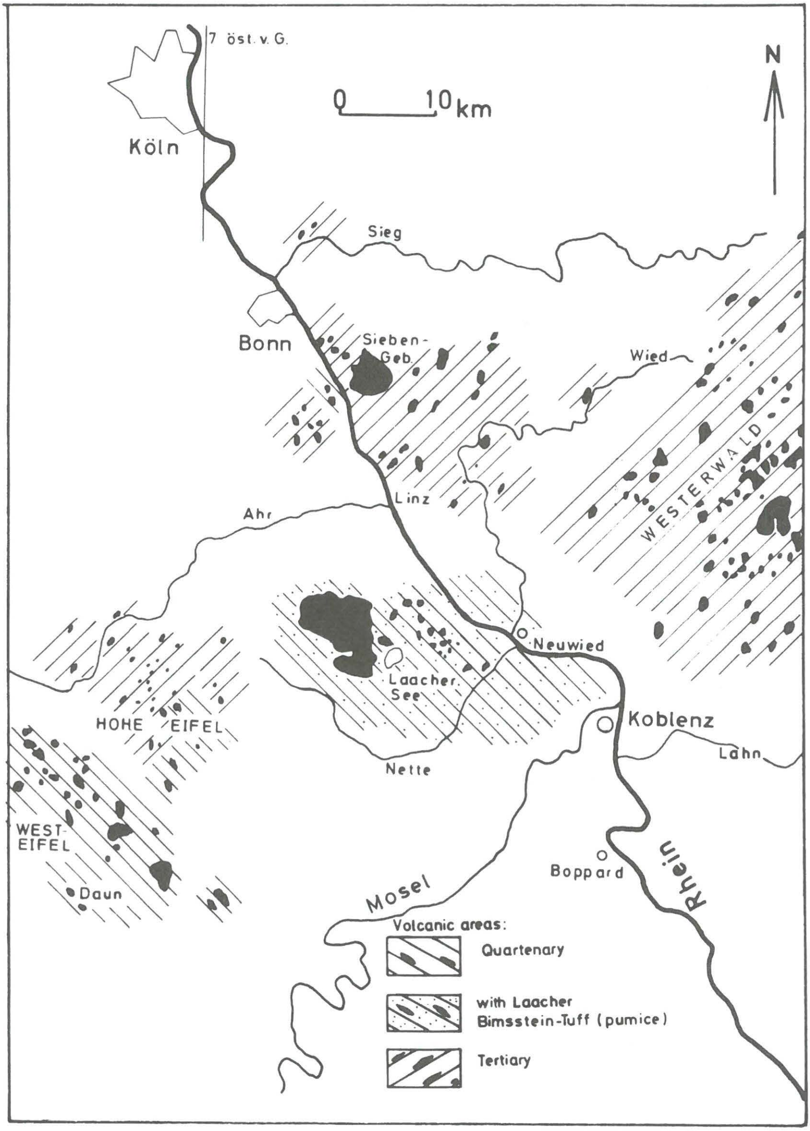


Fig. 9 - Volcanic products in the Rheinisches Schiefergebirge

VOLCANISM	HEAVY MINERALS	PLEISTOCENE STRATIGRAPHY	AGE : C^{14} K/Ar Paleomagnetism
Maar-Volcanism, Laacher See-Tuff (pumice)	Pyroxene	Alleröd	11000 BP
Metternicher	Pyroxene	beginning of Würm	
Kärlicher Brocken-tuff (Basalt-Tuff),	Pyroxene	Kärlicher Interglacial (second to last)	
Basalt			
Selbergit,			
Selbergit-Tuff,	Pyroxene (Hornblende)	Ariendorfer Interglacial (third to last)	350000 BP ?
Basalt			
Basalt	'br. Hornblende' (Titanite)	Leutesdorfer Interglacial (fourth to last)	
Basalt,	Pyroxene (Hornblende)	Ville Interglacial-Complex	BRUNHES/MATUYAMA
Selbergit	————	————	
	Acmite-augite, Rhine heavy minerals		

Table 1: Stratigraphy of Quaternary Volcanism

has been systematically investigated in the last decade (figure 10 on page 32). The profile is divided into sections A - Jb, each consisting of a sediment layer, mostly terminating in a soil reflecting warm climatic conditions (Brunnacker, 1971, Brunnacker, Streit & Schirmer, 1969).

Sections A - C consist of fluvial sediments, covered from section D upwards with loess. Recently the sequence 'soil of section Ba to section D' was considered as one complex in analogy to the 'Ville interglacial complex' of the Lower Rhine region (tab. 2). This complex is believed to represent the lower part of the 'Cromerian complex'. In the lower gravel layers of section Ba, the earliest Quaternary ice wedge casts in Europe occur. In the overlying Moselle gravels of section Bb the Matuyama/Brunhes boundary has been demonstrated (Brunnacker et al., 1976).

Volcanism is first indicated by Acmite-augite in the upper part of section Ba. From section Gb upwards, brown hornblende is found in great quantities, due to the intensive volcanism (Razi Rad, 1975). In the overlying sections the hornblende is replaced by pyroxene. Moreover tuff layers are interspersed in section F, Gb and H. The 'Kärlicher Brocken-tuff' which forms the base of section Ja, was formerly quarried here.

The mollusca-fauna (Ložec) supports such subdivision on geological/palaeopedological grounds. The same holds true for the mammalian fauna (Poplin). An elephant resembling *Archidiskodon meridionalis*, for example, is found in the gravels of section Ba or Bb. *Mammontheus trogontherii* is often found in section F, reminding of the situation of the main fauna found in the 'Grey Mosbacher' sands. Very often mammal remains are found at the base of section Gb and these relate to the period of the Leutesdorfer interglacial (Brunnacker et al., 1974).

GRAVEL QUARRY NEAR ARIENDORF - LOWER MIDDLE RHINE, NORTH OF BAD HÖNNINGEN (Fa. SCHNEIDER)

The Leubsdorf Middle Terrace is covered by an interglacial 'Selbergittuff'. This is overlain by loess originating from three further glaciations, also with tuff layers (figure 11 on page 34). In the underlying terrace gravels considerable amounts of pyroxene indicate earlier volcanic activity. The covering layers, the mollusca-fauna and the larger mammals show that it belongs to the fourth glaciation before the present (Brunnacker et al., 1976).

Gravel petrography shows that this terrace deposit's provenance was from tributory valleys rather than by the Rhine. The unusual thickness of the Leubsdorf terrace deposit, in the centre of the uplift of the Rheinisches Schild, can be interpreted as the filling which occurred during the culmination and in particular at the end of a glaciation. By correlating this terrace deposit with the Kärlich section Gb (tab. 2), this assumption is strengthened. Indeed in the upper part of this latter section as well as in the Leutesdorf profile, pyroxene gradually begins to dominate the brown hornblende. (K.B.)

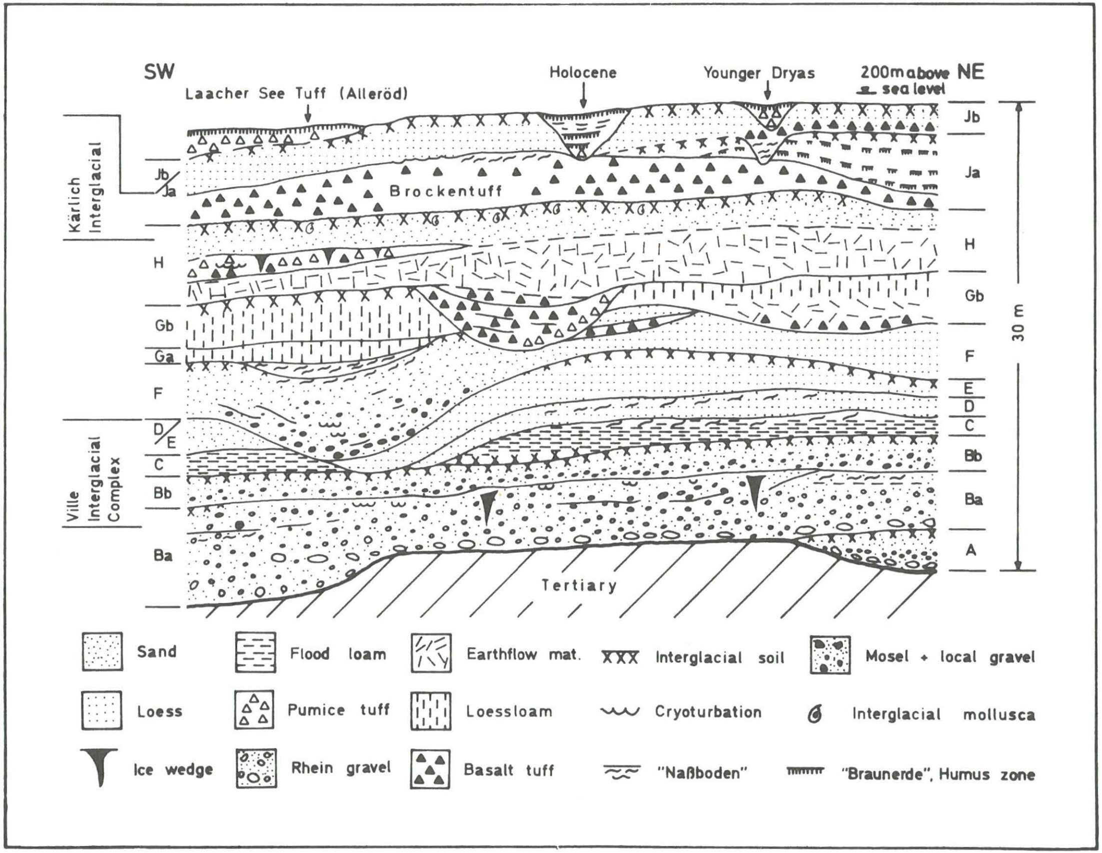


Fig. 10 - SECTION AT KARLICH, NEUWIEDER BASIN

Jb	modern Parabraunerde		Laacher See-Tuff (Allerod)	
	Loess		Eltviller Tuff-horizon	
Ja	Parabraunerde			
	Loess			
H	Parabraunerde	=	Kärlicher Interglacial with Brockentuff	
	Loess		alternating pumice and Basalttuff	
Gb	Parabraunerde	=	Ariendorfer Interglacial	
	Loess		Pyroxene (and brown Hornblende) Basalttuff and brown Hornblende; varied mammal fauna --- main erosion unconformity ---	
Ga	Interglacial	(=	Leutesdorfer Interglacial?)	
	Loess		Pyroxene at the base	
F	Parabraunerde			
	Loess		Basalttuff, Titanite in the middle of the layer; many *Mammontheus trogontherii*	
E	Parabraunerde			
	Loess		(brown Hornblende)	
D	Naßboden (weak)		Ville-Interglaical-Complex (partly Cromerian-Complex)	
	Loess			
C	Naßboden (weak)			
	High flood loam			
Bb	Auenboden			
	Moselle Gravels			BRUNHES
Ba	Auenboden			MATUYAMA
	Mixed Gravels		(Acmite-augite); oldest ice wedge horizon	
	Naßboden (weak)			
	High flood loam			
	Rhine Gravels			
A	Pseudogley-Auenboden			
	Rhine Gravels			

Table 2: Stratigraphy of the middle and younger Quaternary at Kärlich

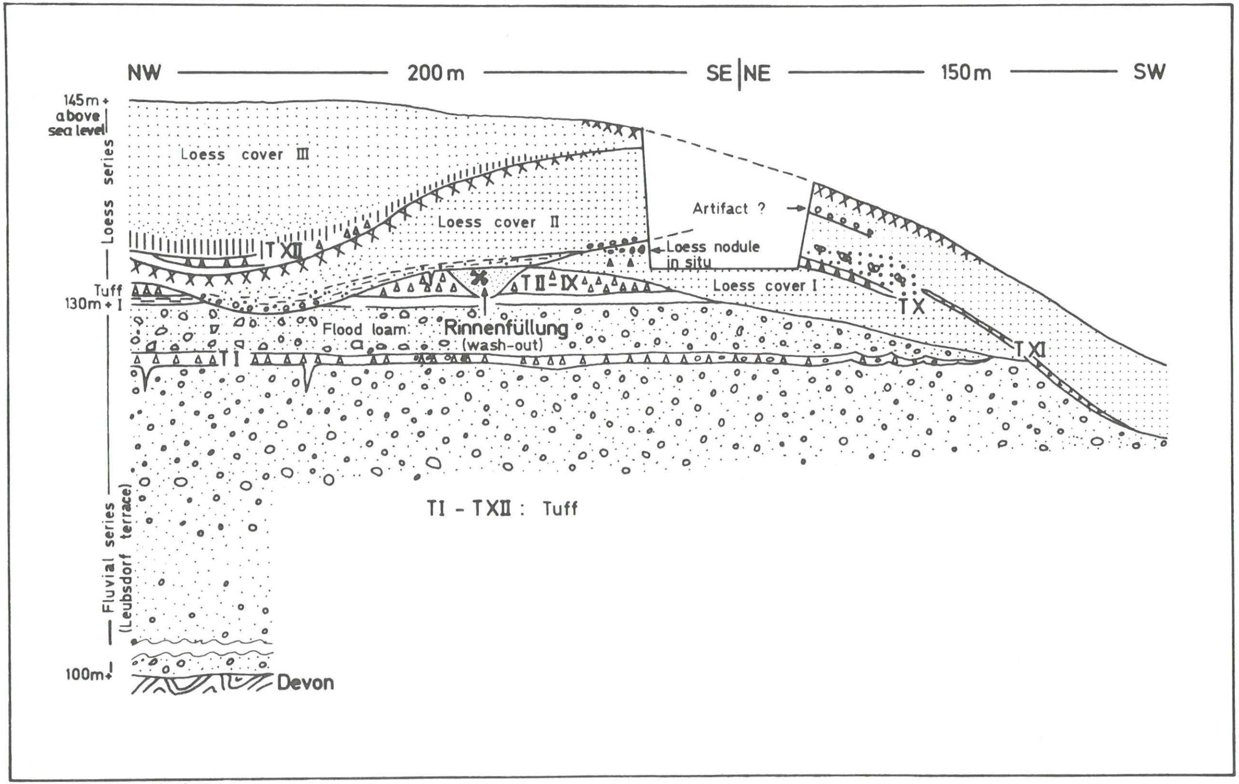


Fig. 11 - THE SECTION AT ARIENDORF, LOWER MIDDLE RHINE

GÖNNERDORF - NEUWIED BASIN:

Site, Excavation: This upper palaeolithic site (Magdalenian) is situated in the northern edge of the Neuwied Basin on top of the middle terrace of the river Rhine and on the east bank of a former stream. Excavation with the aid of the Deutsche Forschungsgemeinschaft (D.F.G.) by the Institute of Prehistory, University of Cologne, was carried out in the years 1968 to 1976. This site is covered with pumice dating from the Alleröd as a result of which the settlement is exceptionally well preserved.

Profile, Age: Below 1.0 - 1.5 m of pumic the Alleröd humus horizon is found. Underlying is a bed of 0.20 - 0.30 m loess/loam with undulating base, still lower is yellow loess. The settlement horizon is according to the relief 0.10 - 0.35 m under the Alleröd level in loess/loam (showing relatively poor bone conservation) or in loamfree loess. Through 14_C a date of 10,430 ± 230 B.C. has been obtained from bone collections.

Settlement remains: From the excavated area (approx. 700 sq.m.) contours of three large and two smaller settlements have been found in the form of concentrations of slate plaquettes, quartz and quartzite pebbles. This stone material was brought in from the vicinity of the excavated area. The centre of the settlements were coloured red, due to pulverised hematite. In the centre of the settlement was a hearth (pit with charcoal and shattered quartz pebbles) and several small pits. In these pits with red filling bone and ivory were particularly well preserved (e.g. fish and bird bones, feet of ice-fox in anatomical connection, complete statuettes from ivory and antler).

Fauna: Mainly horse, also reindeer, ice-fox, red-fox, birds (swan, goose, duck and raven). Less frequent are mammoth, woolly rhinoceros, wolf, saiga antelope, chamois, deer, elk, bison and fish (trout, eel).

There is a seasonal difference in the fauna of the various settlements (winter habitation with a lot of ice-foxes, no deer; summer habitation with deer, elk and hardly any ice-fox).

Flora: Charcoal - mainly pine; pollen - different grasses, pine and juniper etc.

Stone Artefacts: The artefacts have been made from siliceous slate and fresh river quartzite, occurring in the area; from other areas flint was imported. Amongst the tools which have been found should be mentioned: scrapers (8%), burins (30%), backed blades (40%), borers (8%) and splintered pieces (10%).

Antler and Ivory Tools: The production technique is well known due to finds of unfinished pieces (Magdalenian V forms).

Jewellery: Many bored discs (rondelles) made from slate, bored animal teeth (fox and deer), wooden beads, snails as ornamentation and Dentaliums (including some Mediterranean forms). Fossils were also collected (e.g. shark teeth and saurian vertebrae).

Art: Ivory and antler statues of female figures. Engravings on slate with representations of women (mainly dancing scenes), animals (mammoth, horse, rhinoceros, bovines, wolf, lion and birds) and abstract figures.

(G.B.)

DAY 4 DIE RHEINLANDE (GERMANY) II

BROWN COAL MINE FRECHEN

In the Frechen open cast mine (18 km west of Cologne) the Main Seam of the Miocene brown coal formation is mined. Step-like faults of the Ville in the direction of the Erft Basin, a fault system in the eastern part of the Lower Rhine Basin may be seen (Ahorner, 1962). In the eastern section of the mine only 10 m of Main Terrace gravels overlie the brown coal. On the downthrow side of the faultblocks sediments of the Upper Tertiary and Quaternary increase in thickness with increasing depth. As a consequence, west of the Erft Fault (on the western edge of the mine) a complete sequence of layers may be seen attaining more than 200 m of thickness (tab. 3).

In the Lower Rhine Basin the Pliocene is represented by the petrographic facies of the Kieseloölite Formation. There is an alternating sequence of gravel, sand and clay. The name for the formation has been derived from the characteristic black and grey silticeous Oöid pebbles. Associated with these are agate and silicified fossils which derived from the Lothringian Jura. In the fraction of 20 to 50 mm the gravel consists of 90% quartz, 7% Lydite + Kieseloölite + agate and 3% quartzite + sandstone. The sand fraction consists mainly of quartz with 1% feldspar and 0.1% heavy minerals. The heavy minerals show a predominance of stable minerals (mainly zircone, tourmaline, staurolite and rutile). In the clay beds many autigene Anatas crystals occur.

The sediment of the Kieseloölite Formation is divided into three. The lower section consists of an alternating sequence of sand and gravel about 90 m thick (Main Gravel Series), the grain size of the gravel increasing upwards. Pollen analysis of silt lenses show a floral assemblage of Susterian (Brelie, 1959).

The middle section is characterized mainly by a clay sediment (Red Clay Series). Pollen analysis shows a spectrum of Brunssumian. The results of the palaeomagnetic measurements indicate a position in the lower part of the normal magnetized GAUSS-epoch.

Overlying a thin gravel layer are the youngest beds of the Pliocene: The Reuver-Series. In the Frechen mine this series is represented by clay horizon A (figure 12 on page 38). The Kieseloölite Formation terminates within this horizon. This formation is overlain by a younger petrographic facies, considered typical of the Pleistocene river Rhine. This formation is characterized by Ca-carbonate, mica and a mottled pebble spectrum. In these respects it differs from the underlying formation. The quantity of quartz in the fraction 20 - 50 mm drops from 70% in the lower part to about 45% in the upper part of the formation. The sand fraction contains about 10% of felspar and 0.8% of heavy minerals (epidote, garnet and green hornblende) (Boenigk et al., 1972).

This change in petrographic facies observed in clay horizon A is important because the same change has been found in the Reuverian B beds at the type locality of the Reuver Clay. Pollen analysis in the Frechen mine shows that the clay horizon A also dates from Reuverian B-C times. It is note-worthy

	stratigraphy	sediments	thickness
Pleistocene	Late and Middle Pleistocene	Loess coverbeds and gravel of the Middle Terraces	0 - 14 m
	Early Pleistocene	Gravel of the Main Terrace Sequence	60 m
	Earliest Pleistocene	Gravel with intercalated clay layers	30 m
Unconformity			
Pliocene	Reuver - Serie	Clay horizon A (= Reuverium B - C)	10 m
	Rotton - Serie	Clay and sand (= Brunssumium)	40 m
	Hauptkies - Serie	Gravel (= Susterium)	90 m
Unconformity			
Miocene	Indener - Schichten	Clay and sand	50 m
	Ville - Schichten	Main brown coal	50 m

Table 3 : Stratigraphy of the upper Tertiary and Quarternary of the Lower Rhine Basin.

that a mollusc fauna of Tertiary type occurs in the upper levels of this clay horizon. There is no transition to the Pleistocene (Boenigk et al., 1974). The measurement of the palaeomagnetism indicates a position in the upper part of the normal magnetized GAUSS-epoch for clay horizon A.

The well exposed site, located in an area of subsidence with a relatively complete sequence of beds and especially the existence of animal and plant fossils makes clay horizon A a very suitable layer in the discussion about the Tertiary - Quaternary boundary of this region.

Unconformably overlying clay horizon A are Pleistocene gravels with boulders of the river Rhine. West of the Erft fault the sequence begins with gravels of Lower Pleistocene age, for the moment including only one interglacial clay horizon (C) which is referred to the Tiglian complex. The oldest Pleistocene clay horizon contains a Quaternary mollusc fauna. The measured palaeomagnetism may indicate a position in the reverse magnetized Matuyama epoch. The abrupt change from a purely Tertiary mollusc fauna in clay horizon A to a purely Quaternary mollusc fauna in the lowermost Pleistocene deposits indicates a strong climatic incision or a possible gap.

Overlying the lowermost Pleistocene is the sequence of the Main Terrace deposits which can be further subdivided (HT 1 - HT 4) on the basis of their petrographic content. Due to lack of floral and faunal content in the mine, the presence of interglacial phases could not be demonstrated. (W.B. and G.V.D.B.)

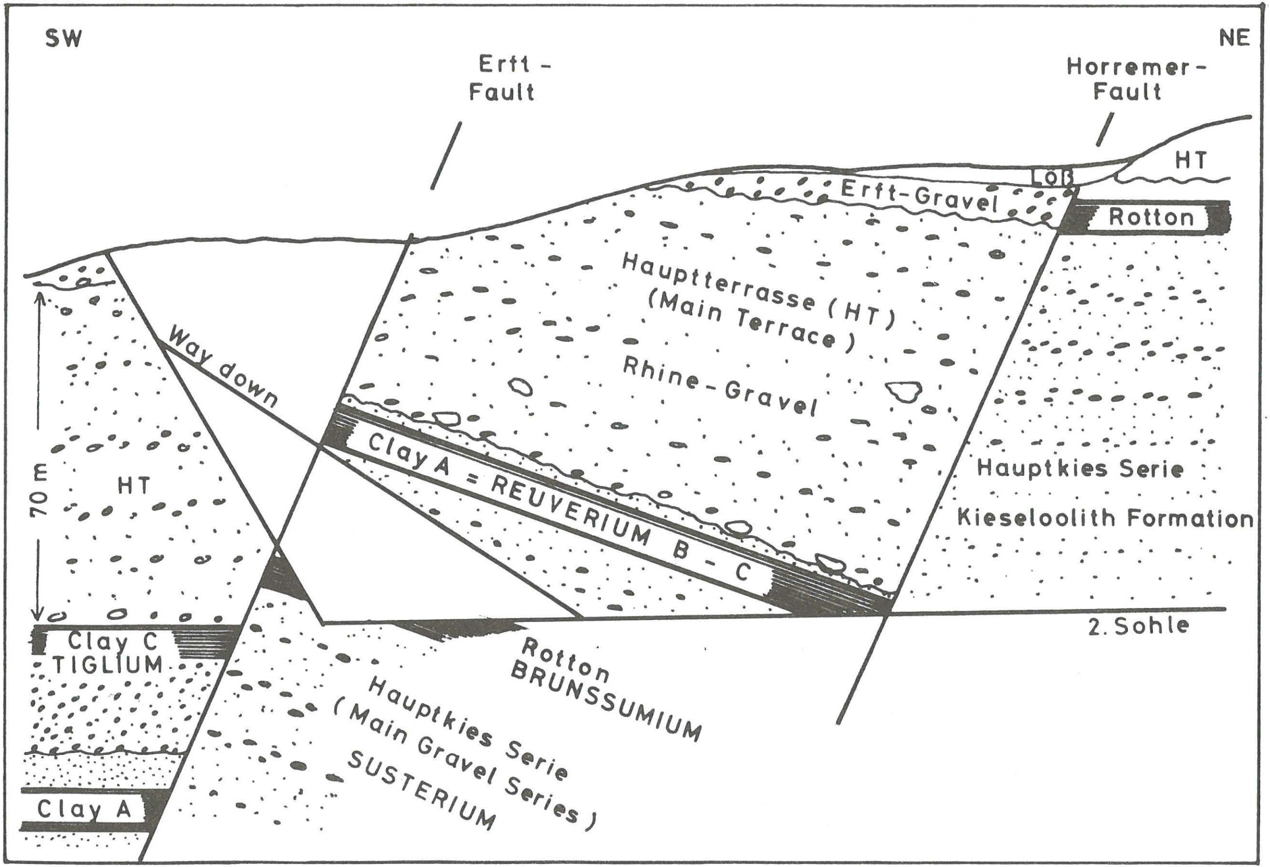


Fig. 12 - THE TERTIARY AND QUATERNARY DEPOSITS IN THE BROWN COAL MINE AT FRECHEN, LOWER RHINE BASIN

FORTUNA MINE OF RHEINBRAUN

The bus will drive along the first platform of the Fortuna mine which is more than 3.5 km long. The gravels of the Main Terrace sequence can be seen along this section (Schnütgen, 1974). As a consequence of tectonic movements the underlying Pliocene sediments and the brown coal of the Miocene are only partly exposed.

At the east edge of the mine an older Middle Terrace deposit cuts the Main Terrace (figure 13 on page 40). Overlying the Middle Terrace deposits is normally magnetized clay with an interglacial but relatively cool flora (Frimmersdorf interglacial). The upper part of the terrace (MT IIb) contains ice wedges and *Dicrostonyx simplicior* and consists of mainly high flood silt. At one time up to three separate loess layers covering the gravel terrace could be observed (Schnütgen et al., 1975).

The occurrence of brown hornblende in the Middle Terraces I and II permits a connection with the Leutesdorf interglacial of the Middle Rhine, which assumption is furthermore supported by the number of covering layers.

At the southern Lower Rhine there are four steps in the middle terrace sequence (Burghardt & Brunnacker, 1974; Brunnacker et al., 1976). As can be seen in the Fortuna mine, the terrace sediments consist of different layers. Ice wedge casts occur in each of the Middle Terrace gravels. Furthermore there are erosional levels interspersed in the gravel accumulations. The Middle Terrace IIb at the northern Lower Rhine most probably comes in contact with an old advance of the northern inland ice. (K.B.)

GRAVEL QUARRY AT HOLZWEILER

The gravel quarry at Holzweiler (15 km south of Mönchengladbach) is situated in the Main Terrace of the left bank of the Lower Rhine on top of the east-west running Jackerather Horst separating the Erft Basin in the south from the Venlo graben in the north. Due to a position on a tectonic horst Lower Pleistocene layers are exposed in the quarry (figure 14 on page 41).

The section is divided into three parts. The lower part consists of sandy Rhine gravels overlain by a thin layer of mixed sediments, in turn covered by very coarse Meuse gravels with boulders. It is furthermore characterized by a low percentage of quartz pebbles, and a high amount of flint and Revin quartzite. The heavy mineral spectrum shows in contrast to the Rhine spectrum a higher percentage of tourmaline and the metamorphic minerals staurolite, kyanite, andalusite and sillimanite. The hornblende is brown unlike the green variety found in the Rhine sediments. In the layer overlying the coarse Meuse gravels, sand and silt, also deposited by the river Meuse, alternate.

The uppermost section is part of the Main Terrace sequence which may possibly be subdivided according to the heavy mineral spectrum (HT2 + HT3).

The Meuse gravels interspersed in the Rhine sediments occur in the whole northern Lower Rhine basin. They offer a good petrographic key horizon and are accepted as the youngest level of the lowermost Pleistocene. Overlying them is the Lower Pleistocene Main Terrace sequence.

The Meuse sediments can be correlated with the Kedichem Formation of the Dutch Quaternary stratigraphy. The boulders in the gravels would in this case indicate the Eburonian Glacial. (W.B.)

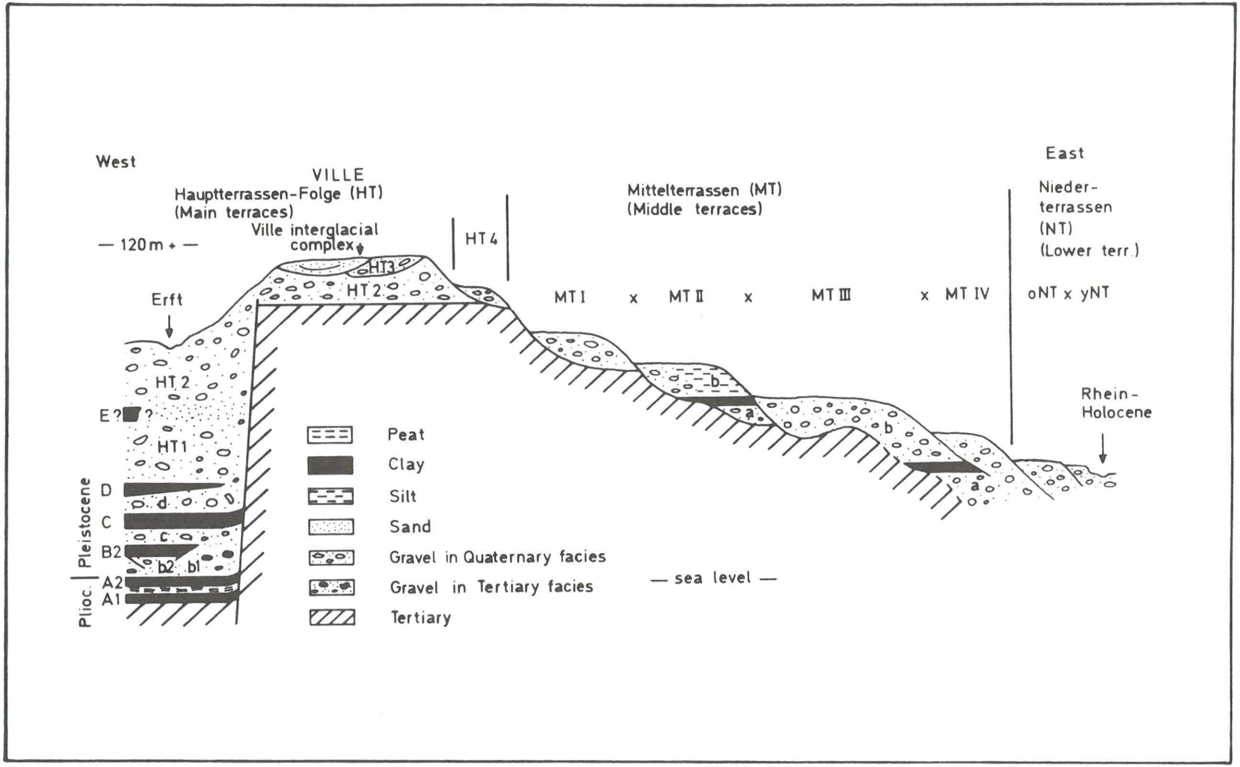


Fig. 13 - SCHEMATIC SECTION OF THE 'JUNG' TERTIARY AND QUATERNARY IN THE SOUTHERN LOWER RHINE BASIN

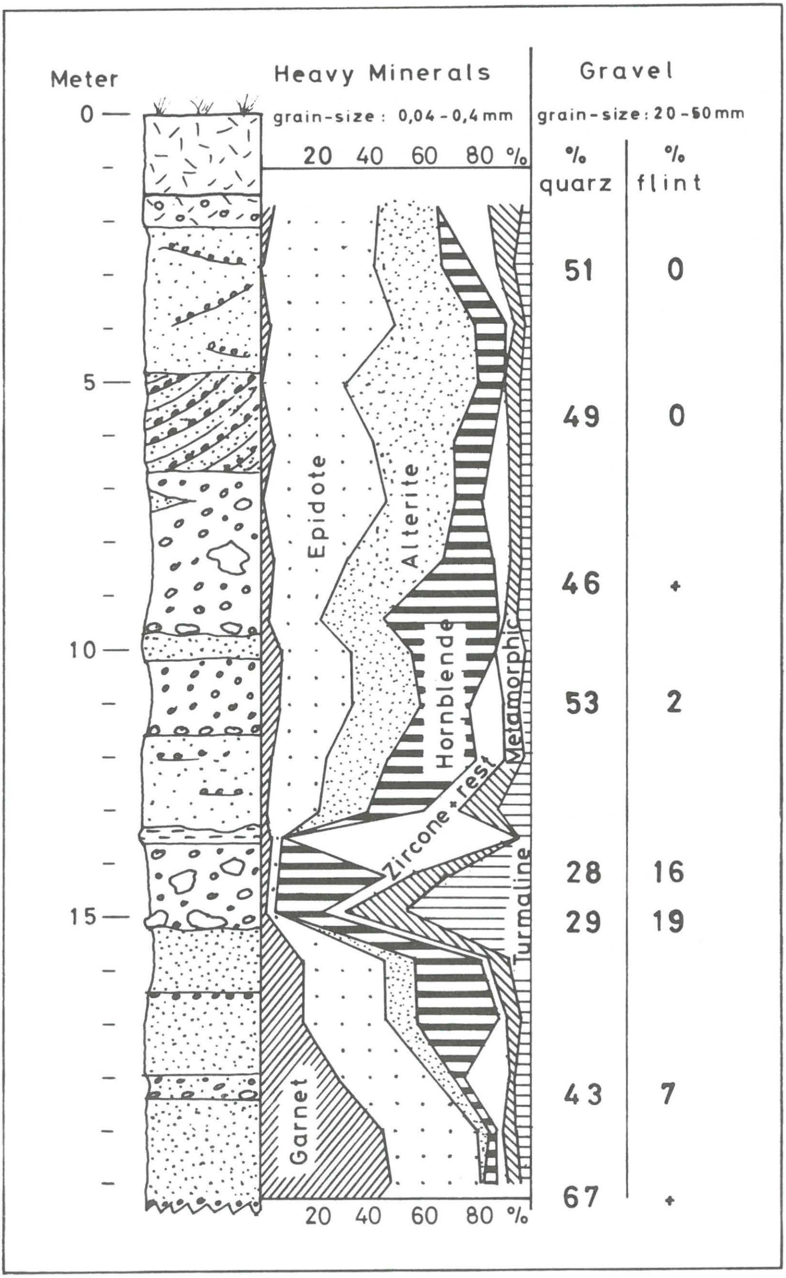


Fig. 14 - ALTERNATING RHINE AND MEUSE GRAVELS IN THE EARLY QUATERNARY AT HOLZWEILER, LOWER RHINE BASIN

BRICKWORK QUARRY DREESEN IN RHEINDAHLEN NEAR MÖNCHENGLADBACH

Location and excavations: This is a Middle Palaeolithic site with several cultural levels in the loess. It was discovered before the first World War by Brockmeier. Later work has been carried out by Kahrs and Narr. Between 1964 to 1965 and 1973 to 1975, excavations supported by the Rheinisches Landesmuseum Bonn have been carried out by the Institut für Ur- und Frühgeschichte der Universität Köln.

Section: Overlying the sandy gravel of the Main Terrace occurs a loess deposit which, on the basis of interglacial soils (grey-brown podzolic soils, occasionally together with pseudogleyed horizons) can be divided into three parts. The lowest part consists of 'dust loam' from the third to last glaciation, covered by 'partly doubled' soil.

The middle part is characterised by a series of thin grey bands and mottles. The topmost part, dating from the last glaciation, may be subdivided by interstadial 'Nassböden' (gleyed mottled horizons) corresponding to the situation in the Lower Rhine Basin (figure 15 on page 43).

Cultural Levels: Artefacts mainly consist of flint. There is no possibility of bone preservation.
Level I ('Patina-Komplex'): Many artefacts are distributed over a large area. Artefacts are patinated and polished and altered by frost action as well and are Late Middle Palaeolithic.
Level II ('Westwand'): About 1,500 artefacts have been collected from a limited area (280 sq. m.). It has so far been possible to reconstruct ten flint nodules. An oval pit has been interpreted as a habitation ground plan. Among the stone artefacts are many blades with predominantly fine, pearl-like edge retouche. The artefact spectrum has no equivalent in the Middle Palaeolithic of the western part of Central Europe.
Level III ('Ostecke'): A large occupation area with several separate concentrations. A few bone remnants have survived in the form of manganese concentrations. There are also grinding stones made from quartzitic sandstone. Among the stone tools are mainly points and side scrapers. Typologically similar to the 'Ferrassie Type'.
Level IV: Until now few artefacts have been recovered amongst which a large prepared Levallois core, an elongated Levallois flake and a retouched blade. Probably Upper Acheulian.

Apart from these cultural levels, isolated artefacts occur in other parts of the section. (G.B. and K.B.)

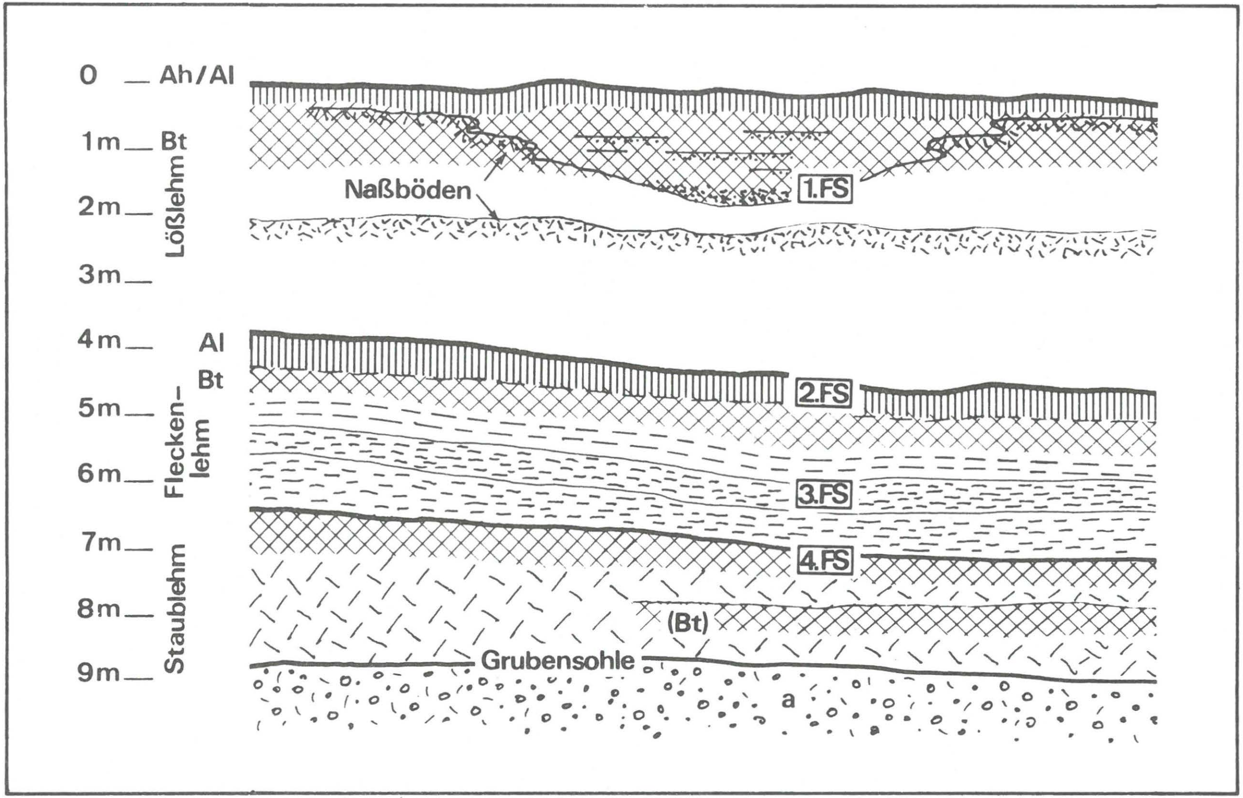


Fig. 15 - BRICKWORKS SECTIONS AT RHEINDAHLEN, LOWER RHINE BASIN

DAY 5 : THE TEGELEN-REUVER-BRÜGGEN AREA

Introduction

Ever since Clement and Eleanor Mary Reid (1915) published their famous account of the Pliocene Floras of the Dutch-Prussian Border, the border area between The Netherlands and Germany in the vicinity of Tegelen and Reuver has been a key area in the study of continental Plio-Pleistocene deposits in Western Europe. Since that time more beds, containing fossil plant material have become known and the stratigraphy of the exposures, though at present more or less clearly understood, has offered many problems of correlation. The fossil plant material in general has come from several clay horizons which alternate with sand beds. The litho-facies is fluviatile.

One problem of the area is that clay beds of different age may occur in lateral juxtaposition. This problem was presented at the beginning of the century and it was generally believed at that time that the clay beds exposed in the pits near Tegelen were the same age as the clay beds exposed in pits on German territory east of Reuver. However, the studies of Reid clearly revealed the great difference in floral composition of the Tegelen flora and the Reuver flora, the latter being richer in exotic and extinct species than the former. According to the present available data the beds containing the Reuver flora are of Pliocene age and those containing the Tegelen flora type of early Pleistocene age.

Moreover, the pits in the Tegelen area have yielded many remains of fossil mammals, and lately large collections of micro-mammals have been made (Freudenthal and v.d. Meulen, 1976). These finds enable precise correlation of the Tegelen Clay beds with other mammal containing beds elsewhere in Europe. Besides many more fossils have been found, such as other vertebrates, molluscs and ostracods.

General Lithostratigraphy

Many of the pits to be visited are dug in the escarpment of the Main Terrace on the eastern flank of the river Meuse valley (figure 16 on page 45). In the area one proceeds from north to south by a series of faults from the Venlo Graben to the Peel Horst (= Horst of Brüggen-Erkelenz) (figures 17 & 18 on pages 46 and 47). In all pits fluvial gravels and coarse sands belonging to the Sterksel Formation (= Younger Main Terrace Deposits of German authors) are found unconformably on beds of lower Pleistocene and Pliocene age. In the table (figure 19 on page 48) an outline of the various lithostratigraphic units has been given which can be found in the various groups of pits. In fact each tectonic unit (faultblock) has its own succession. In the Venlo Graben area clay and sand beds of lower Pliocene age are capped by beds belonging to the lower Pleistocene Tegelen Formation and the upper Pliocene Reuver Clay is absent. On the other hand, on the Peel Horst only this bed of upper Pliocene age is found. Therefore, the conclusion must be that during some stages tectonic movement have differed from those of other stages.

Heavy mineral analysis and gravel content indicate that all beds with the exception of those of the Kedichem Formation have been transported by the river Rhine. In greater part of the Kieseloölite Formation the river Rhine

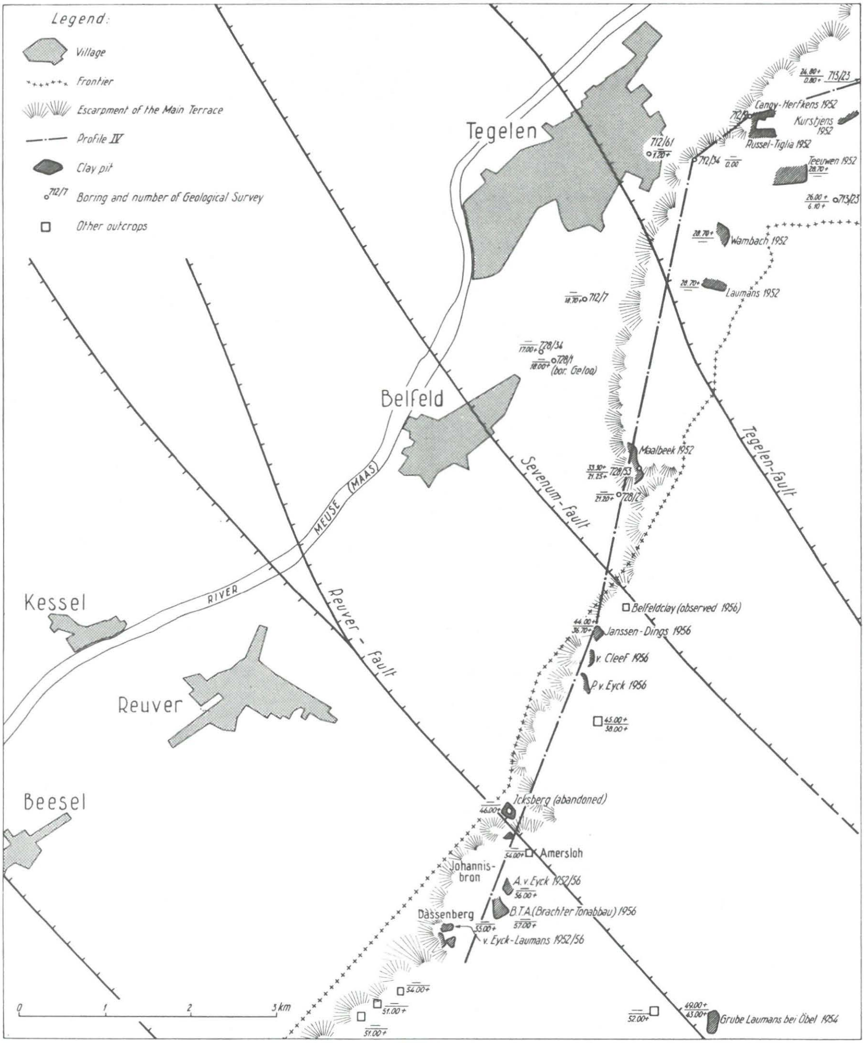


Fig. 16 - LOCATION OF CLAY-PITS IN THE TEGELEN-REUVER AREA

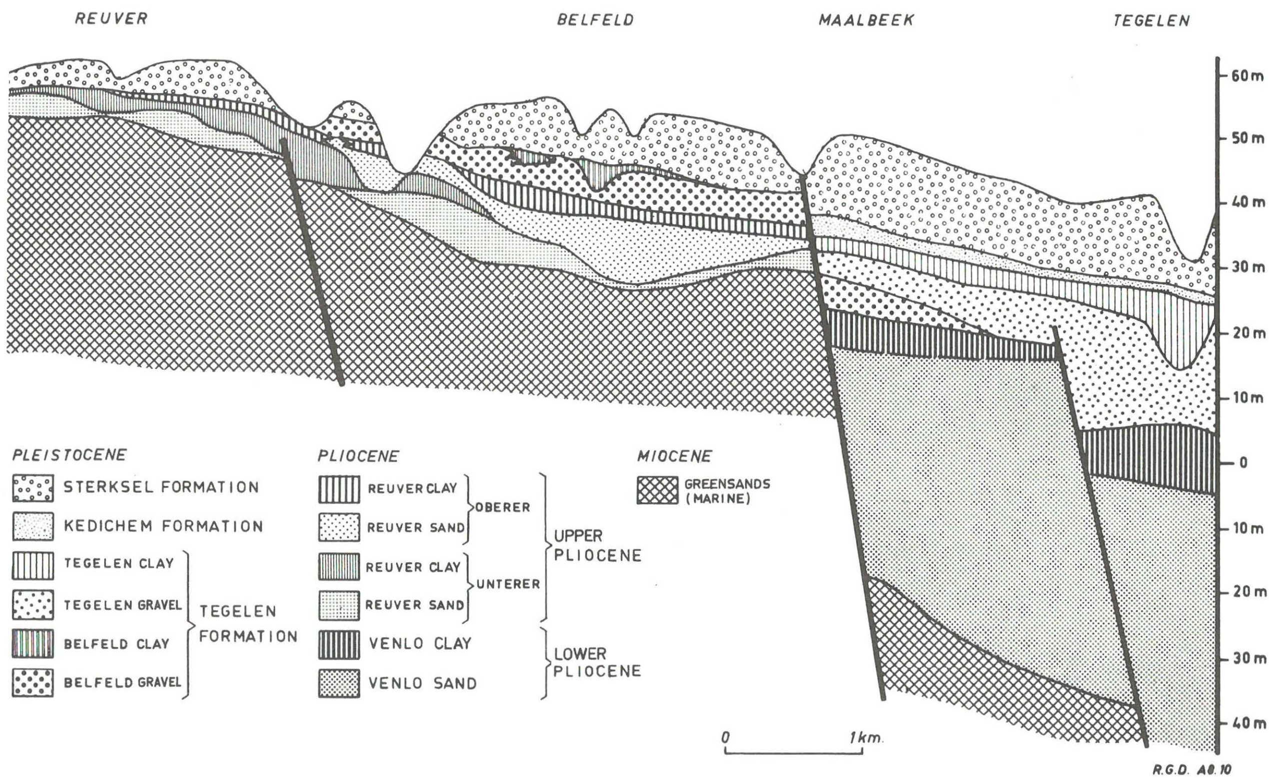


Fig. 17 - SECTION OF THE REUVER-TEGELEN AREA LOCATION

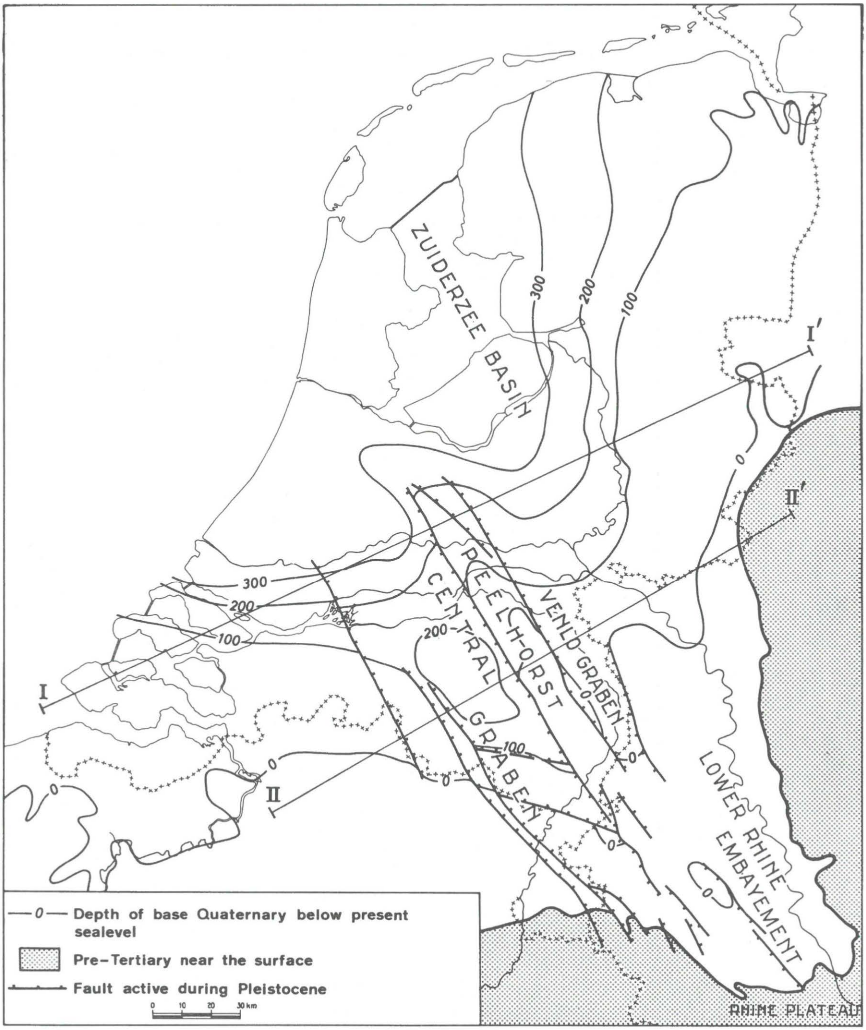


Fig. 18. Structure contour map of base of the Quaternary

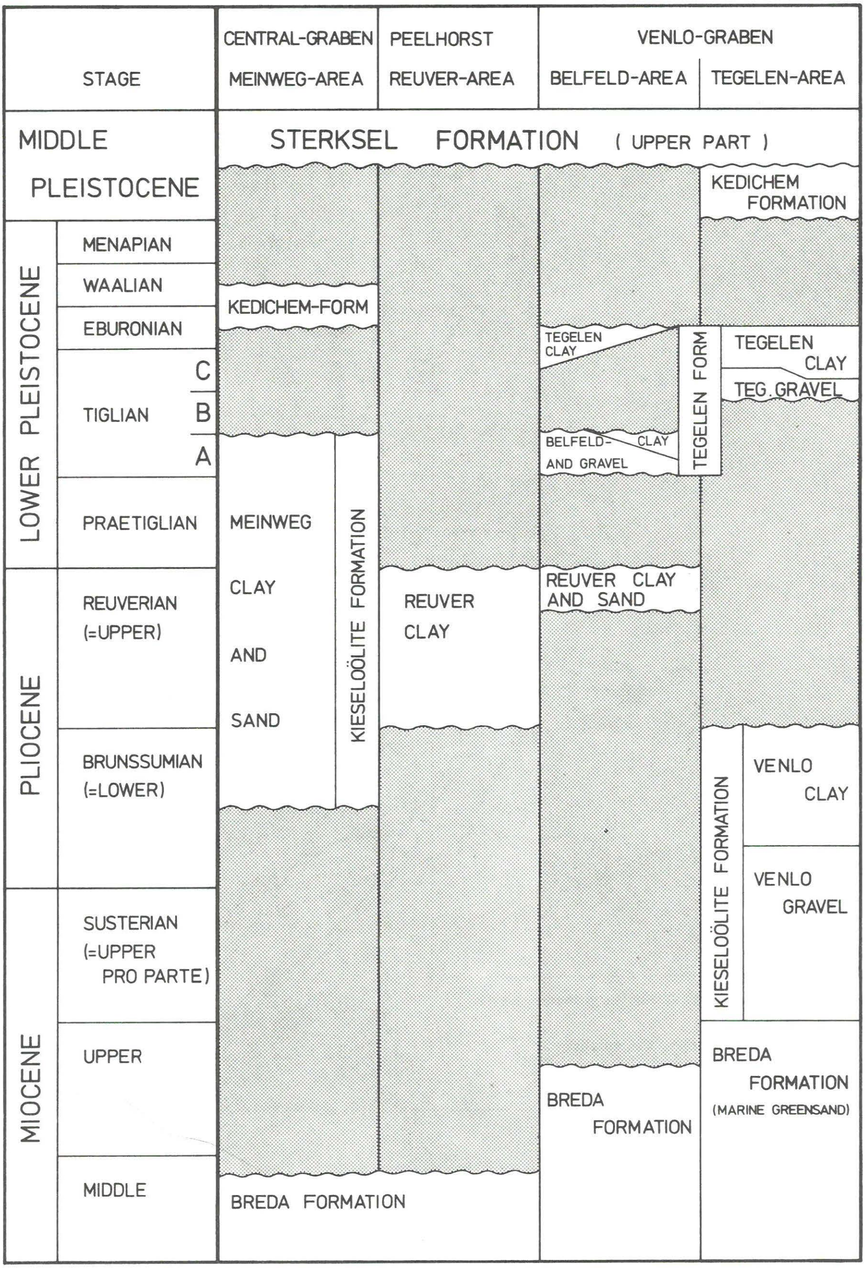

STAGE
CENTRAL-GRABEN
MEINWEG-AREA
PEELHORST
REUVER-AREA
VENLO-GRABEN
BELFELD-AREA
TEGELEN-AREA
MIDDLE PLEISTOCENE
STERKSEL FORMATION (UPPER PART)
KEDICHEM FORMATION
LOWER PLEISTOCENE
MENAPIAN
WAALIAN
EBURONIAN
TIGLIAN
C
B
A
PRAETIGLIAN
KEDICHEM-FORM
TEGELEN CLAY
TEGELEN FORM
TEGELEN CLAY
TEG. GRAVEL
BELFELD- CLAY
AND GRAVEL
MEINWEG CLAY AND SAND
KIESELOÖLITE FORMATION
PLIOCENE
REUVERIAN (=UPPER)
BRUNSSUMIAN (=LOWER)
REUVER CLAY
REUVER CLAY AND SAND
VENLO CLAY
VENLO GRAVEL
KIESELOÖLITE FORMATION
MIOCENE
SUSTERIAN (=UPPER PRO PARTE)
UPPER
MIDDLE
BREDA FORMATION
BREDA FORMATION
BREDA FORMATION (MARINE GREENSAND)

Fig. 19.

was unconnected with the Alpine area and stable minerals predominate. In the uppermost part of the Reuver Clay the heavy mineral composition changes abruptly as shown by Boenigk (1970, see also Zagwijn, 1974).

From now on the heavy minerals are dominated by unstable minerals among which is saussurite, which shows that the river Rhine was complete along its present Alpine course.

General Chronostratigraphy and Biostratigraphy

The following account is based essentially on Zagwijn (1960, 1963). The pit of Russel-Tiglia Egypte at Tegelen serves as stratotype of the Tiglian stage.

At present (1975) the pit is not being worked and exposures are not very good. It is hoped, however, that it will be preserved as a geological nature reserve and measures taken to show part of the exposures permanently.

The pits east of Reuver in which the Reuver Clay is exposed, serve as stratotype of the Reuverian stage (Upper Pliocene). At present a few pits are still being worked.

In the beds of Reuverian age the flora (fruits and seeds, pollen, leaves, wood) still contains a fair number of exotic and extinct genera such as *Sequoia, Taxodium, Nyssa, Aesculus, Liquidambar* and many others. In the oldest clay bed of the area of lower Pleistocene age, the Beldfeld Clay, the above mentioned genera are absent, though *Pterocarya, Carya, Eucommia, Phellodendron* are present. Also *Fagus* is present in the pollen-diagrams of this bed even in noteworthy values. This Belfeld Clay has been attributed to the lowermost part of the Tiglian Stage (Tiglian A).

Detailed correlation with a well-section in the Meinweg area farther to the south has shown that between beds showing the pollen-analytical characteristics of the Reuver Clay and beds showing those of the Belfeld Clay, clay and lignite beds are intercalated the pollen-diagrams of which show a quite different character, namely that of an open landscape, lacking any thermophilous trees, and clearly indicating a time of cold climatic conditions. These beds have been attributed to the Praetiglian (cold) Stage which is considered the lowermost stage of the Pleistocene.

The composition of the floras found in the Tegelen Clay is largely similar to that of the flora of the Belfeld Clay with the exception, however, of *Fagus* which is completely missing from the Tegelen Clay. Most of the Tegelen Clay has been attributed to the upper part of the Tiglian Stage (Tiglian C). Elsewhere in The Netherlands indications of the presence of a cool or cold phase between Tiglian A and C have been found, though more information is badly needed on this point.

Pollen-diagrams of the upper part of the Tegelen Clay clearly reveal a climatic deterioration and the uppermost clay beds show the presence of treeless landscapes,and flora of cold character. This part of the Tegelen Clay has been attributed to the beginning of the Eburonian (cold) Stage. In the lower part of the fine sand deposits of the Kedichem Formation covering in many pits near Tegelen and the Tegelen Clay frost wedge casts have occasionally been observed. These beds have been attributed to the Waalian (warm) Stage and are truncated by an unconformity which probably represents a considerable span of time. At the plane of unconformity frost wedge casts and cryoturbation have been found. The covering coarse grained deposits of the Sterksel Formation are of Middle Pleistocene age.

All mammal fossils (Kortenbout and Zagwijn, 1962, Freudenthal and v.d. Meulen, 1976) from the area have been found in the Tegelen Clay Member at various levels. In the stratotype of the Tiglian, pit Russel-Tiglia Egypte, in the middle part of the Tegelen Clay Member a narrow gully, filled by sand, is found. From this level a great number of remains of small mammals (rodents insectivores) has been extracted these last years. This fauna permits a close correlation with some mammal faunas elsewhere in Europe dating from the Upper Villanyan.

Absolute Datings

Palaeomagnetic studies by Van Montfrans (1971) indicate that the upper part of the Tegelen Clay Member may date from Olduvai Event times (about 1.7 m.y.). However, a similar age has been advocated also for the uppermost part of the Reuver Clay Member by Brunnacker (1975), though this author considers an older age of the Reuver Clay Member (uppermost part) also possible. As fossil mammal faunas from Central France dated around 1.9 m.y. are very close to the fauna of the Tegelen Clay Member, Zagwijn (1974) followed the dating given by Van Montfrans (loc. cit.).

STOPS will be in various clay and gravel pits, depending on accessibility of the exposures. (W.H.Z.)

DAY 6 : THE CAMPINE AREA (BELGIUM) AND THE WESTERN NETHERLANDS

BEERSE: BRICKYARD ST. FRANSISCUS

In this outcrop at 30m OP the oldest Quaternary deposits are exposed. They belong to the Campine Formation of which three members are to be seen: an upper Turnhout Member, a middle Beerse Member and a lower Rijkevorsel Member. At a depth of about -30 m another clay member was encountered in borings. Together with the upper three members it forms the Campine Clay Formation which was correlated with the Tegelen clay of The Netherlands by Dubois (1904).

The age of the Campine Formation was determined by pollenanalytical and palaeomagnetical investigations. The top of the Turnhout Clay Member was estimated at about 0.9 m.y. while the Rijkevorsel Clay Member was dated as older than 1.6 m.y.

THE HOLOCENE OF THE WESTERN NETHERLANDS

Introduction (Amsterdam area)

At the end of the Weichselian the area now occupied by the western Netherlands was a flat plain underlain by fluviatile and eolian deposits, mostly sands. This landsurface was flooded by the sea during the post-Weichselian transgression.

The very gentle slope of this plain towards the west made it an especially sensitive area to register the course of the transgression. Absolute rise of sea level, isostatic adjustment and tectonic subsidence all operated in this area. Conditions existed which promoted the superposition of a complete sequence of deposits formed during the transgression, and also showed minor fluctuations of sea level. A number of sedimentary cycles are present, each of which represents a transgression and regression.

The deposits of the transgression formed behind coastal barriers, which protected them in the lagoon to the east. In the lagoon sediment was supplied through coastal inlets by the sea and by distributaries of the Rhine and the Meuse. At times the fresh-water influence of these rivers permitted the formation of peat deposits on a large scale.

During times of rapid transgression the sea entered the lagoon through inlets easily, whereas during phases of decreasing transgression the influence of fresh-water increased. The result was the formation of marine and brackish, mainly clayey sediments during phases of transgression, sand deposits being present in gullies only. Deep erosion took place in the main gullies. In general fresh-water sedimentation and peat growth shifted to the east during a transgressive phase. During decreasing transgression fresh-water influence shifted almost to the inlets of the coastal barrier which thus became river outlets. Peat growth during such phases generally reached the coastal barrier area in the west.

Deposits in the basal part of the Holocene sequence

During the early part of the transgression the present North Sea floor was flooded. At the end of the Boreal, about 7,550 BP, the coast line approached the present coast line of The Netherlands. As a result of a warmer and moister climate and rising groundwater level conditions for peat growth became favourable in a back-swamp area which existed in front of the invading sea. This peat zone moved towards the east along the gentle slope of the Pleistocene land surface. Therefore the oldest ages of this basal peat are found in relatively deep positions in the west. Here peat formation began around the Boreal-Atlantic transition. In the more shallow eastern area the basal peat came into existence during the second half of the Atlantic.

In local depressions, however, peat growth was essentially independent of the height of sea level. In such places therefore, peat started to accumulate much earlier.

The Holocene sequences in the three main zones of the coastal plain

Three zones can be distinguished in the coastal plain (figure 20 on page 52):

A. Beach and dune zone

B. Lagoonal and tidal flat zone

C. Perimarine zone.

A. Beach and dune zone

The outermost sandy zone, consisting of a barrier system, resulted from longshore drift and transverse wave action. During the eastward shift of the coastline prior to about 5,000 years BP beach barriers existed and would have

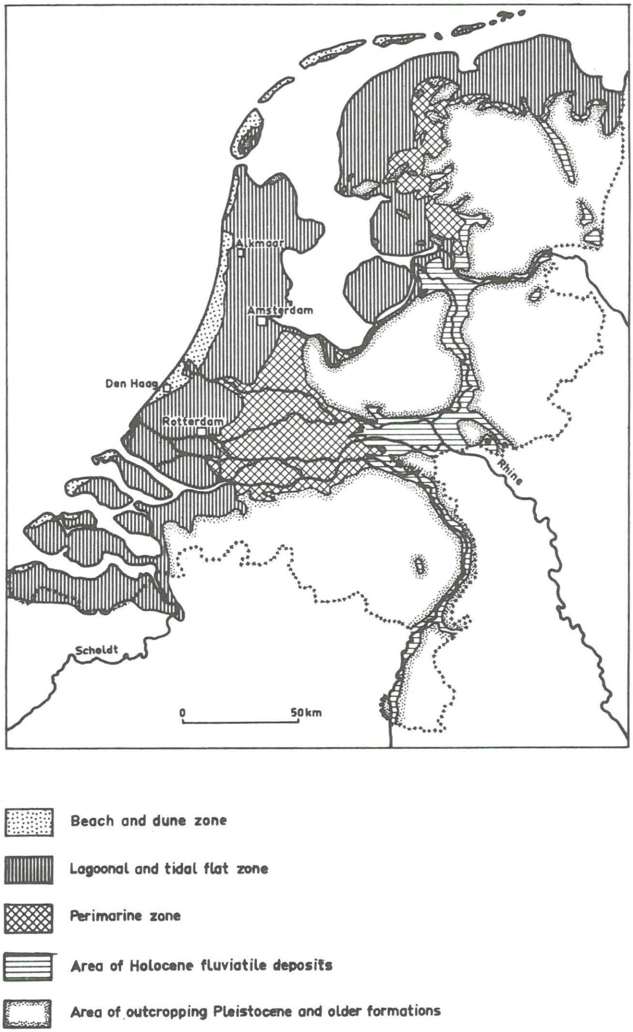


Fig. 20. The distribution of Holocene sediments

been eroded during the subsequent rise of sea level. About 5,000 years ago the coastline had reached approximately the present day position, particularly in the coastal area of Holland where its position was about 10 to 15 km farther to the east. From that time onward a system of beach barriers was built up which has not been subsequently destroyed. This phase of barrier accumulation lasted from about 5,000 years BP to less than 3,800 years BP, locally to about 2,000 years BP. Evidently as a result of decreasing sea level the sedimentary equilibrium was shifted towards the side of sand accumulation. The surplus of sand permitted the formation of dunes high enough to protect the barrier ridges from encroachment by the sea, the level of which was still rising though less swiftly than before. This process of barrier and dune building continued until about Roman times when the coast line had shifted back in westward direction well beyond the present coast line. Finally the process came to an end as no more sand was available to ensure further barrier accumulation. The result was a system of barriers and barrier islands overlain by low dunes, the morphology of which had a pattern similar to that of the barrier-ridges. The pattern was furthermore clearly related to the position of former river and tidal outlets. This landscape is called the Old Dune Landscape. In the centuries following 1,200 A.D. (750 years BP) a new situation developed. Large parts of the older barriers and dunes were eroded and the coast line shifted once more to the east. Only in the central part of Holland, between The Hague and Alkmaar, and in a few other places the old barrier complex was not completely removed. The new coast line was straighter than the old one (figure 21 on page 54). At the same time the off-shore sea floor was considerably deepened.

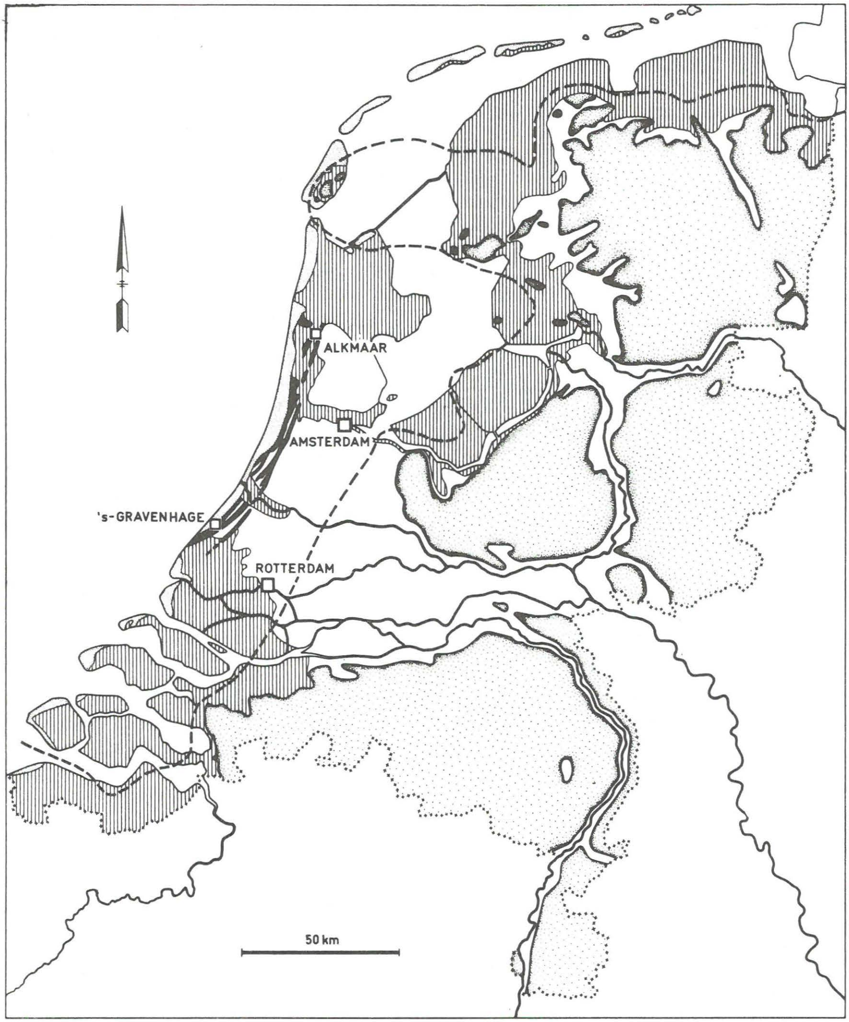
As a result a substantial amount of sand, rich in shell debris was liberated and accumulated on the fore-shore. From here it was blown inland to form a system of high dunes (generally between 20 and 40 m high) which often show parabolic shapes. This is the Younger Dune Landscape. Where the old barrier had been completely eroded the Younger Dunes overly the lagoonal and tidal flat deposits of the next zone landwards. In the central part of Holland they overlie the western 5 - 6 km of the Old Dune Landscape. The cause of the shift in pattern and structure of the coast line after 1,200 A.D. which resulted in the formation of the Younger Dune System, is not known. The increased storminess during the 'Little Ice Age' may have been its cause.

B. Lagoonal and tidal flat zone

As a result of the rapid rise in sea level during the Atlantic, a thick sequence of lagoonal and tidal flat deposits were formed behind the coastal barrier zone. In the western coastal zone these deposits amount to about 15 metres.

Later on in Late Atlantic and Early Subboreal times the speed of sea level rise diminished, a barrier zone which was not destroyed for a long time after was built: as a result marine influence in the lagoonal zone behind decreased. Instead fresh water conditions increased promoting the accumulation of peat. About 3,800 years BP marine sedimentation had practically ended, except in the estuarine areas of the outlets in the barrier system.

The marine deposits dating from before 3,800 years BP are called Calais Deposits; peat deposits which are partly contemporaneous, partly younger, are classified as Holland Peat. Holland Peat occupies almost the whole vertical



Duinkerke Deposits

Younger Dunes

Landwardlimit of the Calais deposits

Older barriers and Dunes

Outcropping Pleistocene and older formations

Fig 21. Distribution of Duinkerke and Calais deposits together with Older and Younger Dunes sequence in the easternmost part of the lagoonal zone. Fingers of the Holland Peat Member intercalated in the Calais Deposits extend far to the west, in many places reaching the barrier and dune zone. These fingers of peat indicate temporary fresh or brackish water conditions interrupting the overall marine facies of the Calais Deposits. Thus the Calais Deposits can be subdivided in four main transgressive cycles each of which can be subdivided in subcycles on a more local scale:

Calais IV	4,600 - 3,800 BP
Calais III	5,300 - 4,600 BP
Calais II	6,300 - 5,300 BP
Calais I	7,500 - 6,300 BP

After the phase of general peat accumulation around 3,800 years BP, renewed marine transgression after ca. 3,500 BP gave rise to newer marine beds called Duinkerke Deposits. In the western coastal plain of Holland and Zeeland the oldest of these are more restricted than the Calais Deposits. They developed at the weakest spots, in the coastal barrier system near river outlets or in tidal flat areas bordered by barrier islands such as in the northern part of The Netherlands and later also in Zeeland.
During the time of formation of the Duinkerke Deposits, the rise of sea level was much less than before, so their average thickness hardly exceeds two metres. The Duinkerke Deposits consist of clay sheets cut by dendritic systems of gullies filled by sand. During deposition of the earlier Duinkerke Deposits peat accumulation behind the barrier zone was especially frequent. Only after Roman times, more specifically Late Medieval times, peat growth came almost everywhere to an end, not least due to interference by man.

Similarly to the subdivision of the Calais Deposits, the Duinkerke Deposits can also be subdivided in a number of transgressive cycles:

Duinkerke III	1100 BP and later	(800 A.D. and later)	(D III)
Duinkerke II	1700 - 1350 y. BP	(250-600 A.D.)	(D II)
Duinkerke I	2500 - 1950 y. BP	(550 BC - A.D.)	(D I)
Duinkerke 0	3450 - 2950 y. BP	(1500-1000 BC)	(D 0)

C. The perimarine zone

The perimarine zone is the zone where sedimentation took place under the direct influence of the relative rise of sea level but where marine or brackish sediments themselves are absent.

Perimarine conditions mainly reigned in backswamp areas and in the downstream part of fluviatile areas where the effect of marine transgression was felt. Here thick fluviatile clay layers alternating with peat layers developed.
Old river courses themselves are indicated by gullies filled by sand. Only during Atlantic times did the downstream fluvial area perimarine deposits come into existence. Prior to this only thin fluvial clay and sand beds were deposited during the early part of the Holocene.

In Middle Atlantic to Subboreal times, however, the eastward shift of the coastline resulted in the shortening of lower river courses. As a result of this much fluvial material was laid down in a rather restricted area, resulting in frequent and repeated blocking of river courses and formation of new ones. In the areas in between river courses a high ground water level was present due to the ever increasing height of sea level. Therefore conditions for peat growth, mainly of wood peat, were particularly suitable. These peat deposits are very similar to the Holland Peat Member of the lagoonal and tidal flat area. In fact the Holland peat of that area can be traced continuously into the perimarine zone. Therefore it is appropriate to use one and the same lithostratigraphic term for the peat deposits in both areas.

The counterpart of the marine and brackish Calais and Duinkerke minerogenic deposits are found in the fluviatile facies of the perimarine zone as Gorkum and Tiel deposits respectively.

The presence of a certain cyclicity permits to subdivide these deposits in a way very similar to that of Calais and Duinkerke Deposits due to a similar mechanism of sea level rise and sedimentation:

Gorkum IV	4600-3800 BC	(G IV)
Gorkum III	5300-4600 BC	(G III)
Gorkum II	6300-5300 BC	(G II)
Gorkum I	7500-6300 BC	(G I)
Tiel III	800 A.D. and later	(T III)
Tiel II	250 - 600 A.D.	(T II)
Tiel I	600 - 100 BC	(T I)
Tiel 0	1500 - 1000 BC	(T 0)

During each transgression downflow was blocked and fluviatile sedimentation in the lower river plain resulted in gully cutting and extensive flooding during high seasonal water. Moreover it is likely that both marine and perimarine cyclicity had a common climatic cause resulting in conditions for marine transgressions being suitable at the same time as conditions for extensive river flooding.

Various temporary exposures illustrating the foregoing will be visited. Appropriate additional data will be available at the time.

(E.O.)

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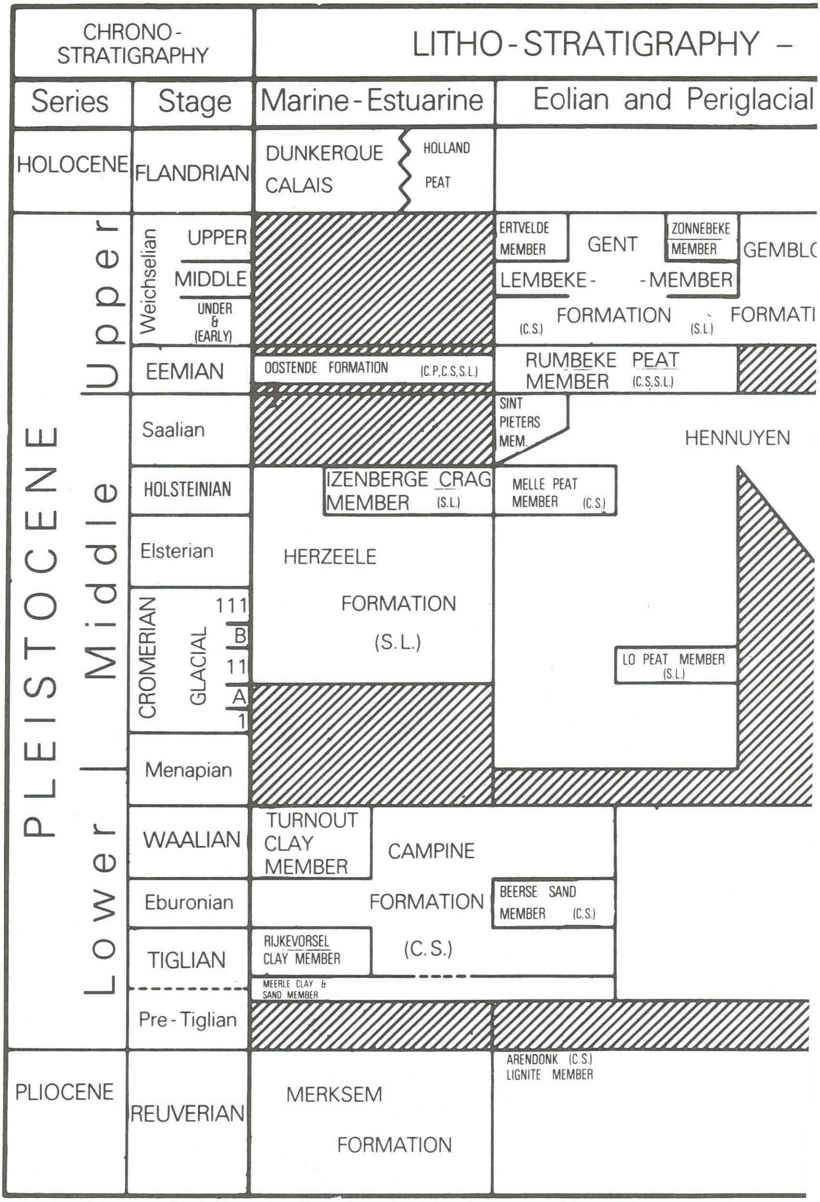
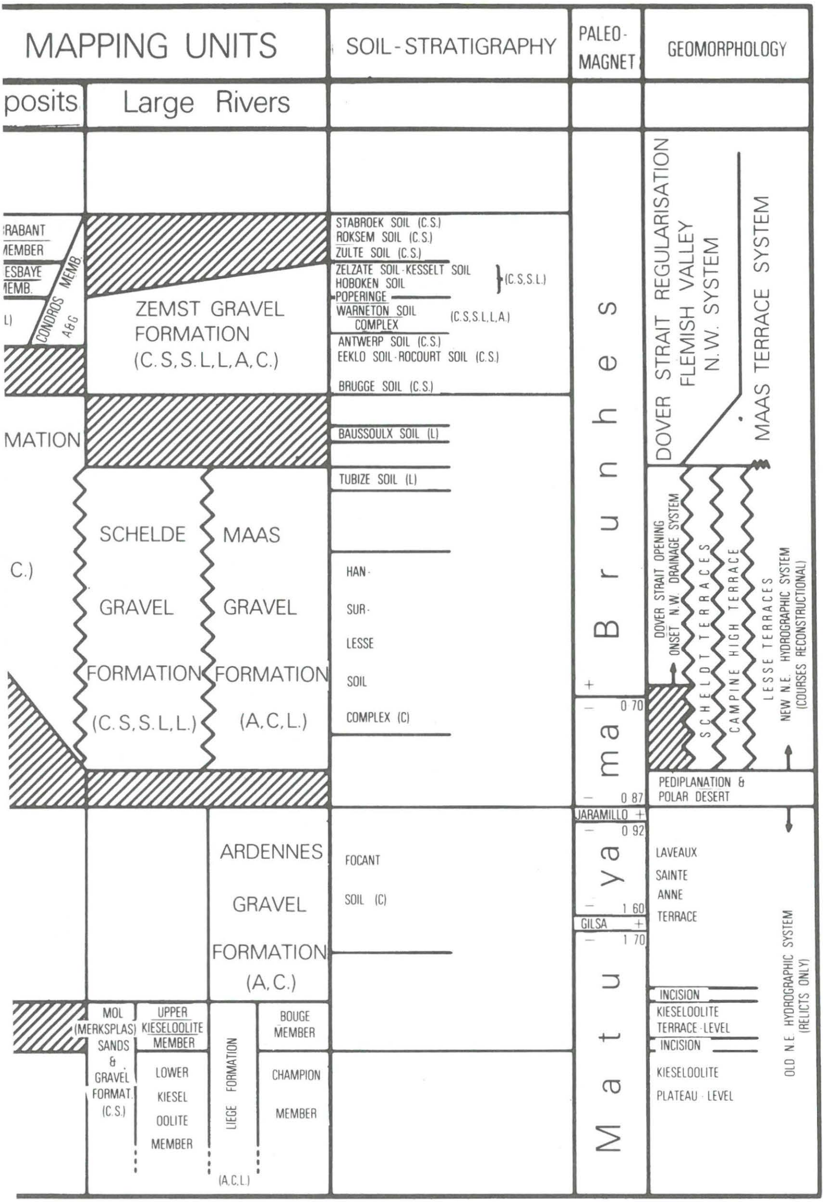

CHRONO-STRATIGRAPHY
LITHO-STRATIGRAPHY –
Series
Stage
Marine-Estuarine
Eolian and Periglacial
HOLOCENE
FLANDRIAN
DUNKERQUE
CALAIS
HOLLAND PEAT
PLEISTOCENE
Upper
Weichselian
UPPER
MIDDLE
UNDER & (EARLY)
ERTVELDE MEMBER
GENT
ZONNEBEKE MEMBER
GEMBLO
LEMBEKE-
-MEMBER
FORMATION (C.S.)
FORMATI (S.L.)
EEMIAN
OOSTENDE FORMATION (C.P.,C.S.,S.L.)
RUMBEKE PEAT MEMBER (C.S.,S.L.)
Middle
Saalian
SINT PIETERS MEM.
HENNUYEN
HOLSTEINIAN
IZENBERGE CRAG MEMBER (S.L.)
MELLE PEAT MEMBER (C.S.)
Elsterian
HERZEELE
FORMATION
(S.L.)
CROMERIAN
GLACIAL
111
B
11
A
1
LO PEAT MEMBER (S.L.)
Menapian
Lower
WAALIAN
TURNOUT CLAY MEMBER
CAMPINE
Eburonian
FORMATION
BEERSE SAND MEMBER (C.S.)
TIGLIAN
RIJKEVORSEL CLAY MEMBER
(C.S.)
MEERLE CLAY & SAND MEMBER
Pre-Tiglian
PLIOCENE
REUVERIAN
MERKSEM
FORMATION
ARENDONK (C.S.) LIGNITE MEMBER

Table 4



MAPPING UNITS
SOIL-STRATIGRAPHY
PALEO-MAGNET
GEOMORPHOLOGY
posits
Large Rivers
RABANT
MEMBER
ESBAYE
MEMB.
CONDROS MEMB.
A&G
L)
ZEMST GRAVEL FORMATION (C.S,S.L,L,A,C.)
STABROEK SOIL (C.S.)
ROKSEM SOIL (C.S.)
ZULTE SOIL (C.S.)
ZELZATE SOIL-KESSELT SOIL
HOBOKEN SOIL
(C.S,S.L.)
POPERINGE
WARNETON SOIL COMPLEX
(C.S,S.L,L,A.)
ANTWERP SOIL (C.S.)
EEKLO SOIL-ROCOURT SOIL (C.S.)
BRUGGE SOIL (C.S.)
MATION
BAUSSOULX SOIL (L)
TUBIZE SOIL (L)
C.)
SCHELDE GRAVEL FORMATION (C.S,S.L,L.)
MAAS GRAVEL FORMATION (A,C,L.)
HAN-SUR-LESSE SOIL COMPLEX (C)
Brunhes
+
0.70
ma
0.87
JARAMILLO
0.92
ya
1.60
GILSA
1.70
Matu
Matuyama
DOVER STRAIT REGULARISATION
FLEMISH VALLEY
N.W. SYSTEM
MAAS TERRACE SYSTEM
DOVER STRAIT OPENING
ONSET N.W. DRAINAGE SYSTEM
SCHELDT TERRACES
CAMPINE HIGH TERRACE
LESSE TERRACES
NEW N.E. HYDROGRAPHIC SYSTEM (COURSES RECONSTRUCTIONAL)
PEDIPLANATION & POLAR DESERT
ARDENNES GRAVEL FORMATION (A.C.)
FOCANT SOIL (C)
LAVEAUX SAINTE ANNE TERRACE
INCISION
KIESELOOLITE TERRACE-LEVEL
INCISION
KIESELOOLITE PLATEAU-LEVEL
OLD N.E. HYDROGRAPHIC SYSTEM (RELICTS ONLY)
MOL (MERKSPLAS) SANDS & GRAVEL FORMAT. (C.S.)
UPPER KIESELOOLITE MEMBER
LOWER KIESEL OOLITE MEMBER
LIEGE FORMATION (A.C.L.)
BOUGE MEMBER
CHAMPION MEMBER

C17 - ITINERARY

	September 1st	Arrival from Dover at Calais (France)
DAY 1 :	September 2nd	8.00 a.m. Departure Calais Morning: Calais area and Herzeele Afternoon: Veurne Night at Ieper (Belgium)
DAY 2 :	September 3rd	8.00 a.m. Departure Ieper Morning: Kemmel, Warneton, Volkegem, Ghent (touristic stop) Afternoon: Tongrinne Night at Luxemburg (Luxemburg)
DAY 3 :	September 4th	8.00 a.m. Departure Luxemburg Morning: Eifel area Afternoon: Kärlich, Ariendorf, Gönnersdorf Night at Köln (Cologne, Germany) (Evening visit to Museum)
DAY 4 :	September 5th	8.00 a.m. Departure Köln Morning: Frechen, Fortuna Afternoon: Rheindahlen, Holzweiler Night at Venlo (The Netherlands)
DAY 5 :	September 6th	9.00 a.m. Departure Venlo Morning: Reuver Afternoon: Tegelen Night at Eindhoven (The Netherlands)
DAY 6 :	September 7th	8.00 a.m. Departure Eindhoven Morning: Beerse (Belgium) Afternoon: Amsterdam (tunnelpit if accessible) Night at Amsterdam (The Netherlands) (Arrival at about 5 p.m.)

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